Report of the First Intermediate Check and Review on Fusion DEMO Reactor R&D

January 24, 2022
The Science and Technology Committee on Fusion Energy

This report summarizes the deliberations at the Science and Technology Committee on Fusion Energy (hereafter, "*Committee*") on the first Intermediate Check and Review on R&D for the fusion prototype reactor "DEMO" (CR1).

1. What is CR1?

At first, the definition of CR1 is confirmed in accordance with the past decisions by the *Committee*.

(1) Purpose of CR1

According to "Japan's Policy to promote R&D for a fusion DEMO reactor" (the Science and Technology Committee on Fusion Energy in December 2017) (hereafter "*Committee's document*"), the Check and Review is intended for analyzing the progress of DEMO R&D in Japan and confirming the maturity level of technology for transition to the DEMO phase.

According to the *Committee's document*, in CR1, the launch of the conceptual design of DEMO and development of the elemental technology required for the design are supposed to be determined, taking into consideration factors such as Broader Approach (BA) activities in the past.

(2) Basics of CR1

In the *Committee's document*, the goals to be achieved at the CR1 stage (including the goals related to public relations) were established. Thus, the status of achievement of the goals must be confirmed in principle. (Refer to Attachment 1 for the Check and Review Items (plan))

The *Committee*'s *document* then states that flexibility must be given to the Intermediate Check and Review to cope with the uncertainty in the future. Based on this situation, the goals to be achieved up to the second Intermediate Check and Review (CR2) must be reviewed, as well as the issues toward CR2, taking into consideration the latest domestic and overseas situations, in the implementation of CR1.

2. DEMO R&D policies up until now

The DEMO R&D policies up until now are summarized below.

The *Committee's document* states the purpose of DEMO is to clarify technical validation and economic feasibility. Similarly, the *Committee's document* gives the goals of DEMO as the achievement of steady and stable electrical output exceeding hundreds of thousands of kilowatts in preparation for the practical application of fusion energy by the middle of the 21st century.

In accordance with these policies, the *Committee* compiled “A Roadmap toward Fusion DEMO Reactor (first report)” (July 2018). The R&D have been conducted based on these policies.

The main result of the past R&D is the basic conceptual design of DEMO formulated by the Joint Special Design Team for Fusion DEMO in collaboration with industrial, academic, and governmental sectors. It presents a basic concept that has the prospect of satisfying the following three objectives: [1] electrical output of hundreds of thousands of kilowatts, [2] an operating rate for practical use, and [3] self-sufficiency of fuel. With regard to the major components, including toroidal field coils, breeding blankets, and divertors, the concept has been established as an extension of the ITER technical basis. With regard to the technologies that ITER does not have, the concept has been established with the technology and operating experience of power plants in the industrial sector and with the solutions by new technologies from academic sectors. Also, with regard to core plasma, the concept has been established based on the expected results of ITER and JT-60SA. (*For details, refer to document 2-2 for the *Committee* on June 24, 2021)

3. Change in the domestic and overseas situations surrounding fusion energy

Prior to the implementation of CR1, it is important to fully understand the latest domestic and overseas situations surrounding fusion energy. The following must especially be noted: the domestic and overseas situations surrounding fusion energy have been changed in recent years, and the phase has been shifted to competition in fusion development among major countries.

The following factors may contribute to the acceleration of fusion development in these major countries.

The first is the technical factor. The ITER Project has proceeded steadily, and the confidence in technical maturity has been enhanced. As R&D and construction activities of the ITER Project and BA activities and the procurement of major components have proceeded, the accumulation of know-how newly acquired and useful for DEMO leads to enhancing the confidence in the technical maturity.

The second is the socio-economic factor. The social demand for the achievement of carbon neutrality has been increased as never before, with the Paris Agreement regarded as an important opportunity. The widespread recognition of the importance of energy security must not be overlooked. The features of fusion energy, which is free from carbon dioxide emissions in the process of power generation and does not present any issues of energy security such as the uneven distribution of fuel, satisfies the needs of the times.

Additionally, we need to note the potential for innovation in the fusion field associated with the advance of science and technology (e.g., innovation of plasma control by using artificial intelligence and big data) and movement toward the achievement of the fusion power generation by foreign countries and venture companies.

(*For the state of competition in fusion development that has been accelerated in various countries toward the achievement of carbon neutrality, refer to Attachment 2)

4. State of achievement of goals required at the time of CR1

The goals to be achieved by the time of CR1 are stated in the *Committee's document*. The state of achievement of the goals is described below. For this, reference is made to the "Action Plan for DEMO Development" formulated for the effective follow-up (by the Science and Technology Committee on Fusion Energy in December 2017) (hereafter called "Action Plan").

(1) Action Plan Follow-up

In January 2021, the Taskforce on Comprehensive Strategy for DEMO Development (hereafter called the "DEMO Taskforce") that was established under the *Committee* compiled the document titled "Follow-up of the Action Plan for DEMO Development: In Preparation for the First Intermediate Check and Review" (refer to Attachment 3), and presented it to the *Committee*. In the results of this investigation, the state of progress of the respective development items was confirmed. For example, as for the reactor design, it was evaluated that the actions to be completed by the CR1 have been almost achieved and the progress has been favorable. After the results of the overall progress evaluation of the respective items were summarized, the DEMO Taskforce evaluated that the achievement of the goals by the CR1 stage has been "generally satisfactory".

(2) Confirmation of other latest situations

Situations after compiling "Follow-up of the Action Plan for DEMO Development: In Preparation for the First Intermediate Check and Review" (by the DEMO Taskforce in January 2021) were additionally confirmed.

(3) Relationship of the CR1 goals with the state of progress of Action Plan

Based on the results of (1) and (2) above, the relationship of the CR1 goals with the state of progress of the Action Plan was compiled (refer to Attachment 4). As a result of confirming them, the goals by the time of CR1 were evaluated to have been achieved.

With regard to JT-60SA, the research was already launched, and the generation of ECR plasma has been achieved. It must be noted that the achievement of the next research stage (including the generation of tokamak plasma) is a very important issue toward CR2.

5. Issues toward CR2

(1) Analysis based on the investigation results of the state of progress of Action Plan

On the basis of the investigation results of the state of progress of the Action Plan compiled by the DEMO Taskforce (including the confirmed results shown in Paragraph 4(2) above), the following important issues toward CR2 were confirmed.

- It is essential to maximally utilize the know-how acquired from the ITER Project and the BA activities, including the experiences of components development in the ITER Project. The development of components of which Japan is responsible for procurement for ITER needs to be accelerated in order to contribute to future DEMO development.
- Discussions on the fulfillment of a development system by securing human and financial resources and the priority order of resource allocation are required.
- Taking into consideration the scale of DEMO project, it is important to establish a system to strengthen the collaboration among the stakeholders from industrial, academic, and governmental sectors in Japan and develop it into the system that allows the construction and operation of DEMO.
- The Joint Special Design Team for Fusion DEMO comprising the industrial, academic, and governmental sectors is required to utilize the know-how that has been acquired in the ITER Project and BA activities, and the past experiences of the DEMO conceptual design for the future DEMO plan.

(2) Analysis taking into consideration the latest situations

The analysis result of the issues toward CR2 based on the latest situations in Section 3 above is shown below.

- The US and the UK have announced their vision for the acceleration of the achieving of fusion power generation. As the vision statements themselves have many unreleased parts and uncertain elements, additional analysis is required. However, it is worthwhile to review whether the timing of the achievement of fusion power generation in Japan can be accelerated, taking into consideration the determination of the US and the UK to accelerate their vision for this.
- Although a closer look reveals a difference in the strategies of the respective countries toward the achievement of fusion power generation, there is an essential technology that is commonly necessary to achieve the realization of DEMO (i.e., fusion power generation). For Japan, gaining such essential technology is important and should be immediately addressed.
- Even if the innovative technologies including high-temperature superconductivity that have been focused on by various countries may not be in time for DEMO, which is the first fusion power plant, it is appropriate that we continue to pursue R&D of the mid- to long-term key technologies in the era of fusion power generation.
- In the US and the UK, the collaboration among corporations associated with

fusion and the review of the sites and safety have been started while the acceleration of the timing of achieving fusion power generation is being reviewed. For outreach activities, the international situation in recent years needs to be taken into consideration.

- Constant communication with society is essential to deepen the public understanding on fusion as an energy source. In Japan, from such a viewpoint, the outreach headquarters has already been established and the relevant activities have been launched, based on the proposal by the *Committee* in collaboration with the related organizations. We need to develop the discussion about the additional measures for the development of outreach activities while looking back on the previous experiences.

(3) Important issues toward CR2

The following points are listed as important issues toward CR2, taking into consideration Paragraph 5 (1) and (2) above.

- In Japan, it is also an important issue to develop the technical review on whether the timing of the achievement of fusion power generation can be accelerated or not. When accelerating any timing, we should reconsider the goals to be expected for CR2 and reexamine the priority order related to the R&D for DEMO.
- A review of the timing of achieving power generation is a complicated issue to be accompanied with the review from various viewpoints, and we need to find out the relevant situations, including the strategies by the US and the UK. Thus, we must carefully examine them for about a year after CR1.
- With regard to JT-60SA, the research was already launched, and the generation of ECR plasma has been achieved. It is a very important issue to achieve the next research phase (including the generation of tokamak plasma) toward CR2.
- With regard to the outreach activities, the outreach headquarters was established, the activity promotion plan was formulated, and various approaches have been provided by the related organizations. It is important to develop these approaches additionally in the future.
- In the industries in various countries, the collaboration with the industries related to fusion energy has been promoted as fusion energy has been shifted from the research phase to the power generation phase. From now, the challenge is to deepen awareness of the importance of fusion energy among companies that have not been involved in fusion to date.
- In addition, developing the discussion about the site and safety is also a future issue, as fusion shifts to the power generation phase.
- The points shown above may include issues that are beyond the range of roles of the *Committee* and the DEMO Taskforce. The deliberations at the *Committee* need to be contributed to during future discussions by a wide variety of related organizations to promote the development of discussions.
- In addition to the above, in preparation for the arrival of the fusion power generation era, coping with a wide range of tasks from the technical

development to academic research required for fusion energy, and actively promoting the participation from other fields to develop and secure a wide variety of human resources required for fusion energy are also important issues.

6. Conclusion

In the investigation result of "Follow-up of the Action Plan for DEMO Development In: In Preparation for the First Intermediate Check and Review" (refer to Attachment 3), the DEMO Taskforce evaluated that the achievement of the goals to be achieved by the CR1 stage has been "generally satisfactory" after the entire result of the progress evaluation of the respective items was summarized. Also, after the further additional investigation was conducted and the relationship of the CR1 goals with the state of progress of the Action Plan was assessed (refer to Attachment 4), it was determined that the goals by the time of CR1 have been achieved.

In addition, issues toward CR2 are summarized in Paragraph 5 above. Paragraph 5(1) points out that the development of components for ITER of which Japan is responsible for procurement needs to be accelerated in order to contribute to future DEMO development. Paragraph 5(2) points out that the gaining of essential technology required to achieve DEMO, i.e., fusion power generation, should be immediately addressed. We would like to emphasize that it is important to deal with these issues immediately. Furthermore, as described in Paragraph 5(3), the goals to be achieved for CR2 may need to be reconsidered by enhancing the technical examination of whether the achievement of fusion power generation can be accelerated or not.

Toward the achievement of DEMO, though R&D has proceeded to the degree that the roadmap to the achievement of DEMO can be formulated, it is still halfway through, and the many issues presented here also need to be solved in the future. Therefore, a wide range of processes from technical development to academic research necessary for fusion energy must be addressed and a wide range of human resources necessary for fusion energy must be fostered and secured. Moreover, these tasks must steadily proceed while carefully gaining understanding from society. It is convincingly clear that R&D for DEMO is significantly important, in anticipation of the practical application of fusion energy in the future and considering the major goals set out, such as energy security, economic security in Japan and the achievement of a carbon-neutral society. Thus, in order to solve the many issues to achieve DEMO, we would like to emphasize the importance of efforts by the stakeholders from the industrial, academic, and governmental sectors working in conjunction, centering on the Joint Special Design Team for Fusion DEMO and the DEMO Taskforce. In view of the characteristics of the DEMO project, we also expect that future discussions will be developed by not only the *Committee*, which is under the Ministry of Education, Culture, Sports, Science and Technology, but also by a wide variety of related organizations.

(End of report)

Tentative Translation

(Attachment 1)

Check and Review Items (plan)

Items	Objectives by the 1st intermediate C&R	Objectives by the 2nd intermediate C&R	Judgment criteria for transition to the DEMO reactor stage
① Validation of burn control in the self-heating area by ITER	・Create a technical target achievement plan for ITER.	・Reflect ITER's collaborative research in the ITER technical target achievement plan.	・ITER maintains fusion power of Q=10 or higher (for over several hundred seconds) and validates burn control.
② Establishment of an operational technique for stationary high-beta plasma for operation of the DEMO reactor	・Proceed with ITER collaborative research and preparatory studies on stationary high-beta plasma and start JT-60SA research.	・JT-60SA achieves a high-beta non-inductive current drive. ・Have integrated simulations including the divertor verified by JT-60SA and other projects. ・Create a plan for JT-60SA divertor research compatible with the DEMO reactor's plasma-facing walls.	・Gain prospects for non-inductive steady operation by ITER's achievement of non-inductive current drive plasma and integrated simulations based on ITER's knowledge of burn control. ・JT-60SA validates the stationary operation of a high-beta (bN = 3.5 or higher) collisionless plasma regime compatible with the DEMO reactor's plasma-facing walls.
③ Establishment of integrated technologies by ITER	・Establish ITER's manufacturing technologies for superconductive coils and other key components and build an integrated technological foundation through the construction of JT-60SA.	・Launch ITER operation. ・Acquire integrated technologies to manufacture, install and adjust the ITER apparatus.	・Establish integrated technologies through ITER operation and maintenance and confirm the safety technology.
④ Material development for the DEMO reactor	・Obtain low activation ferrite steel's reactor irradiation data of dosages up to 80 dpa and finalize the materials for testing under a neutron irradiation environment similar to nuclear fusion. ・Complete the concept design of the nuclear fusion neutron source.	・Complete the validation of heavy irradiation data by reactor irradiation of low activation ferrite steel up to 80 dpa. ・Evaluate the initial irradiation behavior of blanket and diverter functional materials by reactor irradiation and validate the principles of lithium-securing technology. ・Start the construction of a nuclear fusion neutron source and create a plan for collecting material irradiation data.	・Draw up the structural design criteria. ・Establish lithium-securing techniques on a pilot-plant scale. ・Collect initial irradiation data on low activation ferrite steel and blanket and divertor functional materials with a nuclear fusion neutron source.
⑤ Technical development of reactor engineering for the DEMO reactor	・Formulate divertor development policies. ・Create technical development plans for reactor engineering requiring early preparation, including superconductive coil technology. ・Collect the necessary data for blanket design from the cold testing facilities.	・JT-60SA, LHD, etc. collect the necessary data relevant to the divertor, including the properties of the plasma-facing materials. ・Create development plans for the superconductive coil, divertor, remote maintenance, heating/current drive, fuel system, measurement/control, etc. for the engineering technology of a medium- or plant-sized reactor, and complete the concept designs of these items for the development test facilities. ・Establish foundation technology for the power generation blanket, build ITER-TBM No. 1, and complete the safety verification tests on the actual device.	・Establish reactor engineering technologies that support DEMO reactor design, including such items as the superconductive coil, divertor, remote maintenance, heating/current drive, fuel system and measurement/ control, based on the outcomes of the development test facilities and the performance results of ITER, JT-60SA, etc. ・ITER collects tritium and validates the evaluation technique for tritium behavior with the nuclear fusion neutron source.
⑥ Designing the DEMO reactor	・Formulate the overall objectives for the DEMO reactor. ・Draw up a basic concept design of the DEMO reactor. ・Submit requests regarding reactor core and reactor engineering developments.	・Complete the DEMO reactor's concept design that ensures high safety standards and economic feasibility by incorporating reactor core and reactor engineering developments. ・Identify issues in developing reactor core and reactor engineering to establish a technological foundation for engineering design and create a development plan.	・Acquire social acceptability, confirm economic feasibility at the stage of practical use, and complete the DEMO reactor engineering design by coordinating reactor core and reactor engineering developments. ・Draw up policies on safety laws and regulations.
⑦ Social relations	・Establish a headquarters for promoting social awareness. ・Draw up an awareness activity promotion plan.	・Promote social awareness initiatives and conduct social relations activities.	・Proceed with social relations activities toward the construction and operation of the DEMO reactor.

(Attachment 2)

Competition in Fusion Development Accelerated in Various Countries toward the Achievement of Carbon Neutrality

A. Change of trends in policies

A-1. The "European Research Roadmap to the Realisation of Fusion Energy" (2018), formulated by EU-related organizations (EUROfusion), states that fusion must generate 1 TW of electricity at the fusion power plant (i.e., 1,000 power stations each generating 1 million kW) worldwide during the course of the 22nd century. Fusion development has been promoted under the policy of "The European Green Deal" by von der Leyen, President of the European Commission (who took office in 2019). The intermediate evaluation conducted in three stages during the period from May to November in 2020 evaluated that a fusion reactor (DEMO) generating power must be established around 2050.

A-2. The U.S. Department of Energy (DOE) Fusion Energy Sciences Advisory Committee (FESAC) released a "10-year National Strategic Plan for Fusion Energy and Plasma Science" (in February 2021). It states that the construction of a fusion pilot plant (FPP) will be ready by the 2040s. The National Academy of Sciences proposed that the implementation should be determined by 2028, and power generation would be achieved in the period between 2035 and 2040 (February 2021). Review of safety regulations has been started, centering on the Nuclear Regulatory Commission (NRC).

A-3. In the United Kingdom, the new policies by Prime Minister Johnson labelled "The Ten Point Plan for a Green Industrial Revolution" (November, 2020) and "Towards Fusion Energy—The UK Government's Fusion Strategy" (October, 2021) explicitly state that a commercially viable fusion power plant is scheduled to be constructed by 2040. After seeking locations for the power reactor (in December 2020) and receiving applications from fifteen locations (in June 2021), five candidate locations were publicly disclosed (in October 2021). While the Regulatory Horizons Council (RHC) of the UK government announced its recommendations for the future regulations on fusion (in May 2021), the government published the material for discussion about the regulations for fusion (Green Paper) (in October 2021), and started collecting opinions (corresponding to public comments).

A-4. The Korean Government (National Fusion Energy Committee) has set the goal of the validation of power generation with the furnace for validating fusion-based power generation (K-DEMO) in the 2050s in their "Fourth Master Plan to Promote Development of Fusion Energy (2022 to 2026)" (December 2021). It specified the eight core technology groups required for the validation of fusion power generation (coil, blanket, diverter, etc.) and noted that they would be secured through ITER and/or Korea Superconducting Tokamak Advanced Research (KSTAR).

A-5. A plan is also being promoted toward the achievement of home-grown fusion power in China. According to the plan, it will be modified into a power reactor

(DEMO) by the 2030s after a scheduled unit of China Fusion Engineering Test Reactor (CFETR) on the same scale as ITER is constructed in parallel with ITER.

B. Activation of investment in fusion ventures

B-1. Commonwealth Fusion Systems, spun off from Massachusetts Institute of Technology, USA, raised an additional investment of more than 205 billion yen in December 2021 (more than 220 billion yen in total). It aims to put the fusion experimental reactor into operation in 2025.

B-2. General Fusion in Canada also raised more than 14 billion yen in total in capital in November 2021 (more than 33 billion yen in total).

(Attachment 3)

Follow-up of the Action Plan for DEMO Development

In Preparation for the First Intermediate Check and Review

Taskforce on Comprehensive Strategy for DEMO Development

January 27, 2021

I. What has been discussed up to this point

The Taskforce on Comprehensive Strategy for DEMO Development (hereinafter referred to as the "taskforce") formulated the "Action Plan for DEMO Development" in February 2016. Then, it revised the action plan according to change in the schedule of the ITER Project. The revised action plan was approved by the Science and Technology Committee on Fusion Energy in its meeting held on December 18, 2017, as the authorized action plan as of then.

II. Importance of the progress status follow-up in preparation for the Check and Review

(1) The policy titled "Japan's Policy to promote R&D for a fusion DEMO reactor" (adopted in the meeting of the Science and Technology Committee on Fusion Energy on December 18, 2017) requires the first Intermediate Check and Review (hereinafter referred to as CR1) in around 2020 and the second one (CR2) within a few years from 2025. At those milestones, the action plan must have been executed without delay.

(2) The taskforce is supposed to shoulder the responsibility to oversee the progress of the action plan from an All-Japan perspective as the control tower of DEMO development in Japan. Accordingly, it examines the state of the progress of the action plan and reports the result to the Science and Technology Committee on Fusion Energy.

III. About this report

This report summarizes the result of the progress status review prior to CR1. As the action plan is not only for a short term until 2020 but sets out a roadmap towards around 2035 when the construction of DEMO would be started, this progress status review also focuses on evaluating the progress to this roadmap goal, that is, the start of the DEMO construction phase. From this viewpoint, when additional actions were considered necessary after CR1 for a specific action item while the progress of the action item as of CR1 was assessed to be satisfactory, they were also brought up in the report, provided that they were annotated with the words "After CR1," meaning that they would be additionally necessary after the approval of the continuation of DEMO development at CR1.

It can be concluded that the state of the progress is satisfactory as of CR1 in general although issues remain in some action items. <u>It is our hope that CR1 will be held</u> on the basis of this progress follow-up report.

Simultaneously, many actions were suggested to be taken after CR1. To make those actions successful, it is essential to take advantage of experiences gained from the development of the devices for the ITER, which needs to enter into a full-scale operation in 2022 or later. It is imperative to accelerate the development of the devices for ITER that Japan is responsible to supply in order to utilize them in future DEMO development too. It is quite obvious that the enhancement of R&D capacity backed by sufficient human resources and funds is needed when all these actions are viewed from a higher perspective. The following actions should be very important: discussion on the priority order of resource allocation, full utilization of knowledge gained from the ITER Project and Broader Approach (BA) activities, and deepening discussion on further collaboration with industries.

It is foreseeable that the creation of an environment for animated discussion among the stakeholders in Japan on the construction and operation of DEMO, which is a major-scale project, and the establishment and expansion of the development groups and networks capable to carry out such a project will become very important after CR1. It is important to stress the necessity of those actions after CR1.

IV. Overview of the state of progress

An overview of the results of the progress status review is described in the following sections for each project task. Note that actions described with the annotation “After CR1” are those that need to be taken after CR1 as “additions to a certain action item whose progress was approved by CR1.”

0. DEMO Design

The progress of this task is considered satisfactory as most of the actions planned in the period before CR1 have been completed. The groundwork for the work acceleration has been laid, such as the participation of the National Institute for Fusion Science (NIFS) and universities, although the feasibility of advanced blankets (BLK) for the test blanket modules (TBM) of DEMO needs to be examined after CR1.

1. Super-conducting Coils

It can be considered that the actions to be completed by CR1 have been mostly achieved. The preliminary conceptual design developed as the result of the planned action is based on the ITER method but not exactly the same. Therefore, the design must be verified by prototyping and testing after CR1. In addition, it is considered necessary to formulate a budget plan for the entire R&D activities including costs for test systems after CR1 if any cost reduction plans are adopted, because new knowledge is required such as the study of radiation resistance insulation materials, which are not used in the ITER method (PR method), in addition to estimating cost reduction ratio to the ITER method.

2. Blanket

Technical feasibility of the water-cooled solid breeding BLK will have been established in general by CR1 as the preliminary conceptual design of the DEMO BLK. As to ITER-TBM, design work has been started with a focus on producibility. The construction of the Blanket Test Facility has been started, and the design of the safety test equipments to be introduced has been carried out smoothly. Quick data collection is expected after the completion of the introduction. Concerning tritium engineering tests, the design of the de-tritiation system of ITER is on schedule. But the design work of the large T-handling facility has just been started and needs to be accelerated after CR1. As for the advanced BLK, design work and basic data collection have started. However, development needs to be accelerated after CR1, including establishment of a development framework.

3. Divertor

The real-time control of detachment plasma is an indispensable element if a tungsten-copper alloy (W/Cu alloy) water-cooled divertor (DIV) is selected in the initial phase of DEMO. R&D aimed at understanding the elementary steps of detachment plasma and establishing a control scenario based on the gained understanding has been making steady progress toward CR1. Meanwhile, acceleration is required in many action items on a long-term basis after CR1 to achieve the final goal. In addition, further actions for the “DIV-class steady-state high density plasma experimental device” and the “heat load testing equipment for neutron irradiated materials and components” to be installed in the hot lab will need to be planned on the basis of the future progress of research after CR1.

4. Heating and current drive system

Good progress is being made in action items related to electron cyclotron heating (ECH) and neutral beam injection (NBI) that the National Institutes for Quantum Science and Technology (QST) is in charge of for contributing to ITER and JT60-SA toward CR1. After CR1, it is essential to take advantage of experiences gained from the development of the devices for ITER fusion operation, which needs to start a full-scale operation in 2022 or later. The development of the radio frequency (RF) negative ion source for the NBI of

ITER, which Europe is in charge of, is experiencing issues in terms of high energy and long pulse. However, collaborative efforts are being made through international joint research including NIFS to solve those issues. In addition, basic research on the development of the maintenance-free and cesium-free negative ion source is being conducted by universities and the NIFS. Thus, a domestic framework to address issues on the reliability of the NBI is being established. Such efforts need to be continued after CR1. As to challenges to improve the reliability of ECH, progress has been made in the development of frequency-tunable Gyrotron, output power enhancement in RF band, and the design of mirrorless antenna. In contrast, design and development work for high-speed frequency switching, high-efficiency operation, fully continuous operation, antenna maintenance, and transmission system, none of which are directly incorporated in the plan towards contributing to ITER and JT60-SA, needs to be accelerated after CR1 by establishing a nationwide development framework quickly.

5. Theory and simulation

In general, the action plan has been carried out in a timely manner based in part on discussion and suggestions on the development and use plan until around 2025 by the Theory and Simulation Working Group of the Joint Special Design Team for Fusion DEMO (hereinafter referred to as the “special team”) and other teams, and satisfactory outcomes will have been obtained by CR1. However, there are still some action items for which acceleration is required. In particular, the following tasks are closely linked to the progress of Check and Review (C&R) items by CR2: application, verification, and continuous development of DIV simulation code (SMC) to tests of JT-60SA and ITER; application, verification, and continuous development of integrated core plasma SMC to tests of JT-60SA and ITER; and continuous development and use of first principle based SMC for disruption, burning plasma, turbulence transport, and plasma edge. Thus, closer attention needs to be given and measures will be necessary to avoid any delay in progress after CR1.

6. Core plasma

It was confirmed that action items to be completed by CR1 have been carried out according to the plan in general. Especially, excellent progress has been made in the actions for “JT-60SA research plan” and “JT-60SA first plasma.” As to particle control technology, continuous efforts will be necessary to upgrade the technology after CR1. In addition, efforts to secure the continuous availability of computer resources will also be required for research on modeling and simulation.

7. Fuel system

It was confirmed that all action items to be completed by CR1 have been completed. After CR1, support will have to be provided for the following action items: “development of underlying technology for fuel cycle system (such as removal of impurities and isotope separation),” where new issues have been identified, “development for securing lithium (Li) resource in pilot plant scale,” and “basic technology development for ^{6}Li enrichment,” which needs to be scaled up.

8. Fusion Materials and Standard, Code

(1) Structure Materials for Blanket

Excellent progress is being made on low-activation ferritic steel towards CR1, such as the establishment of its mass-production technology and the development of related element technologies. Meanwhile, upgrade of its corrosion test database through the use of the cold test facility, collection of data on irradiation effects, and establishment of a model of irradiation-induced degradation and related standards and criteria will have to be accelerated after CR1, including the preparation of an irradiation field.

(2) Other materials

As to the advanced BLK materials, study has been started in the area of its utilization methods and database creation with cooperation from the NIFS and universities. After CR1, an irradiation field will have to be prepared, and irradiation effects and related items will need to be evaluated for materials used for DIV and functional materials for diagnostics and control systems, besides the aforementioned items.

(3) Fusion Neutron Source

Excellent progress has been made on the conceptual design of the fusion neutron source. It is necessary to strengthen cooperation with universities and other research institutes to accelerate engineering design after CR1. In addition, outreach activities to appeal the value of the fusion neutron source will also need to be strengthened after CR1.

9. Safety

Actions concerning safety have made good progress partly due to the utilization of the cooperation mechanism between Japan and Europe. Good progress has also been made in the analysis and assessment of safety as shown in the development of the basic code by the special team. The special team is also working on technology handed down by hiring young engineers. Study on principles underlying safety regulations will also need to be started soon after CR1 so that undo/redo in engineering design can be avoided in the future.

10. Operating rate and maintenance

The preliminary conceptual design conducted until 2019 towards CR1 is considered to have fulfilled all the requirements in general. Meanwhile, conceptual design work after 2020 will have to cover the development of measures to solve technical issues identified during the preliminary conceptual design (such as a structure to allow the reuse of DIV and back plates, and hot cell devices), and the integrated design of the reactor structure and remote handling equipment based on the measures need to be finished by 2024. Thus, conceptual design work needs to be accelerated as a whole after CR1.

11. Diagnostics and Control

Specific actions for the development of the system and devices to perform these functions are grouped into the following three groups: (i) theoretical study on control parameters; (ii) design work of diagnostic methods and equipment; and (iii) verification of theories, diagnostic methods, and control logics using ITER and JT-60SA. The goals set by CR1 have been achieved for all those actions without delay. However, more actions are required toward CR2, and each of them requires highly detailed engineering. Considering such challenges, the current R&D capacity may not be sufficient to achieve the goals set by CR2. In addition, irradiation from a neutron source is indispensable to complete the actions of irradiation tests.

12. Public relation

The outreach headquarters (HQ) has been established, and has started concrete outreach activities.

13. Helical system

Good progress has been made in general in each task of the plasma experiment, reactor engineering and design, and numerical simulation reactor. On the basis of the outcomes from those activities, a better understanding is being obtained of torus. From now on, highly reliable reactor design and accurate simulation model development will be required by reflecting the results of plasma experiments using the large helical device (LHD) in reactor design and numerical simulation reactor and by strengthening cooperation between those actions.

14. Laser Fusion

It is noteworthy progress that the number of researches that aim at applying the technologies developed through the study of high-power laser and laser fusion to DEMO development is increasing steadily. From this fact, it can be concluded that actions concerning laser are making good progress in general toward CR1. It is worth noting that research on the evaluation of the physical properties of solid deuterium and tritium mixture (DT) was started using a maximum-scale T-handling facility among universities as part of the joint research program on DEMO development, even though it was started behind the schedule. It is also worth noting that multiple research outcomes were by-products of the research whose final goals were not directly related to the development of DEMO or fusion energy.

Task name: 0. Demo Design

The progress of this task is considered satisfactory as most of the actions planned in the period before CR1 have been completed. The groundwork for the work acceleration has been laid, such as the participation of the National Institute for Fusion Science (NIFS) and universities, although the feasibility of advanced blankets (BLK) for the test blanket modules (TBM) of DEMO needs to be examined after CR1.

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Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Concept and construction plan	Physics and engineering guidelines	19	*	Special team	Prepared design basis list as guidelines for sharing of physics/engineering standard values, which are basis for determining DEMO parameters, and reasons for their determination. Will reflect design review results continuously, as needed.	Satisfactory	The design basis list has been prepared. Continuous revision will be needed after CR1 as well.	
	Basic conceptual design	19	*	Special team	Defined specifications of each major component (BLK, DIV, VV, SC, etc.) and plant equipment, keeping the gap from existing technology minimum and conducted press release on their results Improved design system code (TPC) for tokamak fusion reactor.	Very satisfactory	Parameters for reference have been determined. After CR1, the team will improve them based on cost analysis and future progress of JT-60SA.	
	Conceptual design	26		Special team/Industries	Under preparation for start-up		Reactor design R&D activities to support design concept should be made in parallel after CR1.	
	Fuel cycle strategy	26		Special team/TF	(Special team) Working on securement methods of initial load tritium (T). Working on fuel cycle system design as well. (TF) Proceeding with activities while keeping attention to 7 “Consistency with fuel system” in Japan’s strategy.		Good progress for CR1 is evident. Progress is continued towards 2026. DD start-up and production with high-temperature gas reactor are under discussion.	
	Integrated simulator	26		Q/N/Universities /Special team	(Q) Developed equilibrium control simulator (MECS) and improved simulator so that 3D eddy current is taken into consideration. Developing PID control method using machine learning techniques. Developing technologies related to DIV and disruption. (N/Universities/Special team) Cooperating with the aforementioned actions.		Good progress for CR1 is evident. Actions for overall integration are required after CR1.	
	Cost evaluation	31		Special team/Industries	(Special team/N) Improved cost evaluation model at system code level. Separated physical cost and production cost. Developed model including equipment as power plant, which is not included in ITER. Made rough estimation of construction cost. (Industries) Contributed to plant model development.		Good progress for CR1 is evident. Working on activities in cooperation with industries.	Cooperation with industries should be reinforced to detail cost calculation.

Equipment design	Basic design of SC	19	*	Special team/Q	(Special team) Worked on the basic concept made on the premise of improving design stress of low temperature structure materials, according to ITER scheme. Worked on the concept of schemes other than the ITER scheme (where radial plates are not used) to reduce cost. (Q) Cooperated with the Special team	Very satisfactory	Basic design has been successfully completed. The team can start the next steps.	
	DEMO TBM targets	19	*	Special team/Q	(Special team/Q) Worked on advanced BLK concept through joint research and have mostly achieved DEMO TBM objectives.	Satisfactory	Results are sufficient for CR1. As actions after CR1, conditions for determination and constraints are necessary for DEMO TBM in addition to comparing currently existing concepts. Big progress after CR1 can be expected, as NIFS and universities started participating.	After CR1, technical feasibility of advanced BLK should be studied to set the rational goal of DEMO TBM.
	Draft plan of equipment configuration with BOP	19	*	Special team/Industries	(Special team/Industries) Developed rough draft of concepts of main heat transport systems (primary and turbine systems) and power supply system.	Very satisfactory	Studies on plant systems that are unique to nuclear fusion have progressed.	Continuous support by industries is also required for BOP conceptual design after CR1.
Safety policy	Draft of Safety policy	19	*	Special team/Industries	(Special team/Industries) Conducted impact analysis based on safety analysis and evaluation of draft plan of impact mitigation/prevention, in accordance with policies for defense in depth application, protection with multiple barriers, and safety function achievement.	Satisfactory	Results were determined to be sufficient for CR1.	
	Assessment of Safety aspect	31		Special team	Under preparation for start-up		Safety requirements items started to be organized on the basis of study results obtained so far.	
	Organizing of safety feature of DEMO plant	26		Special team/Industries	(Special team) Started impact analysis based on safety analysis and evaluation of draft plans for accident/event prevention and mitigation.		Actions have been started smoothly as data collection has been commissioned to universities with the aim of improving the accuracy of source term evaluation for materials related to safety in vacuum vessels.	
	Draft for safety regulations	26		TF/Special team	(Special team) Studying to decide which legal regulations are appropriate for fusion facility construction, referring to nuclear regulations in and outside of Japan.		After CR1, studies should be accelerated so as not to create waste in future engineering design.	
Database of Physics, Engineering & Materials	DEMO physics DB Engineering/materials DBs	26		Q/Universities/F/Special team	(Q) Planning to add data from JT-60SA and ITER to various tokamak physics DBs. Added fatigue data of 300°C, 400°C, and 550°C and data related to anistropy effects on impact properties to materials DB. Will organize data so that probability functions of properties can be obtained. (Universities) Have participated in materials DB project through joint research. (F) Supported DB development through cluster activities in Fusion Energy Forum. (Special team) Planning to summarize DBs.		Method of securing structural integrity based on probability distribution is the Japan team's original idea. Because it is rational method, it might be global standard. It seems to be promising.	

Task name:
1. Super-conducting Coils (SC)

It can be considered that the actions to be completed by CR1 have been mostly achieved. The basic design of concept developed as the result of the planned action is based on the ITER method but not exactly the same. Therefore, the design must be verified by prototyping and testing after CR1. In addition, it is considered necessary to formulate a budget plan for the entire R&D activities including costs for test systems after CR1 if any cost reduction plans are adopted, because new knowledge is required such as the study of radiation proof materials, which are not used in the ITER method (PR method), in addition to estimating cost reduction ratio to the ITER method.

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Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
SC design	Basic design of concept	19	*	Special team/Q/Industries	Collected Japanese experts' opinions through WG activities based on a policy of keeping the technical gap from the ITER method minimum Developed the radial plate (RP) method using Nb3Sn cable in conduit conductor similarly to ITER method as basic concept. Worked on manufacturing simplification (cost reduction) in parallel to meet requirements from industries. The following perspectives have been obtained: (1) Manufacturing accuracy of TF coils can be mitigated to 2–4 times higher than that of the ITER method, by using error field correction coils. (2) Shear stress of conductor insulator can be decreased significantly by using rectangular jackets for rectangular conductors.	Satisfactory	Basic design of concept with ITER method has been developed, and design parameters have been decided. Cost reduction measures have also been developed in parallel. Activities on SC conceptual design will follow on from these actions.	
	SC conceptual design	26		Special team/Q/Industries	In FY2020, started working on the layer winding method for rectangular conductors and evaluating cost based on the RP method to explore options further for cost reduction.		R&D activities for SC preliminary conceptual design plan should be carried out in combination with improving cost reduction measures made for SC basic design of concept.	
	Decision of major option for SC conductor	19	*	Special team/Q/N/NIMS/ Universities	The Nb3Sn wire, main candidate, did not seem feasible depending on strain value in conductor, but it is expected to be feasible when using the short twist pitch conductor equivalent to the ITER-CS conductor, by extrapolating from the ITER-CS insert coil test results.	Satisfactory	The Nb3Sn wire has been selected as the main candidate. Activities on SC conductor conceptual design will follow on from this action.	
	Conceptual design of SC conductor	26		Special team/Q/N	Started detailing conductor design including twist structure in FY2020, following on from activities in FY2019. (Planning to start working on common research subjects concerning "Understanding of degradation mechanism of conductor current" in FY2021)		It is required to detail SC conductor design and verify conductor feasibility through R&D for Nb3Sn selected in previous actions.	
	Proposal of R&D plan	19	*	Special team/Q/ Universities/ Industries	Suggested following R&D activities critical for SC coil selected in preliminary conceptual design [To verify SC conductor feasibility] (1) Confirmation of workability of the short twist pitch conductor by prototyping conductors. (2) Actual measurement using conductor prototypes. This is because only extrapolated values are used to test conductor performance. [To realize coil specifications (magnetic field strength)] (3) Intensification of extremely low temperature structure materials.	Satisfactory	To use rectangular conductors, R&D plan dedicated for it is required.	For prototyping conductors, re-establishment of wire manufacturer's equipment should be considered.

SC conductor and coil tests	Study of test facility for SC conductor	19	*	Q/N/Special team	Suggested large-scale SC test equipment with high magnetic field be newly established to evaluate SC properties in 14T or higher, which is the conditions of use, because the upper limit of the external magnetic field in the existing test equipment is 12T–13T.	Satisfactory	Activities on SC conductor test equipment will follow on from this action.	
	Test facility for SC conductor	26		Q/N/Special team	Started working on details of tests, as well as “SC conductor conceptual design (20 -> 26) and “SC conductor test (20 -> 33)” in FY2020.		The following actions need to be accelerated after CR1. · Specifications of specific test facility · Development of overall plan of R&D and test facility, such as prototyping conductors, making model coils, and using them for conductor test facility	
	Test of SC conductor	33		Q/N/Industries	Started working on details of prototyping conductors and tests, as well as “SC conductor conceptual design (20 -> 26) and “SC conductor test facility (20 -> 26)” in FY2020.		The following actions need to be accelerated after CR1. · Studies on conductor test methods to correctly evaluate decrease in performance due to the electromagnetic force of the Nb3Sn wire	
High strength structural materials/radiation-proof materials	Study on high strength structure material	19	*	Q/NIMS/Special team	Made preparations to start full-scale development of high strength structure materials with higher strength than ITER (4K: 0.2% proof stress, 1,200 MPa or higher) in FY2020 or later: · Setting a development target and establishing a development system · Starting property evaluation test of existing materials and prototyping new materials for their development · Preparations for JSME standards	Satisfactory		
	Trial production and test of high strength materials	33		Q/Industries/ Special team	Prototyping new materials and conducting property evaluation tests in FY2020.		Smooth start-up of full-scale development is important after CR1.	
	Study of radiation-proof materials	19	*	Q/Special team	Worked on requirement specifications to enhance strength of radiation-proof materials and their feasibility, keeping the use of, in particular, rectangular conductor in mind, through WG activities by experts in Japan.	Satisfactory		
	Trial production & test of Radiation-proof materials	33		Q/Industries/ Special team	Started working on “Development of design standard for insulation materials for DEMO” through joint research in FY2020.		Smooth start-up of full-scale development is important after CR1.	
Related BOP (cooling and coil power supply)	Basic design concepts of cooling and coil power supply	19	*	Special team/Q	Developed following basic design concepts based on ITER design and knowledge · Cooling system: estimate of refrigerating capacity and required consumption power · Coil power supply system: study on power supply configuration in which compatibility to pulse operation is considered part of plant system design	Satisfactory		
	Conceptual design of cooling and coil power supply	26		Q/Special team	Started working on next steps based on ITER model as conceptual design in FY2020, following on from activities in FY2019.		After CR1, studies on rationalization are required in addition to detailing of design.	

Task name: 2. Blanket

Technical feasibility of the water-cooled solid breeding BLK will have been established in general by CR1 as the basic design concept of the DEMO BLK. As to ITER-TBM, design work has been started with a focus on producibility. The construction of the BLK engineering test building has been started, and the design of the safety test facilities to be introduced has been carried out smoothly. Quick data collection is expected after the completion of the introduction. Concerning T-engineering tests, the design of the de-T system of ITER is on schedule. But the design work of the large T-handling facility has just been started and needs to be accelerated after CR1. As for the advanced BLK, design work and basic data collection have started. However, development needs to be accelerated after CR1, including establishment of a development framework.

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Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Solid breeder with water-cooling blanket	Establishment of Basic/standard database	35		Q/Special team	Implementing work for establishment of database of material properties necessary for design and standardization in BA activities and ITER-TBM development.		Database development for material properties has been carried out on schedule, but database development required for design evaluation (e.g., Failure DB) needs to be accelerated including decision of policy.	Activities to organize database for designing including data corresponding to real environment are needed.
	Basic design concept of DEMO BLK system	19	*	Special team/Q/Industries	Mostly completed basic design concept of box-shaped BLK with honeycomb rib.	Satisfactory	Basic design concept is expected to complete in general.	
	Conceptual design of DEMO BLK system	26		Special team/Q/Industries	Started to work on draft design of cylinder-shaped housing which has good pressure resistance and producibility, aiming to simplify DEMO BLK. Started optimizing T-breeding performance and evaluating heat transport analysis.		It is necessary to organize design requirement conditions for DEMO BLK, define reliability and application limits of structure/function materials, and sort out tasks for achieving target performance including operation rate.	It is critical to involve actively and continuously with simulation reactor ITER-TBM design group and domestic manufacturers.
	ITER-TBM production results	35		Q	As for producibility using F82H as component, preliminary work is ongoing including weldability study. Will specifically start full-scale producibility-focused design work in FY2021.		Producibility-focused design work should be accelerated to certainly achieve design approval from the ITER Organization.	It is critical to involve actively and continuously in domestic manufacturers.
	Design and plan of TBS and test facility and acquisition of data w/ cold test	21		Q	BLK engineering test building started to be constructed in the QST Rokkasho Fusion Institute, which will be completed in March 2021. Design of safety evaluation test facilities to be introduced has been mostly completed, which will be fully prepared in the early half of 2022.	Satisfactory	Building construction and facility preparation has been ongoing on schedule towards CR1, but data acquisition will be performed in 2022 or later. Task will be carried out in parallel to design activities for approval of final design.	It is necessary to establish domestic cooperation framework, focusing on research activities using facilities in the BLK engineering test building.
	Plan and design of T-engineering test facility	21		Q	ITER de-T system design is ongoing on schedule. The final design will be completed by FY2025. Started large T-handling facility design work through the T-related issues study WG in the special team.	Satisfactory	ITER de-T system design has been ongoing on schedule towards CR1. However, conceptual design of large T-handling facility for DEMO should be accelerated after CR1.	Study activities through T-related issues study WG should be accelerated.
Advanced BLK	Proposal of advanced BLK concept for DEMO TBM	26		Special team/N/ Universities	Organized conditions for inside of DEMO and started simulation of fluid dynamics under the magnetic field for liquid metal self-cooling BLK through QST joint research.		Comparison of cooling methods should be studied further while continuously accelerating feasibility evaluation of design with heat removal from first wall under DEMO conditions.	Numeric calculation should be improved, including coupled analysis of structure.
	Trial production and test with small modules of advanced Blk	26		N/Universities	Started tests on MHD pressure drop reduction technology, material compatibility in dissimilar material welded joints of piping, and liquid breeder/coolant purification technology through NIFS joint research.		Acquisition of experiment data, which would be rationale for technology/material selection and setting of design conditions, has started for advanced BLK concept work.	Feedback to activities on acquired data concept Selection of future test items to which results of conceptual design work are reflected

	Integrated flow loop test under real environment	31		N/Universities	(NIFS) Conducting property evaluation of fluid dynamics under the magnetic field and test for hydrogen isotope recovery technique, etc., using Oroshhi-2, metal liquid/molten salt integrated flow loop equipment.		It is required to reduce experiment costs, shorten experiment cycles, and increase the number of implemented tasks, by improving test methods with loop equipment or other actions.	

Task name: 3. Divertor

The real-time control of detachment plasma is an indispensable element if a tungsten-copper alloy water-cooled divertor (DIV) is selected in the initial phase of DEMO. R&D aimed at understanding the elementary steps of detachment plasma and establishing a control scenario based on them has been making steady progress toward CR1. Meanwhile, acceleration is required in many action items on a long-term basis after CR1 to achieve the final goal. In addition, further actions for the "Steady state & Div-like high density plasma test facility" and the "heat load testing equipment for neutron irradiated materials and components" to be installed in the hot lab will need to be planned on the basis of the future progress of research after CR1.

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Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Div Development Targets The Feasibility & Applicability for Demo-design	Decision of applicability of W water cooled DIV component to DEMO	26		Special team/Q/N/ Universities	(Special team) Developing DIV concept based on ITER (Status of DEMO DIV design is described in the Special team's DEMO design report.) (Q) Conducting comparison of common problems in BA DEMO design activities (This is described in the BA/DDA final report.)		If W/Cu alloy can be used in high heat load target parts, it can be handled with technology equivalent to ITER. However, re-examination will be necessary if W/Cu alloy cannot be used or rate of radiation from detachment plasma is not achieved.	ITER DIV should be verified with real machine.
	Assessment of advanced DIV and decision making for development	19	*	Special team/Q/N/ Universities	(Special team) Completed working on physics/engineering tasks for advanced magnetic DIV design. The control system for plasma equilibrium, design to strengthen TFC & PFC, and their installment have been influenced. Advantages such as heat/particle load reduction are expected, but extrapolation applicability to DEMO physics model is not sufficient. (Q) Worked on physics/engineering tasks for advanced magnetic DIV design in BA DEMO design activities. (This is described in the BA/DDA final report.) (Universities/N) As for advanced cooled DIV, heat transfer tests using high-temperature high-pressure He loop in Georgia Institute of Technology was conducted in the PHENIX Project of the Japan–US Joint Research Project for fusion research, to reveal heat transfer mechanism due to He jet impingement cooling and to clarify issues.	Satisfactory	For DEMO after initial DIV, continuous studies of advanced cooled DIV are needed after CR1.	
	Heat-load test facility for plasma facing components, Development & cold test	26		Q/N/ Universities/ Special team	(Q) Cold test facility: Currently available JEBIS (Naka Fusion Institute) is used mainly for ITER DIV development. Has not started R&D activities for production/tests of primary tasks for DEMO (W/Cu alloy piping and W/Ferritic steel piping) (due to insufficient budget and manpower.) (Q) Has not started working on high-heat load testing equipment in hot lab. (Universities) Evaluated T behavior in neutron irradiated W through the Japan–US joint research Working on high temperature neutron irradiation as well.		Concrete progress is needed after CR2 to incorporate plans and design of high-heat load testing equipment in hot lab.	

Plasma operation scenario	Development of DIV plasma simulation	26		Q/Special team/N/ Universities	(Q/Special team) Have drawn up development plan and proposal through theoretical simulation WG. Developed heat discharge scenario for DEMO plasma design and are working on DIV operating conditions (region) in steady-state operation using SONIC. (Current status of DEMO DIV design is described in the Special team's DEMO design report.) Worked on priority research tasks, by having set up DIV physics WG and working on improvement of detached DIV model based on proposal from WG. Have completed SONIC code extension to multi-impurity. Preparing benchmarks between SONIC and SOLPS codes (JT-60SA and DEMO.) Benchmarking for JT-60U has been implemented in the past (It will be implemented again after improving various models.) (Universities) As for steam shield effects due to transient heat loads such as disruption, PIC simulation and combination with SONIC are being developed. (Universities) Working on high-refinement of plasma detachment simulation in which fluid code (LINDA), collisional-radiative code, and neutral particle transport code are integrated and comparison with experiments. (Universities/N/Q) Analyzing 3D structural change of DIV plasma in JT-60SA due to the perturbed magnetic field, using 3D fluid code (EMC3-EIRENE.)		Simulation code development and detached plasma model improvement have been carried out, but their appropriateness is not adequately verified. Comparison between similar simulations and verification with experiments are required to complete simulation development in Japan and highly accurate estimate. Priority necessary for designing should be set.	Simulation model should be verified by using test results, which should be reflected to simulation code development.
	Steady state & Div-like high density plasma test facility; Development & experiment	26		Q/N/ Universities/ C3	(Special team) Have set up the DIV physics working group to set positioning and goals Can contribute to designing and tests through joint research, etc. (C3) Started construction of new facility (pilot facility: Pilot GAMMA PDX-SC), aiming to acquire highly extrapolatable database required to realize DEMO DIV-class steady-state high-density plasma experimental device. (C3) Continuously conducting preliminary experiments on plasma heating methods and high-density plasma production that will contribute to pilot facility design, by proceeding with development and verification of detached plasma production using high-temperature plasma, control experiments, and models (LINDA, B2-EIRENE, and neutral-particle transfer) in DIV simulation experiments using GAMMA10/PDX open magnetic field configuration.		Pilot facility construction is being prepared on the basis of annual plan. Meanwhile, as for DIV-class steady-state high-density plasma experimental device, the specific design or construction plan has not progressed, although necessary plasma parameters have been studied.	
	Development of real-time control scheme for detachment plasma	26		Q/N/ Universities	(Q) Developing SONIC corresponding to time evolution (started calculating attached/detached transition with JT-60SA DIV.) Verifying processes of plasma and impurity transport while proceeding with development Planning to conduct verification with real plasma and impurities in JT-60SA. (N/Universities) Performing experimental studies and modeling of dynamic response process of detachment plasma for thermal pulse with linear plasma device.		The status quo is not sufficient because real-time control of detachment plasma is a critical element. It is necessary to demonstrate that detached plasma control is feasible for DIV designed in the current situation, by combining simulation and experiments in ITER, JT60SA, etc.	It is urgently necessary to start experiments with other experiment devices and simulation without waiting for experiments with JT60SA.
	Test of real time control scheme for detached plasma by ITER/JT-60SA	35		Q/N/ Universities	Preparing for start-up			
	Optimization of DIV system by ITER/JT-60SA	35		Q/N/ Universities	Preparing for start-up			

Development of material and devices	Neutron irradiation effects on DIV component materials	35		Q/N/ Universities	(Q) Added fatigue data and data of anisotoropy that affects impact properties on the structure material F82H. Organizing data sufficient to obtain probability functions of properties in future. Started organizing material property handbook of baseline pure W out of plasma-facing material W. Started developing coating and surface modification technology using a friction stir processing (planning neutron irradiation tests). Have completed irradiation tests on Cu alloy (CuCrZr) for heat sink up to 5 dpa (irradiation temperature 100°C–350°C) and started preparing for post-irradiation examination. (Universities/N) Started post-irradiation examination, after completing large-scale neutron irradiation (500°C, 800°C, 1100°C, 1 dpa, with thermal neutron shielding) on W and W alloys using HFIR (research reactor in the US) in the PHENIX Project, the Japan–US Joint Research Project for fusion research. Will acquire databases on thermal conductivity, heat load resistance properties, mechanical properties, microstructure, hydrogen isotope accumulation, and others. (Universities/N) Have experimentally demonstrated diffusion and trapping behavior of deuterium on neutron irradiated W and W alloys using BR2 research reactor in Belgium, and improved accuracy of the model to estimate hydrogen isotope behavior, through joint research with the International Research Center for Nuclear Materials Science, Institute for Material Research, Tohoku University, and network-type joint research with NIFS (preparation of CDPS, linear plasma device). (Universities) Revealed effects of irradiation defect on hydrogen isotope trapping by conducting heavy ion irradiation tests on low-activation ferritic steel, CuCrZr alloy, and oxide dispersion strengthened Cu alloy. (Universities) Development is ongoing through the Japan–US joint research and joint research with Tohoku University. Conducting neutron irradiation in HFIR (US) and BR2 (Belgium).		Study has progressed steadily using HFIR (US) and BR2 (Belgium). Database improvement should be continuously accelerated. In addition to material development, it is necessary to conduct heat load tests in the form of real plasma-facing device and to solve challenges on designing plasma-facing device. It is necessary to incorporate plan and design of high-heat load testing equipment in hot lab.	
	Validation and development of effects, maintenance & repair technologies	26		Special team/Q/ Universities/ Industries	(Special team/Q) Working on remote maintenance methods, cooling methods, and structure of DEMO DIV and cassettes (The current status of DEMO DIV design is described in the Special team's DEMO design report.) Have not started studying inspection and repair methods in DEMO Planning to start collecting information about inspection and repair methods in ITER. (Universities) Developing *in situ* observation method of surface damage using laser-induced supersonic wave.		In addition to regular maintenance, repair technology for which various events are assumed has not been studied sufficiently.	It is necessary to decide responsible person immediately to carry out studies.
Particle flow control	Simulation code of particle behavior in reactor	35		Q/N/ Universities/ Special team	(Special team/Q) Working on the model of hydrogen isotope behavior in the vessel of the experiment equipment and studying accumulation properties of plasma-facing components through joint research and commissioned research.		Currently, it is difficult to study particle balance in detail because it is dependent on plasma burning control and detachment plasma control. But studies should be continued, taking its importance into account.	
	Study of exhaust system applicable for DEMO	26		Special team/Q/N/ Industries	(Special team) Conducting studies using design evaluation of exhaust with TMP for DEMO DIV as candidate example (2 Pa or higher for sub-DIV and 5 Pa for outside of each port; 1 to 2 pumps of approximately 5 m^3/s are needed.)		Particle exhaust for DIV should be proceeded without delay after CR1 as well, as it is the most important function.	

Task name:
4. Heating and current drive system

Good progress is being made in action items related to electron cyclotron heating (ECH) and neutral beam injection (NBI) that the National Institutes for Quantum Science and Technology (QST) is in charge for contributing to ITER and JT60-SA toward CR1. After CR1, it is essential to take advantage of experiences gained from the development of the devices for ITER fusion operation, which needs to start a full-scale operation in 2022 or later. The development of the radio frequency (RF) negative ion source for the ITER NBI, which Europe is in charge of, is experiencing issues in terms of high power and long pulse opertion. However, collaborative efforts are being made through international joint research including NIFS to solve those issues. In addition, basic research on the development of the maintenance-free and cesium-free negative ion source is being conducted by universities and the NIFS. Thus, a domestic framework to address issues on the reliability of the NBI is being established. Such efforts need to be continued after CR1. As to challenges to improve the reliability of ECH, progress has been made in the development of frequency-tunable Gyrotron, output power enhancement in RF band, and the design of mirrorless antenna. In contrast, design and development work for high-speed frequency switching, high-efficiency operation, fully continuous operation, antenna maintenance, and transmission system, none of which are directly incorporated in the plan towards contributing to ITER and JT60-SA, needs to be accelerated after CR1 by establishing a nationwide development framework quickly.

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Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Decision of technical specifications	Decision of technical specifications for ECH/NBI	26		Special team/Q	As for NBI, studies on deflected injection, vacuum pumping system, etc., are ongoing in addition to basic specifications (beam energy, injection power, efficiency, etc.). For ECH, study on oscillation source plant was started, as well as studies on optimization of EC injection position, efficiency improvement of current drive, plasma ignition/startup assistance, and launcher concept.		Technical specification work has been started from reactor engineering viewpoint in addition to requirement specification work based on physics design. Good progress for CR1 is evident.	Framework to establish consistency with development of reactor core and fusion reactor engineering technologies should be built.
Construction of test facility for DEMO	Construction of test facility of maintenance-free negative ion source	26		Q/N	Preparing for start-up			
	Realization of high power and long pulse in ITER ECH system	26		Q	Demonstrated performance (1 MW/300 s) with ITER Gyrotron actual machine units No. 1 to 4 Will continue to conduct high-power and long-pulse tests with the remaining 4 units.		Progress has been made as planned in the development plan towards ITER and JT-60SA. Good progress for CR1 is evident.	
	Technical development of high-power and steady-state ECH system for DEMO	35		Q/N/Universities	Preparing for start-up			Development should be continued to achieve low dispersion of electron beam rate, large opening diameter of cavity, low-loss optical devices inside Gyrotron, etc. To realize fully continuous operation, enhancement of cooling measures to reduce thermal deformation of devices inside Gyrotron and improvement of structural design should be studied.

Realization of high energy and steady state	Realization of high energy and long pulse in ITER NBI system	26		Q	For equipment (MITICA) to test the ITER full-size beam (16.5 MW) in the ITER NB test facility (NBTF), DC 1 MV voltage generation test (integrated test of equipment procured in Japan and from Europe), which is the final step of site acceptance tests of high-voltage power supply (1 MV), is being conducted, which will be completed by February 2021. After that, planning to conduct actual-scale voltage holding test to demonstrate 1 MV voltage holding of vacuum gap around the negative ion source and to start beam acceleration test in 2024. As for test equipment in QST (MeV-class ion source test facility, voltage holding test equipment), development tests necessary for finalizing the design of 1 MeV negative ion accelerator are being conducted, of which results will be reflected to the NBTF. As for large negative ion source (5 MW) of JT-60SA, full power beam tests will be started in 2023 and 100-s-long continuous tests after improving DIV. Until 2019, tests were conducted for realization of stable negative ion production, protection against abnormal electrical discharge, and redesign for high voltage holding, using small negative ion source. As a result, 0.5 MeV, 154 A/m^2, 118 s was achieved, exceeding requirement specifications (0.5 MeV, 130 A/m^2, and 100 s). From 2020, tests where those technologies are applied to real machine of large negative ion source are conducted. As for RF negative ion source, which was adopted for ITER, studies to achieve large current have progressed, but it is facing challenges in terms of “high energy and long pulse.” This is because its beam divergence angle is more than 2 times larger than that of filament-arc (FA) negative ion sources of QST and NIFS, which does not meet ITER requirements. To solve this challenge, direct comparison between FA and RF negative ion sources was made with the same accelerator as part of efforts for solution. Consequently, tests to construct negative ion source switchable to either FA or RF discharge form and to study beam divergence are ongoing in NIFS under joint research of NIFS and IPP.		The part where Japan is directly involved in procurement has progressed relatively as planned towards ITER and JT-60SA. Good progress for CR1 is evident. Meanwhile, there is an issue derived from RF negative ion source procured by Europe. Plan to immediately solve this issue has started. Initiative to carry out activities through all-Japan efforts has also started for equipment procured from outside of Japan.	For DEMO, it is necessary to keep support from NIFS having NBI experts.
	Conceptual design of reliable ECH (mirrorless, high-speed variable frequency, maintenance)	26		Q/N	(Special team) Started conceptual design work (remote steering phased array antenna) to achieve mirrorless antenna (Q) Demonstrated 1 MW oscillation at 4 frequencies (104, 138, 170, and 203 GHz) using ITER Gyrotron (Q) Worked on conceptual design allowing 1 MW or higher power output at frequency higher than 200 GHz Example: 236 GHz, 1.2 MW power output (oscillation power at cavity is 1.35 MW.) Have not started working on antenna maintenance method		It is necessary to build implementation framework to accelerate progress after CR1.	It is necessary to build implementation framework for tasks that have not yet started and tasks for which further progress is needed. · Achievement of high efficiency, one of the actions after CR1, requires development including multi-stage energy recovery technology and oscillation efficiency improvement by oscillation mode locking in cavity. It is necessary to build implementation framework for it.
	Development of radiation resistant materials for ECH and NBI	35		Q/N/Universities	Preparing for start-up			

High reliability	Conceptual design of reliable NBI (maintenance-free negative ion source, remote maintenance)	26		Q/N/Universities	In the development of RF negative ion source, which is one of maintenance-free negative ion sources and adopted for ITER, tests with negative ion source (ELISE), half size ITER negative ion source at IPP Garching have been conducted. Negative ion current under long-pulse (400 s or longer) operations achieved approximately 90% (hydrogen) and approximately 70% (deuterium) of the required level. Making efforts to solve problem of low current at deuterium in cooperation with NIFS NIFS has succeeded in deterring associated electron current by building a parallel trench structure at the negative ion extract. Tests with full-size RF negative ion source test equipment in NBTF (SPIDER) were started in 2018. Some initial failures occurred, but efforts are being made to solve them. After that, full-scale operation will be realized. NIFS has proceeded with academic studies, developing measurement system for plasma in negative ion source and beam extraction/formation, which will be the basis of high reliability of NBI. Study on cesium-free negative ion source is ongoing. Started design of NBI with beam simulation using cavity accelerator that can produce 2-MeV-class beam As for remote maintenance, the ITER Organization is working on the design for remote maintenance technology for ITER.		Europe is aiming to develop RF negative ion source under procurement framework for ITER, but they have not achieved ITER requirement performance. NIFS will conduct supporting research in cooperation with IPP. Activities by NIFS and universities for developing RF negative ion source, cesium-free negative ion source, etc. should be accelerated further after CR1.	
Achievement of high efficiency	Advancement of ECH energy recovery technology	35		Q/N/Universities	Preparing for start-up			
	Development of high-quality electron beam	35		Q/N/Universities	Preparing for start-up			
	Actions after CR1: Conceptual design of highly efficient NBI	26		Q/N/Universities	As for photo neutralizer, proof-of-principle studies in collaboration with universities are being planned through joint research of Joint Special Design Team for Fusion DEMO. DT-mixed beam has not progressed except design. As for compactification technology, studies are ongoing to identify compactification factors for designing real ITER reactor based on NBTF, especially concerning huge power supply.		Activities to develop the test plan have started.	

Task name:
5. Theory and simulation

In general, the action plan has been carried out in a timely manner based in part on discussion and suggestions on the development and use plan until around 2025 by the Theory and Simulation Working Group of the Joint Special Design Team for Fusion DEMO (hereinafter referred to as the "special team") and other teams, and satisfactory outcomes will have been obtained by CR1. However, there are still some action items for which acceleration is required. In particular, the following tasks are closely linked to the progress of Check and Review (C&R) items by CR2: application, verification, and continuous development of DIV simulation code (SMC) to tests of JT-60SA and ITER; application, verification, and continuous development of integrated core plasma SMC to tests of JT-60SA and ITER; and continuous development and use of 1st principle based SMC for disruption, burning plasma, turbulence transport, and plasma edge. Thus, closer attention needs to be given and measures will be necessary to avoid any delay in progress after CR1.

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Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
SMCs for core plasma with 1st principle	Focused dev. & use of 1st Principle type SMC for plasma edge	19	*	Q/N/ Universities/ Special team	(Special team) Has drawn up specific plan of development and use through theoretical simulation WG. The following actions were taken on the basis of this plan: (Q) Worked on improvement of value code for linear MHD stability analysis in the edge pedestal region and on validation of conditions to obtain ELM and observation conditions for the QH-mode, using data from experiment facilities in US, Europe, and Japan. Realized prediction of stationary plasma profile from core to edge, having incorporated prediction model of pedestal distribution in transport code. Started improvement of non-linear MHD code and worked on analysis of physics mechanism related to collapse of pedestal and energy release amount due to ELM. (N/Q) Analyzed effects of 3D external perturbed magnetic field on MHD equilibrium and ELM.	Satisfactory	As "understanding of physics mechanism resulting in ELM avoidance" and "conditions to trigger ELM and quantitative evaluation/prediction of collapse of pedestal and energy release amount after ELM " are required for studies of plasma edge, related code development and validation has progressed. Moreover, it allows prediction of plasma distribution in whole plasma confinement area, which is required for operation scenario development. Overall, good progress for CR1 is evident. After CR1, it is necessary to proceed with integration of non-linear MHD code and DIV code and development of model code and to conduct validation, etc.	Steady progress is evident. Still, it is necessary to continue development to contribute to improve "integrated core plasma SMC" with obtained results. In consideration of such situation, the sub-task "1st principle based SMCs for core plasma" will be changed into "(20) Q/N/U/S: Focused development & use of 1st principle type SMS for disruption, burning plasma, transport with turbulent flow (*)" from 2020 and later to secure continuous activities.
SMCs for core plasma with 1st principle	Focused development & use of 1st principle type SMS for disruption, burning plasma, transport with turbulent flow	*		Q/N/ Universities/ Special team	(Special team) Has drawn up specific plan of development and use through theoretical simulation WG. The following actions were taken on the basis of this plan: (Q) Continuing developing disruption integrated code. (N) Developed hybrid simulation code for high-energy particles, kinetic thermal ion, and MHD. (Q/N/Universities) Continuing validation for energetic particle-driven MHD instability of tokamak and helical plasma while starting study to predict burning plasma. (N/Universities) Developed the1st principle-based local simulation code for turbulent transport. (Universities) Developed the 1st principle-based global-scale simulation code for turbulent transport. (Q/Universities) Conducting experimental analysis of JT-60, etc., using local SMC. (Universities) Started simulation study of internal transport barrier formation using global-scale SMC. (Q) Started benchmarking between codes using realistic equilibrium. (N/Universities) Developing SMC for turbulence transport handling multi-species plasma.		Research and development have been progressing relatively on schedule. These actions require many research resources including human and computational resources at the middle period (2020–2025) and latter period (2026–2035) of AP. It is necessary to continue supporting current advanced actions to realize virtual burning plasma.	It is important to secure computational resources, because 1st principle calculation of turbulence transport based on theory of gyrokinetics requires huge computational expenses. How to secure computational resources until 2021 can be planned, but it is uncertain beyond then. Meanwhile, computational expense reduction is needed for application to transport code required for other sub-tasks. Because modeling of transport coefficient (modeling of first 1st principle calculation results and modeling based on combination of empirical rules from experimental data and machine learning) is needed, it is important to coordinate actions further with other sub-tasks.

Divertor (Div) SMC	Focused development & use of DIV SMC	19	*	Q/N/ Universities/ Special team	(Special team) Has drawn up a specific plan of development and use through theoretical simulation WG. The following actions were taken on the basis of this plan: (Q/Universities) Improved unsteady state of SONIC and enabled study on transient analysis and control methods for impurity transport, detached DIV plasma formation, etc. Improved the extended thermodynamic model that was applicable to impurities in low collisionality regime on the upper side of Scrape-Off Layer (SOL) and incorporated it to SONIC. Developed model of radiation transport and elastic scattering of neutral particles, incorporated it to SONIC, and evaluated effects to detached plasma in DEMO. (Universities/N/Q) Conducted verification in the axisymmetric magnetic field of SONIC and EMC3-EIRENE code and continued analysis of 3D external perturbed magnetic field using EMC3-EIRENE.	Satisfactory	Steadily developing model and SMC related to detached plasma creation by impurity injection and control of impurity contamination into core. Good progress is evident towards CR1.	
	Application of DIV SMC to JT-60SA & ITER, validation & successive development	35		Q/N/ Universities/ Special team	Preparing for start-up. (Q/Universities) Planning verification with existing experiments and experiments in JT-60SA.		After CR1, there will be many development tasks to be carried out, including introduction of plasma drift and improvement of model for detached plasma. Acceleration is required.	Currently, shortage of human resources is serious in this task, although it is important for DEMO and there are many tasks to be developed. Enhancement of human resources is urgently needed. It is also necessary to continuously secure available computational resources for development, DEMO design, and prediction/verification of JT-60SA/ITER.
Integrated SMC for Core Plasma	Development and use of integrated core plasma SMC	19	*	Q/N/ Universities/ Special team	(Special team) Has drawn up a specific plan of development and use through theoretical simulation WG. The following actions were taken on the basis of this plan: (Q) Developed high-speed steady-state transport code GORTRESS, which can be used as a complementary code to integrated code for unsteady-state (TOPICS), and integrated code based on GOTRESS (GOTRESS+), realized prediction of stationary plasma profile using advanced model of turbulence transport, and used it for prediction of JT-60SA. Developed particle model and heat transport model to be incorporated to TOPICS/GOTRESS and verified them using JT-60U experiments. (Q/N/Universities) Developed global-scale transport code (TRESS + GKV) based on the first principle-based code for local turbulent. (Universities) Worked on evaluation of impurity accumulation in DEMO and its effects to plasma performance, using integrated code (TOTAL).	Satisfactory	As for integrated code for tokamak core plasma, the team has developed plasma performance prediction and operation scenario of JT-60SA and ITER, mainly lead by QST. Development has progressed steadily with the aim of verification using experiments. Overall, good progress towards CR1 has been evident.	

	Application of DIV SMC to JT-60SA & ITER, validation & successive development	*		Q/N/ Universities/ Special team	Started working in 2020 (Q) Planning verification with experiments in JT-60SA.		After CR1, it is necessary to accelerate integration with DIV SMC including impurities and development of unsteady-state high-energy particle/transport model.	It is necessary to improve integrated core plasma SMC. Enhancement of human resources is urgently needed for "verification of integrated simulation including DIV using JT-60SA, etc." It is also necessary to continuously secure available computational resources for the 1st principle-based SMCs made for integrated simulation, its verification, and model development.
SMC for fusion materials	Development and use of element-codes for material SMC	26		Q/N/Universities/Special team	(Special team) Has drawn up a specific plan of development and use through theoretical simulation WG. On the basis of this plan, the following action items have progressed: ●BLK structure material: (Q) Developed element model of evaluation code for irradiation swelling; (Universities/Q) Analyzed electron theory of hydrogen behavior in precipitate; (Universities/Q) Started statistical analysis of formation behavior of irradiation defects for quantification of various irradiation fields. ●DIV materials: (N/Universities) Have established population analysis technique of hydrogen atom and molecule using neutral particle transport code including wall materials. Started detailing action plan for DIV materials.		As for BLK structure materials, modeling of formation behavior of helium cavity, which is a major irradiation defect, and understanding of the elementary process of hydrogen behavior in precipitate and point defect formation behavior have progressed. Modeling ~~of~~ on formation behavior of hydrogen cavities and dislocation loops and development of mechanical property assessment code will be tasks after CR1. As for DIV materials, element model of evaluation code for plasma particle recycling targeting tungsten and carbon materials is being constructed. Modeling of irradiation degradation mechanism of CuCrZr alloy and tungsten materials (organizations to implement modeling for both materials have not been decided) will be tasks after CR1.	
	Development, use, and validation of integrated code for materials	35		Q/N/ Universities/ Special team	Preparing for start-up			
Integrated SMC for DEMO System Design	Development and use of SMCs for basic engineering	20	*	Q/N/ Universities/ Special team	(Special team/Q) Developing and improving BLK heat kernel analysis code, error field analysis code, general-purpose code for structural analysis for BLK enclosures, general-purpose code for thermal fluid analysis, system code for T-fuel, T-permeation code, etc. Working on integration of T-inventory evaluation code into BLK heat kernel analysis code. Have developed analysis code for plasma heat load to first wall and working on optimizing the shape of first wall and on limiters.	Satisfactory	Element code necessary for integrated SMC for DEMO system is being developed and integration of some codes has been started, led by the special team.	
	Modeling for plasma response and control	19	*	Q/N/ Universities/ Special team	(Q) Improving equilibrium control simulator (MECS), which can be basis for simulator for operation control of DEMO. (Special team) Developed equilibrium control simulator (MECS_3D) and analytical code of initial excitation (OH_3D) for which 3D eddy current effect was taken into account. (Q) Worked on development of ion temperature gradient control method using machine learning.	Satisfactory	QST and the special team have been jointly and steadily developing the equilibrium control simulator, which is assumed to be the main element code for core plasma in the simulator for operation control of DEMO while constructing the 3D effect model of the conductor structure. Real-time control method has been developed using machine learning.	

Simulator for operation control of DEMO	Development & use of operation simulator available for prediction of plant behavior	35		Q/N/ Universities/ Special team	Started working in 2020. (Q) Working on the operation scenario using the diagnostics control system (e.g., magnetic sensor) and coil power supply control system for verification with JT-60SA by using MECS. (Special team) Working on the highly elongated plasma startup scenario and ignition scenario using MECS_3D and OH_3D. (Q) Conducting verification of ion temperature gradient control method with machine learning, using results of experiments in JT-60U.			

Task name: 6. Core plasma

It was confirmed that action items to be completed by CR1 have been carried out according to the plan in general. Especially, excellent progress has been made in the actions for "JT-60SA research plan" and "JT-60SA first plasma." As to particle control technology, continuous efforts will be necessary to upgrade the technology after CR1. In addition, efforts to secure the continuous availability of computer resources will also be required for research on modeling and simulation.

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Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Plasma design	Physics design and decision of core plasma parameters	19	*	Special team	Have set DEMO core plasma parameters based on physics design activities that were carried out while developing necessary codes.	Satisfactory	Outcome can be reflected to plasma parameters for JT-60SA and ITER. Optimization of core plasma parameters, which is the next action, has also started. This action is completed.	
	Optimization of core plasma parameters			Special team	Started working in 2020		Optimization of core plasma parameters using simulation has already been started. Moreover, operation of JT-60SA was started in 2020. Further progress can be fully expected.	
	Establishment of plasma design DB	19	*	Special team	Have established plasma design database (DB) based on results from experiments with existing equipment inside and outside of Japan.	Satisfactory	Plasma design DB has been developed, which can be extrapolated to the plasma parameter region assumed for DEMO. This action is completed.	
	Revision of plasma design DB			Special team	Started working in 2020		Results from experiments in JT-60SA, of which operation was started in 2020, can be incorporated. Also, the latest DB from theory/simulation study can be reflected, although it is slightly delayed. Further progress can be expected.	Theory/simulation study should progress steadily towards revision of DB available for DEMO plasma design, including securement of necessary servers.
ITER	Revision of ITER research plan	24		Q/N/ Universities/Ij	(Q/N/Universities/Ij) Worked on detailing the operation plan according to baseline in which FP was planned for 2025 and DT for 2035 and revised the ITER research plan in 2018.		Progressing on schedule Plan has been continuously reviewed to reflect the latest study results created from JT-60SA, etc.	The team should work on this task through all-Japan efforts for participation in ITER experiments.
JT-60SA	Revision of JT-60SA research plan	19	*	Q/N/ Universities	(Q/N/Universities) JT-60SA Research Plan Ver. 4.0, final version, was completed in 2018.	Very satisfactory	The final version has been completed with 435 co-authors (174 co-authors from 18 research institutes in Japan and 261 co-authors from 33 research institutes in 14 European countries). This action is completed.	
	First plasma	20	*	Q/N/ Universities	(Q/N/Universities) Started working in 2020	Very satisfactory	The first plasma planned for FY2020 is fully expected to be achieved, as integrated test operation has proceeded on schedule. QST/NIFS/universities have started JT-60SA On-site Laboratory to enhance cooperation.	

	Establishment of plasma control method	21		Q/N/ Universities	(Q/N/Universities) Started working in 2020	Satisfactory	Integrated test operation has been carried out on schedule. Further progress can be expected. QST/NIFS/universities have started JT-60SA On-site Laboratory to enhance cooperation.	
LHD, Heliotron J	Understanding about physics of torus system	25		N/C2	(N) Conducted analysis in which experiments are closely linked to theory simulation to study turbulent effects to confinement performance and contributed to reveal physics mechanism of 3D magnetic field effects of tokamak plasma. (C2) Enhanced understanding on the role of 3D magnetic field structure of torus plasma through research to study abnormal transport and conditions for transport barrier formation while focusing on preparing local plasma measuring device.		Progressing on schedule Three-dimensional magnetic field effects have been understood further as a result of contribution of LHD and Heliotron J. Prediction of fusion burning plasma performance is expected to be improved.	Cooperation among researchers of tokamak and helical through joint research, etc., should be strengthened further.
	Deuterium experiment	25		N	Achieved ion temperature of 10 keV and confirmed presence of isotope effects and good confinement of high-energy particles.		Started accumulating systematic data. Deuterium experiments have been progressing on schedule.	
	Demonstration of particle control (D, He, and impurities)	19	*	N	Demonstrated the presence of phenomenon denoted as “impurity hole” in which impurities are automatically discharged in high ion temperature. Demonstrated that isotope mixing ratio was controllable according to conditions for particle supply and degree of turbulent fluctuation transport in hydrogen–deuterium mixed plasma. Revealed that particle retention of walls including helium was not saturated because of co-deposited layer formation in the environment of low temperature and carbon walls.	Satisfactory	After CR1, it is necessary to work on improvement of particle control technology in action “Deuterium experiment.” Particle control technology in longer (approximately 3 h) electrical discharge should be verified. Preparation of exhaustible DIV, which is an active particle control tool, has been almost completed. However, it is a future task to study whether it is applicable for longer electrical discharge.	

Study of plasma/wall interaction	PWI basic data for W material	26		Universities/C3/C4	(Osaka University) Continuing studies on hydrogen isotope behavior in W during co-irradiation of hydrogen isotopes and impurities (helium, nitrogen, rare gas, etc.) and behavior of W layer melted because of transient heat loads. (Nagoya University) Evaluated retention behavior of hydrogen isotopes and helium in neutron irradiated damaged W material and W deposition layer. Confirmed the retention in W material increased rapidly compared to the bulk materials. (C3) Continuing evaluation of relationship between helium bubble formation on W surface and hydrogen isotope retention, as well as hydrogen isotope retention behavior in irradiation-damaged W using APSEDAS, a compact PWI simulator. (C4) Continuing basic research on W material, including evaluation of hydrogen retention capacity of W redeposition layer and W base metal.		Progressing on schedule. Basic experiments and basic data acquisition in Osaka University, Nagoya University, Plasma Research Center, University of Tsukuba, and Research Institute for Applied Mechanics, Kyushu University have progressed on schedule. PWI data have been accumulated.	Cooperation among universities should be continuously enhanced to integrate data obtained from each university.
	Clarification of issues on W-DIV with long-pulse operation	26		Universities/C3/C4	(Osaka University) Continuing modeling and evaluation of hydrogen retention and permeation behavior during hydrogen isotope/impurity co-irradiation. (Nagoya University) Evaluated structural change in materials due to helium plasma irradiation. The confirmed big structure was formed by irradiation, which contributes to arcing. (C3) Proceeding with study on detached plasma production, including evaluation of effects of multiple gas injection to W-V shaped targets in GAMMA10/PDXDIV simulation experiments. (C4) Acquisition of long-term property data of W material has progressed by using QUEST, acquiring correlation data of hydrogen retention and hydrogen recycling in W material according to difference in plasma irradiation time, temperature of walls, etc., and revealing it was due to erosion and redeposition behavior.		Progressing on schedule Basic experiments, modeling, and basic data acquisition by Osaka University, Nagoya University, etc., have progressed on schedule. Task has been carried out on schedule, as DIV simulation experiments for W materials have been conducted with GAMMA10/PDX in Plasma Research Center, University of Tsukuba, and data of W materials exposed to plasma for a long time have been acquired using QUEST in Research Institute for Applied Mechanics, Kyushu University.	The link between basic experiments/modeling study and real reactor experiments should be continuously enhanced.

Modeling and simulation	Establishment of physical model and expansion of plasma prediction code	19	*	Q/N/ Universities	(Q) Realized improvement of unsteady-state integrated code and development of steady-state transport code in which turbulence transport model and pedestal distribution model are incorporated. Realized prediction of stationary plasma profile from core to edge by combining them. Took actions to realize extension to multi-impurity and unsteady-state for DIV code Proceeded with integration of modeling and simulation, including improvement of linear MHD stability analysis code, improvement of non-linear MHD code, improvement of hybrid code of improved non-linear MHD code and high-energy particle code, and development of disruption integrated code. They were adopted for various evaluations in JT-60SA and ITER. (N/Universities) Constructed physics model and improved plasma performance prediction code for torus plasma For details, refer to Task 5 "Theory and simulation."	Satisfactory	Study on modeling/simulation for various phenomena has progressed on schedule. This action is completed. Tasks requiring further development and improvement are expected to be carried out continuously in activities linked to Task 5 "Theory and simulation" or next action "Development of plasma control simulator."	
	Development of plasma control simulator (including application to ITER, JT-60SA, etc.)			Q/N/ Universities	(Q/N/Universities) Started working in 2020		Development of integrated PID control and automatic gain control of multiple physical quantities and intellectual control using machine learning has started. Further progress can be expected.	Computational resources are critical for modeling/simulation study, but operation of JFRS-1 in the QST Rokkasho Fusion Institute will be terminated at the end of March 2022. It is required to secure successive computational resources.

Task name: 7. Fuel system

It was confirmed that all action items to be completed by CR1 have been completed. After CR1, support will have to be provided for the following action items: “development of elemental technology for fuel cycle system (such as impurity control and isotope separation),” where new issues have been identified, “Establishment of a way for Li securement in pilot plant scale,” and “development of ^{6}Li separation basic technology,” which needs to be scaled up.

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Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Design study of fuel recycling system	Decision of fuel cycle scenario	18	*	Special team/Q/ Universities	(Special team/Q) Developed fuel cycle scenario, including identification of specifications for pellets (injection rate, injection pellet size, injection point, etc.) using the central plasma transport code and identification of amount of particle supply (pellet for core and gas-puff for edge) and amount of particle discharge (particle balance analysis) using the DIV transport code.	Satisfactory	Paper on technical information including analysis results has already published. This action is completed.	
	Demonstration of fuel cycle scenario	26		Q/N/C5/ Universities	(Q/N/C5/Universities) Started working in 2020.		Operation of JT-60SA, to which fuel can be supplied with gas-puff and pellet injection, started in 2020. Steady progress can be expected in the future.	
	Evaluation of fuel inventory	18	*	Special team/Q/ Universities	(Special team/Q/Universities) Evaluated inventory for DEMO, using database organized on the basis of analysis of existing experimental data. Moreover, improving experimental data of T-inventory at temperature of first wall of DEMO.	Satisfactory	Inventory for DEMO has been ready for evaluation. Originally planned activities have been completed. Improvement of data from experiments through cooperation of QST, universities, NIFS, and University of Toyama (C5), which is a new initiative, has progressed on schedule. It will be completed by around 2022.	
	Verification of fuel recycling system specifications	19	*	Special team/Q/ Universities	(Special team/Q/Universities) Decided fuel cycle system specifications based on the aforementioned action “Evaluation of fuel inventory.”	Satisfactory	Originally planned activities have been completed. Reviews will be repeated until around 2022, in accordance with improvement of data from experiments in aforementioned action “Evaluation of fuel inventory.”	
Development of fuel recycling system	Development of elemental technology for fuel recycling system (Impurity control, isotope separation, etc.)	26		Q/C5/ Universities	(Q) Elemental technology has been developed steadily, including proposal of concept for construction of fuel recycling system for DEMO, for which reduction in T-inventory is taken into account, development of catalysts that efficiently recover T, etc. (C5) Development of elemental technology was completed in 2018.		Development of elemental technology has progressed through cooperation of QST and C5. But a new challenge “Development of injection supply technology of D/T mixture solid pellet” has become evident. Actions should be accelerated after CR1 to address it.	Actions should be taken for new challenge “Development of injection supply technology of D/T mixture solid pellet.” Cooperation is required because it is common technology with laser type T-storage/handling technology.

Development of safe handling and equipments for Tritium	Verification of tritium removal and control	24		Q/C5/ Universities	(Q) Element development and verification tests conducted through joint procurement for ITER-DS for de-T system have progressed, and associated measuring control technology has been developed steadily. (C5) Making steady progress, including improvement of β-ray-induced X-ray spectroscope and liquid scintillation counter and implementation of tile analysis of LHD by using them. (Shizuoka University) Continuing studies through BA joint research and NIFS joint research.		Good progress is evident. Research has progressed with a focus on ITER de-T system procurement and BA activities. Analysis using advanced measuring devices is being conducted in the Hydrogen Isotope Research Center, University of Toyama.	Cooperation is required because it is common technology with laser type T-storage/handling technology.
	Basic data for Tritium -and-material interaction	19	*	Q/C5/ Universities	(Q) Has acquired necessary basic data, as studies have progressed, including findings on T-inventory/discharge of ion-irradiated tungsten, effects of irradiation damages on low-activation ferritic steel and tungsten to hydrogen isotope retention, hydrogen isotope behavior in advanced tungsten material, practical use of decontamination method for T-contained fusion reactor materials, T-permeation barrier, and T-inventory of JET tungsten-coated carbon tiles and dusts. (C5) Accumulated data of dissolution/diffusion/trapping behavior of hydrogen isotopes including tritium in tungsten and its alloy, low-activation ferritic steel, and Cu alloy, as well as isotope effects. Acquired data of T-inventory, etc., in JET tungsten-coated carbon tiles and dusts. (Kyushu University) Proceeded with study on T-retention/inventory in plasma-facing wall, especially W. Conducted basic research on each liquid and solid breeding material. (Shizuoka University) Accumulated data through Japan–US joint research, BA joint research, and NIFS joint research. Obtained basic findings on neutron-irradiated W. (Ibaraki University) Acquired basic physical property data of fusion reactor materials through BA joint research and DEMO joint research. (Kyoto University) Acquired data of T-permeation/diffusion in SiC materials.	Satisfactory	Data have been acquired according to plan. This action is completed. It is expected that acquisition of basic data as new findings will be continued as part of the next action “Elemental test of T-contained gas/water-handling equipment (in fuel cycle).”	
	Elemental test of equipments in fuel cycle for gas and water with tritium	26		Q/C5	Started working in 2020		Studies have started for implementation of elemental tests. Further progress can be expected.	

Facility for handling of huge amount of Tritium	Design study of facility for handling of huge amount of Tritium	26		Q	Started working in 2020		The team started working. Further progress can be expected.	
Securement of Lithium	Planning for securement of ^{6}Li	17	*	Q	Conducting basic research for recovery of lithium (Li) from sea water using ionic conductor membrane and developing ^{6}Li enrichment technology, for which patent was acquired. Cooperation with many industries and public institutions has been established. This task is completed.	Very satisfactory	This action has been completed. The team has moved to the next step "Establishment of securing technology of Li resources in pilot plant scale" and "Basic technology development for ^{6}Li enrichment."	
	Establishment of a way for Li securement in pilot plant scale	26		Q/Industries	(Q) Started developing pilot plant concept for study of Li recovery technology using ionic conductor membrane, which will be the technical basis for the selected ^{6}Li production process. (Q/Industries) QST and companies have been developing Li collection technology using ionic conductor membrane.		Implementation of technology demonstration in pilot plant scale is currently uncertain. Actions should be accelerated after CR1.	
	Development of ^{6}Li separation basic technology	26		Q	Started developing elemental technology.		Elemental technology development has started, but participation of more companies is required for plant-scale development. Actions should be accelerated after CR1.	
Initial load Tritium	Assessment of T production	19	*	Special team/ Universities	(Special team) It is currently assumable to obtain initial load T from the heavy water reactor in Canada after starting the ITER operation. (Kyoto University) Developing the starting method that does not need initial load T. Steady state operation for 60–100 days is expected to be achieved. (Kyushu University) Evaluating production quantity in high-temperature gas reactor.	Satisfactory	Obtained results required to start working on the next step "Study on securement method of initial load fuel." This action is completed.	
	Study of securement way for initial load fuel	23		Special team/Q/ Universities	Started working in 2020.		Study has started on the basis of previous actions. Further progress can be expected.	

Task name:
8. Fusion Materials and Standard, Code (1) Structure Materials for Blanket (BLK)

(1) Excellent progress is being made on low activation ferritic steel towards CR1, such as the establishment of its mass-production technology and the development of related element technologies. Meanwhile, expansion of its corrosion test database through the use of the cold test facility, acquisition of data on irradiation effects, decelopment of a model of irradiation-induced degradation and related standards and criteria will have to be accelerated after CR1, including the securing of irradiation sites.
(2) As to the advanced blanket (BLK) materials, study has been started in the area of its utilization methods and database development with cooperation from the NIFS and universities. After CR1, irradiation effect-related items will need to be evaluated for DIV materials and functional materials for diagnostics and control systems while securing the irradiation sites, in addition to the aforementioned items.
(3) Excellent progress has been made on the conceptual design of the fusion neutron source. It is necessary to strengthen cooperation with universities and other research institutes to accelerate engineering design activities after CR1. In addition, outreach activities to appeal the value of the fusion neutron source will also need to be strengthened after CR1.

Report date: December 15, 2020

Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
	Clarification of material spec. & technical spec. for Demo	26		Q/Special team/ Universities	The specifications of low activation ferritic steel F82H for plates were set to draft ~~of~~ the material procurement specification based on the current allowable values and heat treatment conditions that were derived by reviewing their production records. The technical specifications of F82H in other shapes, such as tubes and forgings, will be determined on the basis of the result of their test production, which will be started at an appropriate timing.		Good progress has been made mainly on plate materials. Study on the technical specifications of F82H in other shapes such as tubes and forgings has been started. Further progress is expected.	The shapes the components for the DEMO will need to be made clear through design work.
	Mass-production	26		Q/Industries	The issues on controling the composition during remelting process for defect removal have been studied. A draft of the material procurement specification was developed on the basis of the results of 20-ton class dissolution. In addition, 5-ton class dissolution was planned, and verification to confirm reproducibility has been started.		Steady progress has been made toward the establishment of industrial-scale mass-production technology that will lead to the construction of actual machine based on the outcomes of the BA activities, etc.	Establishment of applicable production technology will be pursued in reference to the specifications required for DEMO.
	Establishment of BLK structure production technology	26		Q/Industries	The applicability of hot isostatic pressing (HIP) joining and forging to the production of BLK structure components has been studied. It was decided to proceed with the establishment of production technology in parallel and linked to BLK design work. As a specific action of this plan, tests to evaluate the producibility of the TBM structural components using F82H have been started. In addition, the development of joining technology for similar and dissimilar materials has been advanced through collaborative research with universities, in which new technology is being introduced such as friction stir welding and linear friction welding.		It was confirmed that a wide variety of options had been made available for the production method of BLKs due to good progress in technical development and advancement in introducing new joining technology in particular. In order to set a direction, continuous study is necessary after CR1 on the evaluation of components made using HIP joining.	Efforts to establish the method to evaluate the integrity of the HIP joints will need to be accelerated. In addition, other potential alternative technologies will also need to be sought in parallel.
	Reliability evaluation & code of small specimen testing technology	26		Q/Industries/ Academia	Collaborative research has been conducted between QST and universities on the evaluation of the reliability of main small specimen test technology, and progress has been made on the development of guidelines by participating in the activities of the Coordinated Research Projects (CRP) of IAEA on small specimen test technology. Through those activities, the first draft of the guidelines is expected to be completed by the end of FY2020. Standardization will be furthered through collaboration among Japan, Europe, and the US.		Although actions have been carried out broadly through domestic and international frameworks, strategies toward standardization will need to be made clear after CR1.	Continuous involvement of the stakeholders is important to establish standards in Japan and internationally.

Low activation Ferritic Steel	Environment data of jointed cover parts by cold test	22		Q	The applicability of laser welding technology with filler metal was examined. The evaluation of the technical applicability including strength properties was continued. Especially, a weldability test was performed to assess conformance to the French regulations, and the validity was confirmed by a competent third-party organization. In addition, data on corrosion in high-temperature and high-pressure water environment have been accumulated, and a draft of guidelines for water chemistry management was proposed.		Progress has been made on joining technology through collaboration with universities and other institutions. Progress has also been made in the study on the impact of environmental conditions. The proposal of the draft of guidelines for water chemistry management is one of the outcomes. Continuous efforts are needed to finalize the guidelines for water chemistry management and examine their validity by both the material development team and the plant design team. It is necessary to accelerate actions after CR1.	The study of the guidelines for water chemistry management needs to be pushed forward in collaboration with the design team and manufacturers.
	80dpa data by fission reactor	19	*	Q	Tensile strength, toughness, and microstructure were evaluated with the materials irradiated to 70–80 dpa at 300°C–350°C.	Very satisfactory	Good progress has been made since the results of mechanical property evaluation were obtained.	
	Verification of 80dpa data by fission reactor	26		Q	Irradiation tests that enable the collection of more reliable data under the irradiation condition of 80 dpa at the temperatures ranged 300°C–500°C are ongoing. Specifically, the plan of new irradiation tests with different heats for the verification of irradiation data was fixed, and the assembly of the irradiation capsule was started.		It was confirmed that irradiation data verification tests have been started.	It is necessary to proceed with microstructure evaluation also from the viewpoint of making effective use of the acquired mechanical property data. Efforts to gain the data with higher reliability are also necessary. This action item needs to be carried out using overseas reactors. Therefore, process management is important to steadly acquire necessary data.
	Environment data of jointed cover parts	31		Q	The irradiation tests of TIG, and EB welded joints with a dose of up to 20 dpa have been completed. Data acquisition will be continued. At the same time, further data acquisition corresponding to the design and corrosion tests under irradiation will be conducted.		Although good progress has been made in irradiation tests using fission reactors, the irradiation tests do not necessarily cover all the joint covering members. Actions need to be accelerated after CR1.	Irradiation tests will also need to be conducted for other alternative joining technologies.
	Evaluation of effects of He & fusion neutron irradiation, establishment of degradation model	35		Q/N/ Universities	A dynamic model of He cavity formation, which is a degradation factor of irradiated materials, has been developed, and the analysis on the effects of irradiation field to the cavity formation has been continuously conducted. Especially, actions aiming at the evaluation of volume swelling, which is one of the basic design data, have been started in BA Phase II.		Although good progress has been made in model development, the reliability of the model, including its validity and ability of extrapolation, is yet to be proved in terms of its applicability to DEMO design. Thus, efforts to prove the reliability need to be accelerated after CR1.	Collaboration with universities and other institutions will need to be further strengthened while development groups and networks are being formed with the participation of researchers in overseas countries. For this purpose, it is important to carry out human resource development consistently.
	Policy towards structural design code based on irradiation results	26		Q/Industries/ Academia	Study on the structural design criteria of in-vessel structural components, including probability-based design, has been started in the form of joint research activity between Japan and Europe as one of the important tasks of BA Phase II. In addition, preparation for new irradiation tests for basic statistical analysis has been started in the Japan-U.S. collaboration. Study on design criteria will be deepened, and development of the database will be accelerated.		This is an important action item, and basic guidelines have been presented. Further progress is expected in discussion on this item because good progress has been made in the formation of R&D implementation framework and in preparation for tests. Actions need to be accelerated after CR1.	A comprehensive strategy will need to be formulated to shape the guidelines into the concrete standards for structural design.
	Academic activity towards material codes	35		Q/Industries/ Academia	Preparation of documents that conform to the structural design standards RCC-MRx has been started as an action for conformity to French regulations mainly regarding the ITER-TBM project, and discussion with third-party organizations has been started to obtain special permission for the use of the materials. A presentation about F82H was given in the meeting of ASTM Committee A01 (steel, stainless steel, and related alloys) in the US.		Interaction with relevant universities and academies will need to be accelerated after CR1 to establish the standards.	Continuous interaction will be necessary.

Advanced BLK materials	S/Q/N/U: Decision for utilization of advanced BLK materials	26		Special team/Q/N/ Universities	Research on advanced BLK materials is being conducted in a collaborative research framework. Data collection has been carried out concerning main functional performances of the flow channel insert for liquid breeder BLKs made of SiC material. Especially, understanding of irradiation effect on electrical characteristics and the behavior of hydrogen permeation and lithium–lead corrosion has been deepened. In addition, the advancement of development in the aerospace industry has been studied. It is the most practical way to use vanadium alloys as the material of liquid lithium breeding BLKs. Simultaneously, their applicability to molten salt lithium lead BLKs has also been studied because of the development of oxygen control technology and oxidation resistance materials. Study on the applicability of aluminium-doped oxide dispersion-strengthened steel (ODS steel), which is expected to enhance environmental resistance and irradiation resistance, has been started in the form of collaborative research in the LHD project.		The ways of utilizing advanced materials are being screened in parallel to the study on advanced BLK concepts. Actions need to be accelerated after CR1.	It is necessary to promote the development of advanced BLK design and related element technologies and to establish the framework to make clear the ways of utilizing advanced materials so that design idea ~~plans~~ can be narrowed down.
	Expansion of database for advanced Blk materials	35		Q/N/ Universities	The data of mechanical, physical, and chemical properties of SiC/SiC composite materials have been accumulated, and preparation of the composite material property handbook has been started. Improvement of the bonding method, enhancement of low activation property, and enhancement of high-temperature strength property data are being achieved for vanadium alloys. As to ODS steel, data from the development of advanced nuclear systems and accident-resistant fuel have been referred to.		Maximum efforts have been made towards CR1 on this action item within the current research framework. However, the database has not reached a level capable to meet needs for advanced BLKs that are supposed in the action plan. Actions need to be accelerated after CR1.	Policies on how to organize the database in the form of an advanced material handbook will need to be studied continuously.

Task name:
8. Fusion Materials and Standard, Code (2)
Other materials

Report date: December 15, 2020

Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Functional Breeding Materials (Neutron breeder & Tritium Multiplyer)	Optimization of production and recycling of functional breeding materials	35		Q	New basic technology for low-temperature refinement process of beryllium (Be) applicable to recycling technology has been developed successfully, and R&D activities and efforts to establish groups and networks that undertake the activities have been started with the aim of realizing the practical use and commercialization of this technology, which will contribute to secure beryllium supply.		New technology that will contribute to the stable supply of beryllium has been developed successfully. The realization of the practical use of the technology and promotion of commercialization are expected. Actions need to be accelerated after CR1.	It is essential to enhance the development capacity in order to realize the practical use and commercialization of the new low-temperature refinement technology that is also applicable to recycling technology of Be. For this purpose, cooperation from relevant organizations such as companies and universities will be sought, including raising funds and budget. In addition, additional actions and the extension of the project length until 2035 will be necessary to secure Be supply including the realization of its reuse.
	Evaluation of mechanical data & establishment of production for breeders	30		Q	The evaluation of the thermal and mechanical properties of the pebble bed has been started following the granulation test that was performed on the basis of the granulation technology established in the BA activities. In addition, the producibility tests and evaluation on mechanical properties of the newly designed pebble bed made from beryllide blocks, which are used as advanced neutron multiplier, have been started.		The technology is one of the remarkable outcomes of the BA activities. It needs to be further upgraded at an accelerated pace after CR1.	Cooperation from relevant organizations will be sought.
	Securement technology for lithium	35		Q	Basic research has been started on lithium (Li) recovery from sea water using an ionic superconductor membrane and development of ^{6}Li enrichment technology. Collaboration with various industries and public agencies is being expanded on the development of Li recovery technology. At first, the development of the concept of a pilot plant for Li recovery technology using an ionic superconductor membrane, which will be the basic technology for a stable Li supply, has been started. The development of element technologies that form the bases of ^{6}Li enrichment has just been started.		The new technology has been developed successfully. Realization of the practical use and promotion of the commercialization of the technology are expected.	Li recovery and ^{6}Li enrichment technologies need to be verified using a pilot plant-scale test facility. For this purpose, cooperation from relevant organizations such as companies and universities will be sought to enhance the development capacity, including funds and budget raising.

Divertor Materials	Irradiation effect by fission reactor	26		Special team/Q/N/ Universities	Plates of a CuCrZr alloy that complying to the ITER grade were produced, and their various properties were evaluated together with CuCrZr alloys used for the cooling pipes for ITER full-scale divertor prototype. Small specimens for tensile tests were produced, and irradiation tests were completed using the High Flux Isotope Reactor (HFIR). Post-irradiation evaluation will be started. The evaluation of defects in the thermal spray coating tungsten strengthened by friction-stir processing (FSP) after cyclic heat load tests has been continued. The properties of the material will be continuously improved, including oxidation resistivity.		Preparation for the irradiation tests of CuCrZr alloys is in progress mainly on tensile tests. Meanwhile, further research will need to be performed on the impact of the radiation environment in DEMO on its components made of those alloys from multiple perspectives. The irradiation tests of tungsten materials rely on collaborative frameworks between universities in Japan and the US. It is necessary to secure the irradiation sites capable of fast neutron irradiations to improve the database. Actions need to be accelerated after CR1.	An irradiation test plans for promoting property evaluation related to integrity assessment needs to be formulated. The securement of an irradiation sites must also be included in the plan.
	Development & evaluation of irradiation resistant materials	35		Q/N/ Universities	Although the development of heat sink materials has been started mainly by universities and NIFS with the development of ODS-Cu alloys, it is still in the phase of basic study stage. Similarly, the development of new alloys and composite materials of tungsten has been started mainly by universities and NIFS but is still in the phase of preliminary material research.		They are still in the phase of basic research as of now. Actions need to be accelerated from now.	It is necessary to elaborate required specifications and reflect them in material development as design work advances. It is also important to collaborate with and introduce material development technologies in various fields.
Materials for diagnostics & Control	Database construction of irradiation effects	19	*	Q/Special team	No action was started. A report was prepared based on the workshop held in NIFS. Further actions on this item are considered to be in the DEMO engineering phase.	To be continued	Newer data than those contained in the report of the NIFS workshop does not seem to have been obtained as of now.	A database on irradiation-induced degradation will need to be created and organized on the basis of the report of the NIFS workshop. Then, irradiation tests and the development of alternate materials will be conducted as needed after the materials of diagnostics and control equipment will be used under the DEMO environment are identified.
	Evaluate irradiation resistance materials	35		Q/N/ Universities	Preparing for start-up			
Others	Q/N/U: Compilation of fusion materials handbook	19	*	Q/N/ Universities	The development of the handbook that mainly covers the physical and tensile properties of low activation ferritic steels has been continued. Data of various properties such as toughness, fatigue, and creep will be continuously added in a step-by-step manner. The development of the material property handbook of baseline pure tungsten has been started. The development of the handbooks of other materials will also be started.	To be continued	The development of the handbooks of structure materials has not been started except for low activation ferritic steels.	Cooperation from relevant organizations will be sought.

Task name:
8. Fusion Materials and Standard, Code (3)
Fusion Neutron Source (FNS)

Report date: December 15, 2020

Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Fusion neutron source (FNS)	Design & construction of A-FNS	30		Q	The conceptual design document (500-page document including figures and tables) of the Advanced Fusion Neutron Source (A-FNS) that mainly covers the design of the entire facility and subsystems was developed with the aim of making clear the necessity of a fusion neutron source, the specification requirements for facility, equipment and devices, and its irradiation test plan. A plan for engineering design work will also be formulated by the end of the fiscal year.		The “Conceptual Design Document” and the “Plan for Engineering Design Work” have been completed. Thus, preparation for the construction of a fusion neutron source is moving forward. Simultaneously, issues in engineering design have been identified. From now, cooperation from NIFS, universities, and research institutes will be necessary. Excellent progress has been made in design work, and further advancement is expected by formulating a detailed action plan.	The development of core technologies such as lithium target, irradiation module, and safety assurance technology needs to be actively carried out by way of collaborative research with NIFS, universities, and research institutes. In contrast, accelerator neutron sources involve a variety of factors. Therefore, the development of technologies that form their foundation should be expanded in new research communities if those technologies can be beneficial to society.

Task name: 9. Safety

Actions concerning safety have made good progress partly due to the utilization of the cooperation mechanism between Japan and Europe. Good progress has also been made in the analysis and evaluation of safety as shown in the development of the basic code by the special team. The special team is also working on technology handed down by hiring young engineers. Study on principles underlying safety regulations will also need to be started soon after CR1 so that undo/redo in engineering design can be avoided in the future.

Report date: December 15, 2020

Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Safety Regulation	(15) Safety feature of Demo (Evaluation by existing codes)	16	*	Special team/Industries	(Q/Special team) Safety assessment was conducted by QST and the special team in collaboration with engineers in Europe as part of the BA activities. The result has been compiled in the report.	Satisfactory	The action item was completed through rational activities, including the implementation of lectures on evaluation methods in cooperation between Japan and Europe.	
	(17) Safety feature of Demo (Decision of safety policy)	19	*	Special team/Industries	(Special team, Industries) The direction was set to apply the principle of Defense-in-Depth and to aim at achieving multiple barrier protection and basic safety functions as a safety policy draft. On the basis of this direction, the identification of potential causal phenomena and source terms, development of accident prevention and impact mitigation measures, and classification of safety requirements in terms of their significance were listed as action items.	Satisfactory	According to the action items described in the left column, analytical evaluation was performed on the basis of current knowledge.	
	(20)Safety feature of Demo (Analysis based on the safety policy)	26		Special team/Industries	(Special team, Industries) Safety analysis-based impact analysis and evaluation of the ideas of accident prevention and impact mitigation measures have been started.		Actions have been started smoothly as data collection has been commissioned to universities with the aim of improving the accuracy of source term evaluation for materials related to safety in vacuum vessels.	Young engineers who work on safety assurance will need to be nurtured and increased. A framework to receive support from engineers who have experience in dealing with nuclear regulations will need to be established.
	(20) Preliminary study on safety regulation	26		TF/Special team	(Special team) The special team is studying to decide which legal regulations are appropriate for fusion facility construction.		Study on regulations will need to be continued at an accelerated pace after CR1 so that undo/redo in engineering design can be avoided in the future.	
Organization of Engineering Issues on Safety	(15) Establishment of failure scenario	26		Special team/Q/Ij/N/ Universities/ Industries	(Special team) Study on equipment failure scenarios has been started. A failure tree diagram has been developed, and failure mode and impact analyses are being conducted using it.		It is necessary to list data to be collected on the basis of the current DEMO design and to start building a mechanism to promote data collection after CR1.	
Safety Analysis & Evaluation	(15) Development of safety analysis code	31		Special team	(Special team) The basic codes have been established by the special team. (Q) The safety analysis codes for the TBM that needs to satisfy the safety requirements for ITER are being developed by QST independently from the special team.		Existing codes necessary for the safety analysis will have been listed and organized after CR1. Note that there are issues in the development of the codes in the future, such as the availability of source codes, because those existing codes were not developed in Japan. It is necessary to set a plan for the development of original codes of Japan.	
	(20) V&V (Chemical reaction, dust behavior analysis, etc.)	26		Q/Universities/ Special team	A study to decide what kinds of new V&V processes are necessary for DEMO construction is being performed in reference to the opinions from experts.		The progress of this action item is considered to meet the plan as of now. The planning of V&V tests and the preparation of test equipment and facilities will be necessary after CR1. The question is whether enough number of engineers with the experience of safety-related tests can be assigned to those tasks, considering the aging of such engineers.	It is necessary to establish a system to increase human resources capable of such tasks, including hiring engineers who have experience in light-water reactors.
	(20) Safety analysis of Demo plant	31		Special team/Industries	The basic safety functions have been evaluated. Continuous safety analysis is underway using newly acquired codes, including TRACE.			

	(20) Decision of design criteria consistent with safety policy in conceptual design	26		Special team/Industries	The formulation of safety goals and design standards that ensure the integrity of the plant has been started.		The progress of this action item is considered to meet the plan as of now.	
Evaluation of Environmental Behavior of Tritium	(15) Assessment & study on restriction target of environmental Tritium	19	*	Special team/Q/N/ Universities	(Special team) “T-related Issues Study Working Group” was established, and an approach to self-control over tritium has been studied as part of the activities of task team 1. The result of the study will be reported in the form of a report in this fiscal year.	Satisfactory	Although the progress was judged satisfactory as of CR1, study on this item will need to be accelerated after CR1, because it involves the matter of regulations, which can be an uncertain factor for DEMO plant development, and pulling the schedule forward as much as possible is desirable. In addition, the basic ideas of the regulations applied to the ITER need to be studied.	A mechanism to gather opinions on guidelines used to set regulations will need to be established.
	(20) Evaluation of volume of release in operation & accident, and development of control technique for containment	34		Special team/ Universities/ N/Industries	(Special team) The evaluation of the impact of DEMO operation on the environment has been started.		The progress of this action item is considered to meet the plan as of now.	Evaluation system will need to be established with the participation of relevant industries.

Task name:
10. Operating rate and maintenance

The preliminary conceptual design conducted until 2019 towards CR1 is considered to have fulfilled all the requirements in general. Meanwhile, conceptual design work after 2020 will have to cover the development of measures to solve technical issues identified during the preliminary conceptual design (such as a structure to allow the reuse of DIV and back plates and hot cell devices), and the integrated design of the reactor structure and remote handling equipment based on the measures need to be finished by 2024. Thus, conceptual design work needs to be accelerated as a whole after CR1.

Report date: December 15, 2020

Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Design of Demo	Pre-decision of maintenance scenario	17	*	Special team/Industries/Q	The details of the maintenance method for blankets (BLKs) and divertors (DIVs) are being studied on the basis of the vertical transport of sector as a primary idea. As to study on the maintenance of BLKs, the following actions were completed: the clarification of maintenance conditions through the study of maintenance scenario, the identification of technical issues in the top-access maintenance system and design to address them, and the formulation of design guidelines for the maintenance cell and cask to prevent the diffusion of radioactive dust during maintenance. With regard to the DIV, the concept of the DIV maintenance equipment composed of the radial and toroidal movers, which was proposed by the Japanese team in ITER EDA, was proposed. Meanwhile, it was high priority to enable the reuse of DIV components such as DIV body in DIV design work, because the DIVs need to be replaced every year to every other year and their components need to be reused as much as possible to reduce radioactive waste. However, there remain technical issues in mechanical bonding between the target and baffle region.	Satisfactory		
	Decision of reactor concept & main parameters	17	*	Special team/Industries/Q	Horizontal maintenance system, vertical transport of sector, and ITER modular maintenance system were compared. A tentative decision was made to go with a vertical transport of sector-based reactor structure (with vacuum vessels, backplates, DIV cassettes, maintenance cell, etc.) as the primary design plan from the viewpoints of the degree of the impact of the maintenance system on the reactor structure and the dose rate condition during maintenance, which must be minimized for environmental protection. Meanwhile, structural integrity needs to be established by developing a draft of the standards for structural design as the basis of design in order to promote the structural design of tentatively selected vacuum vessel (which functions as the boundary to confine tritium and so on) and other components.	Satisfactory		
	Investigation & selection of R&D issues for maintenance	18	*	Special team/Industries/Q	The scope of R&D and development targets was set on the basis of the design of the remote maintenance system. The following element technologies and devices were identified to be developed in order to design and build remote equipment capable of handling heavy objects: (i) radiation-resistant devices and materials (such as reducer, lubricant, motor, and resolver); (ii) power control technology to achieve high-accuracy positioning; (iii) human–machine interface (HMI) technology to improve maneuverability; and (iv) weld joint inspection tool applicable to high-temperature and high-pressure piping.	Satisfactory		

	Study on work sequence & outage for maintenance	24		Special team/Industries/Q	These actions were started in 2020. The time required for maintenance was evaluated on the basis of the current maintenance procedures, and the reactor operation rate was estimated to be 70% with the simultaneous use of 4 casks. The time required for maintenance will be reviewed considering the addition of new maintenance items in the course of proceeding with the conceptual design of remote handling equipment. In addition, the time required for maintenance will be re-evaluated by introducing the RAMI analysis, which can take into consideration the failure mode and failure rate of the remote equipment itself as well as recovery time from failure.		Technical issues arising in the aforementioned actions “Design a tentative maintenance method” and “Determine reactor structure and parameters” will be worked on as part of this action item. Those actions to address the issues will need to be accelerated after CR1 as their results will need to be reflected in the design of the whole reactor structure and remote maintenance system.	
Back-end Study	Study of the back-end scenario	19	*	Special team/Universities/ Industries	· Approximately 1,200 kinds of nuclides generated in the BLKs, which is the maximum activation level, were subjected to nuclide migration analysis after being kept in shallow ground to simulate shallow waste disposal. The result indicated the possibility of shallow waste disposal for used blankets if it is carried out according to the regulations in Japan. Here, the concentration of uranium impurities in beryllium can be reduced to 0.7 wppm or less, which is the criterion set by the regulation of shallow waste disposal, when the production method developed by QST is used. · The draft of the management and disposal scenario for radioactive waste was developed on the basis of the decay characteristics of dose rate and residual heat in the BLKs and DIVs, which require periodic replacement, and in consideration of storage period, decommissioning conditions, and waste packaging methods. · Conceptual design was conducted for radioactive material handling facilities such as the hot cell based on the drafted scenario. In addition, the total volume of waste generated from periodic replacement was estimated by applying waste packaging methods used for waste from light-water reactors. Further, packaging methods that can reduce volume and concentration control methods that can lower applicable waste hazard classification were studied. · Rational management and disposal methods for waste from DEMO are being analyzed from the viewpoints of cost and safety based on the management and disposal policy for three back-end processes (immediate dismantling, safe storage, and burial disposal).	Satisfactory	After CR1, further rationalization will need to be pursued in designing the hot cell based on the current preliminary design because its design has a significant impact on costs. It is desirable to reuse BLK segments and DIV cassettes from the viewpoint of reducing radioactive waste. Therefore, the conceptual design of remote handling equipment in the hot cell should be conducted on the basis of this assumption along with necessary R&D activities if any.	
	Study on regulation for recycling of Radioactive waste	22		Q/Universities/ Industries	These actions were started in 2020. In the hot cell facility ~~facilities~~ for the treatment of the waste and reuse, the following processes are carried out: temporary storage (for dose rate and decay heat reduction), replacement (including thermal cutting and welding), inspection, volume reduction (including thermal cutting), and the initial storage of waste. The development of the codes that are used to estimate the T-inventory of in-vessel components has been started in order to control the radioactive level of tritium-containing in-vessel components while they are going through the aforementioned processes. In addition, functions required for the remote handling equipment used in the aforementioned processes are being studied, and the design of in-vesse components that can be easily replaced by remote handling equipment (connecting structure of BLK segment and BLK module) is being studied.		On the basis of the result of the aforementioned study, the modification of the current hot cell design will need to be accelerated after CR1 by reflecting the result, in order to proceed with the action “Study standards for disposal and reuse of radioactive waste.”	It is essential to receive support from relevant industries and academies for the design of processes carried out in the hot cell. Additional experts in the fields of budgeting and standards for waste disposal and reuse will need to participate in this action item.
	Decision of regulation for recycling of Radioactive waste (toward legal restriction)	26		Q/Industries/ Academia	Preparing for start-up, aiming at starting action in 2023.			

Development and accumulation of maintenance technology	Handling & inspection technologies of nuclear facilities	19	*	Industries	Research was carried out on the following items, and R&D activities necessary to make those items applicable to fusion reactors were identified: cask to prevent the diffusion of radioactive dust, decontamination for remote handling equipment maintenance, information on radiation-resistant device development, in-vessel monitoring technology, and mobile robot technology to check the situation in case of trouble.	Satisfactory		
	Handling & inspection technologies of nuclear facilities	24		Industries	Preparing for start-up, aiming at starting action in 2022		Research will need to be continued after CR1 because those methods are also important input for hot cell design.	Cooperation from the remote technology development team of the Fukushima Daiichi Nuclear Power Plant will be sought.
	Assessment of remote maintenance & inspection technology	21		Special team/Q/Industries	These actions were started in 2020. Technology to maintain the integrity of the structural components (such as vacuum vessels, BLK segments, and DIVs) is being studied as part of inspection and maintenance technology research. For example, handling of special joints, non-destructive inspection (introduction of the latest welding methods and inspection techniques), and the application of Leak Before Break (LBB) design to inaccessible sections for maintenance and inspection are being studied for the vacuum vessel.			

Task name:
11. Diagnostics and Control

Specific actions for the development of the system and devices to perform these functions are grouped into the following three groups: (i) theoretical study on control parameters; (ii) design work of diagnostic methods and equipment; and (iii) verification of theories, diagnostic methods, and control logics using ITER and JT-60SA. The goals set by CR1 have been achieved for all those actions without delay. However, more actions are required toward CR2, and each of them requires highly detailed engineering. Considering such challenges, the current R&D capacity may not be sufficient to achieve the goals set by CR2. In addition, irradiation test with a neutron source is indispensable to complete the actions of irradiation tests.

Report date: December 15, 2020

Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
Prediction by Theory, Existing / International Experiments Inspection by Experiments	Understanding of theoretical stability limit	19	*	Q/Universities/ Special team	(Q/Universities/Special team) Revealed the theoretical characteristics of beta limit, edge localization mode (ELM), vertical displacement event (VDE), and locked mode. Greenwald density limit is adopted as an empirical rule as it has not been understood theoretically.	Satisfactory	This action item has been completed successfully. From now, control methods will be studied, such as the stabilization of resistive wall mode (RWM) and the suppression of ELM.	
	Study of controllable parameters	19	*	Q/N/Universities/ Special team	(Q/N/Universities) Plasma quantities to be measured in each of tokamak and helical reactors were studied qualitatively in the NIFS joint research program “Thechnical Study on the Diagnostics for Control of the Fusion DEMO Reactors” (2012–2013, representative: Shinzaburo Matsuda) with the participation of QST, NIFS, universities and the special team. The result was reported in the form of a report (NIFS-memo-68).	Satisfactory	The qualitative study of controllable parameters has been completed.	
	Equilibrium simulation using magnetic probes positioned distantly	19	*	Q/Universities	(Q) Simulation has been completed on ITER and JT-60SA.	Satisfactory	The study has been well done as seen in the result of the simulation on ITER and JT-60SA. The study will be continued on DEMO in the next action "Verification of equilibrium by magnetic probes positioned distantly."	
	Verification of stability limit & controllable parameters	26		Q/N/Universities/ Ij/Special team	This action item will not be started until the result of experiments on ITER and JT-60SA is seen as shown in the action plan table.			
	DB of control performance in ITER/JT-60SA (methods, reliability, etc.) & response time	35		Q/Universities/Ij/ Special team	This action item will not be started until the result of experiments on ITER and JT-60SA is seen as shown in the action plan table.			
	Verification of equilibrium by magnetic probes positioned distantly	26		Q/Universities	(Q) Testing the hall sensor that is under development by ITER in JT-60SA is planned.		Collaborative research has been carried out between QST and the ITER Organization. Foundation is being built for the test plans that can contribute to the development of DEMO.	QST and the special team will need to collaborate with each other in planning tests on JT-60SA to make them useful for DEMO development. This action item can possibly be worked on by universities using their own facilities. Therefore, a collaborative research framework should be sought.
	Establishment of operation & maintenance DB of diagnostics by ITER/JT-60SA	35		Q/Universities/Ij/ Special team	This action will be started in 2027.			

Development of diagnostics	Classification & selection of diagnostics consistent with Demo design	19	*	Q/N/Universities/ Special team	(Q/N/Universities) This action item was studied in the NIFS joint research program “Thechnical Study on the Operation and Control of the Fusion DEMO Reactors” (2014–2016, representative: Shinzaburo Matsuda) with the participation of QST, NIFS, and universities. The result was reported in the form of a report (NIFS-memo-80).	Satisfactory	Diagnostic instruments that are considered feasible at present have been selected. Thus, this action item has been completed. Further study will be continued in the next action “Decision of candidate diagnostics & development."	
	Establishment of development framework of diagnostics including radiation test	19	*	Q/N/Universities/ TF	(Q) The radiation test modules of the diagnostics and control system have been studied by the Advanced Fusion Neutron Source Design Group and the Plasma Diagnostics Group of the Department of ITER Project of QST.	Satisfactory	Radiation tests that can be studied at present have been discussed. Thus, this action has been completed. Further study will be continued in the next action “Decision of candidate diagnostics & development."	
	Decision of candidate diagnostics & development	26		Q/N/Universities/ Industries/ Special team	(Special team) A working group on diagnostics and control systems is being formed.		A working group that can carry the expected functions started its work in 2020 as planned.	The study of the diagnostics related to the protection of the system (such as surface temperature measurement, vacuum level, and wear monitoring) should also be started.
	Plasma test, radiation test, lifetime inspection	35		Q/N/Universities/ Industries/ Special team	This action item will be started following the preceding action “Determine candidate diagnostics instruments and develop them.”			
	Development & evaluation of candidate diagnostics	35		Q/N/Universities/ Industries/ Special team	This action will be started in 2027.			
	Decision of diagnostics specification	35		Q/N/Universities/ Industries/ Special team	This action will be started in 2030.			
	Development & trial test of maintenance of diagnostics	35		Q/N/Universities/ Industries/ Special team	This action will be started in 2030.			
Evaluation of operation parameters and margin	Preset of operation point & allowable range	19	*	Q/N/Universities/ Special team	(Special team) The reference operating point was set using the system code.	Satisfactory	A zero-dementional parameter set evaluated using the system code has been tentatively set as the reference operating point.	
	erification of operation point & allowable range	26		Q/N/Universities/ Special team	(Q/Universities/Special team) This action item is being studied by the Fusion Reactor Design Group (Joint Special Design Team for Fusion DEMO) and Plasma Theory and Simulation Group of QST Rokkasho Fusion Institute and Advanced Plasma Modeling Group of QST Naka Fusion Institute as well as through joint research program (Tottori University, etc.).		Good progress has been made because of the efforts of QST and other supporting members. The development groups and networks seem to have been established well, which can be seen in contribution from universities through joint research framework.	
	Decision of operation point & allowable range	35		J/N/Universities/ Special team	This action will be started in 2027.			
Prediction (off-line)	Development of plasma operation simulator	19	*	Q/Universities	(Q) The MHD equilibrium control simulator (MECS) and the integrated code TOPICS were developed.	Satisfactory	The simulation codes have been developed.	
	Verification of plasma operation simulator	26		Q/Universities/ Special team	This action item will not be started until the result of experiments on JT-60SA is seen as shown in the action plan table.			

	Improvement of plasma operation simulator	*		Q/Universities/ Industries/ Special team	This action will be started in 2027.			
Real-Time Control System	Development of real time controller for JT-60SA	19	*	Q/Universities	(Q) The real-time control of plasma current, plasma position and shape, and average plasma density was developed for the experiments on JT-60SA started in 2020.	Satisfactory	The development is going well in line with the JT-60SA project plan. Expanded real-time control such as current distribution control will be implemented in order.	
	Operation of real time controller	35		Q/Universities	This action item will not be started until the result of experiments on JT-60SA is seen as shown in the action plan table.			
	Verification & improvment of 1st principle type code, simulator, real time control	26		Q/N/Universities/ Special team	This action will be started after 2020.			
	Development of tools for learning & prediction	26		Q/N/Universities/ Special team	This action will be started after 2020.			
	Apply real-time control	35		Q/Universities	This action item will not be started until the result of experiments on JT-60SA is seen as shown in the action plan table.			
	Verification of performance (accuracy reliability) of int. code, control simulator	35		Q/Universities/ Special team	This action item will not be started until the result of experiments on JT-60SA is seen as shown in the action plan table.			
	Decision of specification for real time control	35		Q/Universities/ Special team	This action will be started in 2030.			

Task name: 12. Public relations

The outreach headquarters (HQ) has been established, and has started concrete outreach activities.

Report date: December 15, 2020

Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress	Progress status evaluation	Steps necessary to achieve the task
Establishment of Outreach Head Quarter (HQ)	Establishment of concept of outreach HQ	19	*	TF/Special team/Q/N/F/ Academia	(TF/Special team/Q/N) The HQ was established in February 2019 ahead of the target date specified in the action plan (end of FY2019) and started its operation.	Very satisfactory	The outreach HQ has been established.	This action item has been carried out well since the outreach HQ has been established and its operation has been started.
	Establishment of fusion outreach Head Quarter	20	*	TF/Special team/Q/N/F/ Academia	(TF/Special team/Q/N) The meetings were held several times after the establishment of the HQ, and outreach activities were carried out.	Very satisfactory	The operation of the outreach HQ has been started. Outreach strategies are being developed and executed.	It is necessary to devise a support mechanism to realize sustainable outreach activities by the outreach HQ.
	Planning of fusion outreach operation	20	*	TF/Special team/J/N/F/ Academia	(TF/Special team/J/N) The outreach activities of JAXA, JAMSTEC, and other institutes were researched, and strategies for outreach and outreach activities were developed by the outreach HQ.	Very satisfactory	The outreach activity promotion plan was formulated on the basis of the outreach strategies developed by the outreach HQ. Then, the promotion plan was detailed as concrete action plans in three categories.	It is necessary for the outreach HQ to evaluate activities to date, identify issues, and set goals for activities in the future.
	Forwarding of fusion outreach operation	35		HQ/TF/Special team/Q/N/F/ Academia	(HQ/TF/Special team/Q/N) This action item was started in 2019. The outreach activities were promoted in each of the three categories according to the outreach activity promotion plan.			
Development of human resources for outreach operation	Study of framework & program for education	19	*	TF/Special team/Q/N/F/ Academia	(HQ/TF/Special team/Q/N) The draft of the outreach-based human resource development plan was studied in the outreach HQ.	Very satisfactory	Internship programs and study tours for high school students were planned in detail. Even in the COVID-19 catastrophe, events and information were provided through the online programs.	It is necessary to set up opportunities to discuss this topic among a broader range of people including the taskforce members, not to mention the outreach HQ members, as it has a broad impact on various fields of society.
	Education for outreach operation	35		HQ/TF/Special team/Q/N/F/ Academia	Preparing for start-up			
Action for Cooperation with Society	Cooperation with society for Fusion roadmap & Demo design activity	19	*	TF/Special team	(HQ/TF/Special team) Activities to inform the stakeholders (SH) have been promoted by the outreach HQ with the support of the taskforce and the special team.	Very satisfactory	Concrete outreach activities are being carried out by the outreach HQ and other supporting members, such as preparing a fusion outreach webpage on the website of the Ministry of Education, Culture, Sports, Science and Technology and publishing an introductory book on fusion.	It is necessary to establish a mechanism and system and expand networks to support the activities of the outreach HQ so that it can reasonably continue their activities.
	Cooperation with society for site decision of Demo plant	26		HQ/TF/Special team	Preparing for start-up			

Task name: 13. Helical system

Good progress has been made in general in each task of the plasma experiment, reactor engineering and design, and numerical simulation reactor. On the basis of the outcomes from those activities, a better understanding is being obtained of torus. From now on, highly reliable reactor design and accurate simulation model development will be required by reflecting the results of plasma experiments using the large helical device (LHD) in reactor design and numerical simulation reactor and by strengthening cooperation between those actions.

Report date: December 15, 2020

Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress for CR1	Progress status evaluation	Steps necessary to achieve the task
	Reduction of thermal load on DIV and particle control	25		N/Universities	The characteristics of detachment plasma are being evaluated, and the long-time stabilization of the said plasma is being experimented on the basis of research on detachment discharge that utilizes impurity gas-puff and resonance magnetic field.		Experiments of plasma operation using the LHD to reduce heat load to divertors (DIVs) are ongoing.	Analysis with a focus on difference in magnetic field line structure in the DIV region between helical and tokamak reactors is necessary from the viewpoint of contribution to the DIVs of DEMO.
	Transport & high energy particle Confinement	25		N/Universities	Research on high-energy particle confinement characteristics is being conducted by measuring NBI ion loss and high-energy particles generated by deuterium discharge. In parallel, research on simulation is also conducted.		Deuterium experiments using the LHD have been started. Research on high-energy particles is making good progress.	It is necessary to advance experiments with the LHD to actions to understand annular plasma systematically and to use the understanding for the prediction of plasma in DEMO.
Plant Engineering & Plant Design	Engineering feasibility of Helical plant by 3D analysis	19		N/Universities	The analysis of a 100,000-kW-class power reactor was newly started using the system code and has made progress in designing the concept for the early realization of DEMO by generating a compact and strong magnetic field. The optimization of the magnetic field configuration has been introduced.	Satisfactory	Progress has been made in the conceptual design based on the mutual similarity of the global confinement characteristics the LHD provides. The accuracy of fusion energy gain factor calculation was improved by the introduction of the detailed evaluation of transport characteristics and stability using the system code to which many numerical calculation modules were incorporated.	It is necessary to conduct detailed analysis by accurately incorporating the isotope effects obtained by experiments in the LHD.
	Engineering feasibility of large & high field SC helical magnet	25		N/Universities	Progress has been made in the study on the production of a helical coil made of high-temperature superconducting materials and the development of related element technologies. The cut test samples of large-bore, high-temperature superconducting material coils were produced, and property tests were conducted. Progress has also been made in the development of underlying technologies for the bonding method used to fabricate a helical coil from cut wire materials.		Technological feasibility is expected to be established for the development of high-grade, high-temperature superconducting materials applicable to the magnet for fusion reactors. It is a world-leading outcome. It is necessary to conduct high-current conductor tests in a high-temperature and high magnetic field environment using the large-bore, high magnetic field conductor test facility.	It is necessary to select the best one of the three high-temperature superconducting materials under development and demonstrate the producibility of a large-bore coil made of the selected material. The productivity of a helical coil, such as the bendiness of the material and applicable bonding methods, will need to be demonstrated by prototyping small coils.
	Engineering feasibility of long life liquid cooling blanket	25		N/Universities	Progress has been made in the development and design of molten salt BLK and liquid metal BLKs, as well as in element tests using the heat and mass transfer loop. Especially, useful outcomes were obtained in corrosion tests in molten salt under a high-temperature magnetic field and tests to evaluate the MHD pressure drop characteristics of liquid lithium–lead alloy.		Progress has been made in various experiments including those of new concepts using the heat and mass transfer loop. It is a world-leading outcome.	It is necessary to reflect the advancement of the study in the conceptual design of the power reactor and to reflect the outcomes to R&D activities.
	Development of low activation structure materials	25		N/Universities	It was demonstrated that the feasibility of bonding and machining low activation vanadium alloys could be significantly improved while maintaining their strength in a high-temperature range when they were highly purified. Progress has also been made in research on bonding technology between them and other metals.		Research on low activation structural materials that can be an alternative to low-activation ferritic steel has advanced.	It is necessary to demonstrate the large-scale productivity of vanadium alloys.

	Development of plasma facing component with high heat load & related materials	25		N/Universities	The world's best heat removal capacity was achieved by the development of the advanced brazing technology that realized bonding between tungsten and copper alloy. Progress has also been made in the development of the method to produce nanoparticle dispersed Cu alloy by combining the mechanical alloying method and the high temperature hydrostatic pressure press technique. In parallel, basic experiments to evaluate the flow behavior of DIV pebbles made of fusible metal alloys or ceramics were carried out.		The R&D of high-strength copper alloys was advanced, and remarkable outcomes were obtained in the development of bonding technology between these copper alloys and tungsten.	The characteristics of the DIVs made of W/Cu alloys under neutron irradiation will need to be examined for further advancement. Verification experiments will be necessary for pebble DIVs by prototype small-scale test equipment.
	Conceptual design of Helical plant	26		N/Universities	Conceptual design work for a 100,000-kW-class power reactor has been started in full swing based on the conceptual design of a 1,000,000-kW-class power reactor that had been developed as of the end of FY2018 and according to the direction to scale it down and reduce construction costs. Progress has been made in the study of remote maintenance and replacement scenarios for BLKs and DIVs.		The newly started conceptual design work for a 100,000-kW-class power reactor can be considered to have reached a level so that a summary report can be prepared within half a year or so for its outcomes based on the activities to date.	It is necessary to demonstrate the feasibility of the remote maintenance and replacement scenarios for BLKs and DIVs by carrying out middle-scale element experiments.
Numerical Plant Experiment	Simulation of elemebtary physics process	26		N/Universities	Simulation code systems capable of handling physical processes related to equilibrium, stability, transfer, and heating in the regions inside a helical-type device such as the LHD, including core plasma, boundary plasma, and plasma-facing wall, have been developed and expanded along with physical models to be used by making use of the plasma simulator (a supercomputer system) effectively. The developed codes and models are being verified by comparing the results of simulations using them with the results of experiments using the LHD and other devices.		Good progress is being made in research on various phenomena using modeling and simulation.	Collaboration between simulation-based theoretical research and experiment-based research will need to be further strengthened.
	Simulation of Sophisticated physical binding & layer biding	26		N/Universities	Hybrid simulation codes were developed for the MHD, high-energy particles, and kinetic thermal ions and used to analyze the instability of high-energy particle acceleration in the LHD or tokamak reactor. The integrated transport codes (task3D) for the helical-type plasma were developed and are used for the transport analysis of the LHD experiments and the verification of transport models. A turbulence transport model is being developed on the basis of the result of gyroscopic motion simulation, and a transport model using the latest statistical mathmatical methods is also being developed, in order to incorporate them into the integrated transport codes. Research on the optimization of the magnetic field configuration is being carried out by applying the developed models and code systems.		Good progress is being made in research on various phenomena using modeling and simulation.	Collaboration between simulation-based theoretical research and experiment-based research will need to be further strengthened.

Task name: 14. Laser Fusion

It is noteworthy progress that the number of researches that aim at applying the technologies developed through the study of high-power laser and laser fusion to DEMO development is increasing steadily. From this fact, it can be concluded that actions concerning laser are making good progress in general toward CR1. It is worth noting that research on the evaluation of the physical properties of solid deuterium and tritium mixture (DT) was started using a maximum-scale T-handling facility among universities as part of the joint research program on DEMO development, even though it was started behind the schedule. It is also worth noting that multiple research outcomes were by-products of the research whose final goals were not directly related to the development of DEMO or fusion energy.

Report date: December 15, 2020

Sub-task name	Actions	Deadline	Items to be completed by CR1	Organization to implement actions	State of progress	Degree of progress	Progress status evaluation	Steps necessary to achieve the task
Comprehensive understanding of material-plasma interaction	Numerical modelling of material wear by plasma	27		C1/ Universities/N	Progress is being made in research on plasma erosion utilizing-radiation hydrodynamic simulations and plasma particle simulations that were developed through research on laser fusion. Joint research with the QST has been started with the aim of understanding plasma formation process initiated by the interaction between runaway electrons and ice pellets injected for disruption control.		Steady progress is being made in research on the process of an object receiving pressure from the thermal load of high-power laser and of laser erosion partly because of the usefulness of such information in laser processing technologies. It is a good movement that actions to utilize actively the theories and simulations developed through laser fusion research in DEMO development are spreading.	Further acceleration is expected in the research activities if the environment, where the computer resources for DEMO development can be used for research on laser fusion and for the contribution of laser fusion study to DEMO, is prepared.
	Model experiment of material wear by plasma	27		C1/ Universities/N	At the Graduate School of Engineering of Osaka University, a laser-produced molten layer was formed on the surface in a magnetic field, and unstable structures occurring in the molten layer were observed. A comprehensive understanding of molten layer behavior under a magnetic environment is being gained by comparing the result of the observation with molten layer behavior observation data obtained in the actual tokamak device. In addition, spectroscopic data were also collected using laser-produced high-Z plasmas in order to observe the behavior of impurity particles occurring on the reactor wall.		It is a remarkable achievement that the precious data necessary to understand the impact of heat gradient and strong magnetic field on the behavior of a molten layer formed by a transient thermal load exerted on the reactor wall have been accumulated. The data of pulse laser-produced high-Z plasmas and their spectroscopic data are also valuable as they contribute to complementing missing atomic and molecular data.	Laser can be used not only as the direct source of heat load but also as a source to produce high-flux electron, ion, and neutron beams, which can be used to conduct a model experiment.
	Detailed design of material test facility	20		C1/ Universities/N	The design of a material test system that focuses mainly on heat load tests is underway at the Institute of Laser Engineering of Osaka University. The design work focuses on achieving the ability of the test system to produce higher heat loads with higher repetition cycles based on the existing heat load testing equipment (sub-millisecond pulse glass laser).	Satisfactory	The design of the material test system (laser system) has been started on the basis of the existing equipment as a benchmark. It is noteworthy progress. A 100- to 200-kW-class pulse laser system capable of producing higher heat loads with higher repetition cycles is being designed. The design will be completed before the predetermined due date.	The test system is expected to be used not only for the test of fusion reactor wall materials but also for broader purposes as a standard system for pulsed heat and pulsed pressure sources. The test system is expected to contribute to the promotion of development in the fields that have wanted such a test system.
Development of liquid metal wall	Detailed design of basic experimental facility for liquid metal wall	20		C1/ Universities/N	A liquid metal diffusion pump is being studied at Nagaoka University of Technology as the exhaust system for a laser reactor. Besides this, the experiments of controlling liquid metal flow are being conducted with the aim of applying it to the electrodes of pulse power systems.	Satisfactory	Good progress is being made toward CR1 because the experiments of controlling liquid metal flow have been started though they are for other purposes. However, research towards the DEMO development has not begun because of budget issues. It needs to be accelerated after CR1.	As to liquid metal, the NIFS and the Tokyo Institute of Technology are doing the R&D on it. Activities to make use of knowledge obtained from them for the DEMO development are expected.
Pellet production and injection technologies	Detailed design of pellet production system	19		C1/N/ Universities/ Industries	The measurement of the homogeneity of solid DT has been started as a joint R&D program for DEMO development. It aims at developing DT pellet production and injection technologies applicable to DEMO. Data obtained from the measurement will be used for the detailed design of the pellet production method.	Satisfactory	The research activities have been started towards CR1 as part of the joint R&D program for DEMO development, though the start was delayed because of budget issues. It is a noteworthy achievement that the methods to evaluate the physical properties of solid DT and the quality of DT pellets have been established, including success in solid DT production and observation for the first time in Japan. However, this action item will need to be accelerated after CR1 along with ensuring budget allocation.	The aging of the T-handling facility at the Institute of Laser Engineering of Osaka University is obvious. This facility can contribute to DEMO development effectively by renewing its devices and equipment because of its highest capacity in terms of permissible tritium amount to be used among all facilities possessed and operated by universities in Japan, that is, 2 PBq a per year (500 TBq in 3 months, and 30 TBq per day).

	Detailed design of pellet injection system	19		C1/N/ Universities/ Industries	The measurement of the homogeneity of solid DT has been started as a joint R&D program for DEMO development. It aims at developing DT pellet production and injection technologies applicable to DEMO. Data obtained from the measurement will be used for the detailed design of the pellet injection device.	Satisfactory	In addition to the aforementioned progress, discussion on the design of the pellet injection device was made with the QST and NIFS during preparation for submitting an application for a joint R&D program for DEMO development. It is noteworthy progress. It is necessary to accelerate activities towards detailed design after CR1.	The significance of outcomes obtained through the current joint research program can be increased by continuing the discussion with the QST and NIFS on the pellet injection device.
Stock and handling technology of tritium	Detailed design of Tritium stock & providing system	18		C1/C5/N/ Universities/Q	Technology development and device design for tritium handling and its supply to laser experiments are being conducted as a joint research between the University of Toyama and Osaka University.	Satisfactory	The scale of tritium handling intended by the joint research is not as large as what is expected from the DEMO development project due to budget limitation. Although the intended scale is small, it still contributes to the education of tritium handling and is worth noting. Taking into account the budget limitation, progress can be considered satisfactory. However, accelerating actions will be still necessary after CR1.	The age-related degradation of the T-handling facility at the Institute of Laser Engineering of Osaka University is obvious. This facility can contribute to DEMO development effectively by renewing its devices and equipment because of its highest capacity in terms of permissible tritium amount to be used among all facilities possessed and operated by universities in Japan, that is, 2 PBq a per year (500 TBq in 3 months, and 30 TBq per day).
	Conceptual design of Tritium recycle system	18		C1/C5/N/ Universities/Q	Technology to collect tritiated hydrogen gas (HT) from high tritium containing waste and to purify it is being developed in collaboration with certain companies.	Satisfactory	It is not intended for contributing to DEMO development due to budget limitation. It is worth noting that the technologies developed through the fusion development met the technical needs of certain companies, which in turn led to the ongoing advancement of the tritium collection technology through the collaborative research with those companies.	The age-related degradation of the T-handling facility at the Institute of Laser Engineering of Osaka University is obvious. This facility can contribute to DEMO development effectively by renewing its devices and equipment because of its highest capacity in terms of permissible tritium amount to be used among all facilities possessed and operated by universities in Japan, that is, 2 PBq per year (500 TBq in 3 months, and 30 TBq per day).
	Detailed design of Tritium recycle system	22		C1/N/ Universities/Q	As described before, an HT collection and purification system is being designed and developed in collaboration with certain companies. Detailed designing of the tritium collection system towards DEMO has not begun yet.		It has not reached the level of research that can contribute to DEMO development due to budget limitation.	The age-related degradation of the T-handling facility at the Institute of Laser Engineering of Osaka University is obvious. This facility can contribute to DEMO development effectively by renewing its devices and equipment because of its highest capacity in terms of permissible tritium amount to be used among all facilities possessed and operated by universities in Japan, that is, 2 PBq per year (500 TBq in 3 months, and 30 TBq per day).
Diagnostics under extreme condition	Investigation of laser-produced extreme condition	18		C1/C5/N/ Universities	Plasma diagnostic technologies applicable in extreme environments are being developed. Such extreme environments include those where intense noise and background are generated, such as neutrons, gamma rays, X-rays, and electromagnetic pulses, by irradiating the plasma with ultra-high intensity laser. The extreme environments were expressed quantitatively by comparing the values calculated using Monte Carlo simulation code with the measurement data.	Satisfactory	It is a noteworthy outcome that the quantitative characterization of extreme radiation environments generated by ultra-high intensity laser has become possible using Monte Carlo simulation code.	It still remains at a level of calculation applicable only to laser experiments at present. It is expected that the quantitative characterization method will be advanced to such a level that it can contribute to DEMO development by the initiation of joint research with DEMO researchers and by comparing various measurement data with calculated values through the joint research.
	Offer of laser-produced extreme condition	35		C1/N/ Universities	The neutron detection technology resistant to the aforementioned extreme environments was developed and provided to the NIFS for the use in the diagnostic instrument for deuterium plasma experiments. In addition, methods to evaluate the operation of diagnostic instruments in extreme environments are being studied in collaboration with overseas research institutes.	Satisfactory	It is worth noting that the laser-produced extreme environments have contributed to the development of the diagnostic instruments for magnetic field confinement fusion plasma, though it is not directly related to DEMO development. As described before, the extreme environments are expected to be utilized in the radiation resistance evaluation tests of devices used in DEMO through collaborative research with DEMO researchers.	High intensity laser-produced radiation and electromagnetic pulses can also be utilized for the tests of devices used not only in DEMO but also in space environment. These technologies developed through fusion research are expected to contribute to broader technical fields.

(Attachment 4)

Relationship of the First Intermediate Check and Review (CR1) Goals with the Progress State of Action Plan

CR items	Goals to be achieved by the time of CR1	Investigation results of the state of progress of action plan	Evaluation axis/point of view	Current state analysis	Achievement state of goals by the time of CR1
	The Science and Technology Committee on Fusion Energy in December 2017	DEMO TF in January and July 2021			
[1] Validation of burn control in the self-heating region by ITER	・Create a technical target achievement plan for ITER.	・Worked on detailing the operation plan according to baseline in which FP was planned for 2025 and DT for 2035. The ITER research plan was revised in 2018.	・Has the research plan leading to the retention of Q value of approximately 10 or more (several hundred seconds or more) and the validation of fuel control by ITER been formulated? ・Have the contents of ITER collaborative research been reviewed?	・The ITER research plan was formulated to refine test details and steps in the period of staged operation (H, He, D, and DT). ・ITER collaborative research was described in the JT-60SA research plan.	・According to the investigation results of the action plan progress state, goals by the time of CR1 were achieved.
[2] Establishment of an operational technique for stationary high-beta plasma for operation of the DEMO reactor	・Proceed with ITER collaborative research and preparatory studies high-beta plasma and start JT-60SA research.	・With regard to ITER collaborative research and steady high-beta preparatory research, in the revision of research plan, JT-60SA research plan Ver.4.0 (the latest version) was completed in 2018. In addition, SMC development and the operation scenario establishment for JT-60SA and ITER, mailnly lead by QST. Development has progressed steadily with the aim of verification using experiments. Overall, good progress towards CR1 has been evident. ・While JT-60SA succeeded in the generation of ECR plasma in March in this year, the generation of tokamak plasma has not been achieved yet due to the incident. We would like to entrust how to evaluate the achievement state of the goals, which is the launch of research by JT-60SA, to the Committee members. ・ In this January, DEMO TF compiled the results of the action plan progress investigation, and concluded that the technology has been matured for the conceptual design of DEMO. We are convinced that the conclusion does not need to be changed in particular.	・Has the JT-60SA research plan formulation toward the achievement of non-inductive current drive plasma by ITER been completed and has the research on the integrated simulation including the diverter been conducted? ・Has the JT-60SA plan matched to the DEMO plasma facing wall been considered? ・Has the research by JT-60SA been launched?	・ITER collaborative research was described in the JT-60SA research plan. The cooperative agreement between ITER organization and BA activity was concluded. ITER organization participated in the JT-60SA integrated commissioning and steadily conducted ITER support research. ・High-beta steady-state research was promoted in anticipation of DEMO, and JT-60SA research plan Ver.4.0 was formulated. ・After the completion of assembly of JT-60SA in March 2020, research has been conducted as the integrated commissioning. After repairing the damaged portion of the superconducting coil, tokamak plasma is planned to be generated.	・According to the investigation results of the action plan progress state, goals by the time of CR1 were achieved.

[3] Establishment of integrated technologies by ITER	・Establish ITER's manufacturing technologies for super conductive coils and other key components and ~~of~~ build an integrated technological foundation through the construction of JT-60SA	・Technologies of manufacturing major components including the validation of performance confirmation at 1 MW/300 seconds with ITER Gyrotron actual machine unit No.1 to 4 Machines have been steadily established.	・Have ITER major components been manufactured on schedule?	・Five ITER TF coils have been completed so far. As they passed through the ITER Gyrotron completion test and the acceleration power supply for the Gyrotron was completed, the manufacturing technology has been developed. NBTF is in the process of being tested and the prototype divertor is under the production process. Situations of other components (actual machine for neutral beam injection, remote handling equipment, measuring instrument, and detritiation system) have been developed as scheduled.	・ According to the investigation results of the action plan progress state, goals by the time of CR1 were achieved.
		・As the evidence of the establishment of integrating technologies after JT-60SA construction is completed, integrated test operation has been carried out on schedule.	・Has the integrated technical basis been established?	・JT-60SA completed construction at the end of March and established the integrating technical basis.	
[4] Material development ~~of~~ for the DEMO reactor	(1) Obtain low activation ferrite steel's reactor irradiation data of dosages up to 80 dpa and finalize the materials for testing under a neutron irradiation environment similar to nuclear fusion	(1) Tensile strength, toughness, and microstructure were evaluated with the materials irradiated to 70 to 80 dpa at 300 to 350°C. The results of mechanical property evaluation were obtained. Because the specifications of low activation ferritic steel F82H plates were set to draft the material procurement specification based on the current allowable values and heat treatment conditions that were derived by reviewing their production records, materials to be used for the test in the neutron irradiation environment similar to fusion were determined.	(1) Has the data required for the formulation of the structural design basis been acquired?	(1) Main results are shown below. ・The trend of suppressing degradation of irradiation was confirmed in the tensile test after irradiation at 80 dpa. ・Through the toughness test after irradiation at 340°C and 68 dpa, it was confirmed that the embrittlement level was the same as that after irradiation at 400°C and 20 dpa. ・By organizing irradiation data, it was confirmed that low-activation ferritic steel F82H was superior to similar standard steel in irradiation resistance. ・Technology for retrieving lithium from the sea water was validated at the level of laboratory. ・Since 6Li separation factor of 1.05 was achieved, the basic technology related to 6Li concentration is in sight. ・The innovative technology for refining beryllium was developed and patented.	・According to the investigation results of the action plan progress state, goals by the time of CR1 were achieved.
	(2) Complete the concep design of fusion neutron source.	(2) The “Conceptual Design Document” and the “Plan for Engineering Design Work” have been completed. Thus, preparation for the construction of a fusion neutron source is moving forward. Simultaneously, issues in engineering design have been identified.	(2) Has the conceptual design of fusion neutron source allowing the acquisition of irradiation data of low activation ferritic steel and the functional materials of blanket and divertor been completed?	(2) Based on the results of IFMIF/EVEDA Project, the design review for the whole fusion neutron source A-FNS plant including the accelerator system, target system, test module, and post-irradiation test facility was developed, and the conceptual design was formulated.	

[5] Technical development of reactor engineering for the DEMO reactor	(1) Formulate divertor development policies.	(1) The real-time control of detachment plasma is an indispensable element if a tungsten-copper (W/Cu) alloy water-cooled divertor (DIV) is selected in the initial phase of DEMO. R&D aimed at understanding the elementary steps of detachment plasma and establishing a control scenario based on them has been making steady progress toward CR1.	(1) Has the baseline of divertor development been indicated? Has the acquisition plan of divertor-related data by JT-60SA, Large Helical Device (LHD), etc., been incorporated?	(1) In the basic design of DEMO conceptual design formulated by the special team, the baseline of divertor concept and the plan of acquiring divertor-related data were arranged.	・According to the investigation results of the action plan progress state, goals by the time of CR1 were achieved.
	(2) Create technical development plans for engineering requiring early preparation, including superconductve coil technology.	(2) With regard to the superconducting coil, it can be considered that the actions to be completed by CR1 have been mostly achieved. Consequently, the basic design of concept developed was drew up.	(2) Has the reactor engineering development plan been formulated?	(2) In the basic design of DEMO conceptual design formulated by the special team, the reactor engineering development plan was arranged.	
	(3) Collect the necessary data for blanket design from the cold testing facilities.	(3) Technical feasibility of the water-cooled solid breeding BLK will have been established in general by CR1 as the design concept of the DEMO BLK. The applicability of laser welding technology with filler metal was examined. The evaluation of the technical applicability including strength properties was continued. Especially, a weldability test was performed to assess conformance to the French regulations, and the validity was confirmed by a competent third-party organization. In addition, data on corrosion in high-temperature and high-pressure water environments have been accumulated, and a draft of guidelines for water chemistry management was proposed.	(3) Has the data required for the manufacturing of ITER-TBM Unit 1 Machine and the safety confirmatory testing with the actual machine been acquired?	(3) The test devices to validate the safety of ITER-TBM are under the production process, and the blanket engineering test building in which the devices are supposed to be installed was completed.	

[6] Designing the DEMO reactor	(1) Formulate the overall objectives for the DEMO reactor .	The progress of this task is considered satisfactory as most of The actions planned in the period before CR1 have been completed. The groundwork for the work acceleration has been laid, such as the participation of the National Institute for Fusion Science (NIFS) and universities, although the feasibility of advanced blankets (BLK) for the test blanket modules (TBM) of DEMO needs to be examined after CR1. (1) Prepared design basis list as guidelines for sharing of physics/engineering standard values, which were the basis for determining DEMO parameters, and reasons for their determination.	(1) Have the overall goals to forecast the practical application of nuclear fusion (corresponding to the basic concept of "Japan's Policy to promote R&D for a fusion DEMO reactor") been formulated?	(1) The basic concept of DEMO toward the validation of power generation with nuclear fusion energy (i.e., basic design of DEMO conceptual design) was defined and the whole image of nuclear fusion energy power plant was established.	・According to the investigation results of the action plan progress state, goals by the time of CR1 were achieved.
	(2) Draw up a basic concept of the DEMO reactor.	(2) Defined Specifications of each major component (BLK, DIV, VV, SC, etc.) and plant equipment, keeping the gap from existing technology minium, and conducted press release on their results. Improved design system code (TPC) for tokamak fusion reactor improved. Parameters for reference have been determined.	(2) Is it the basic design of the conceptual design matched to the development of reactor core and reactor engineering technology, taking consideration into the security of high safety and the prospect of economic efficiency?	(2) Three overall goals of DEMO (power generation, availability, and T self-sufficiency) and design requirements (ALARA, waste, and flexible furnace core components design) shown in the report by the Science and Technology Committee on Fusion Energy were satisfied, and the basic design of the DEMO conceptual design reflecting the important points of energy policy (safety, stable supply, economic efficiency, and environmental load) was formulated.	
	(3) Submit requests regarding reactor core and reactor engineering developments.	(3) Before finalizing the basic design of DEMO conceptual design, development items including various issues of the conceptual design (fuel cycle strategy, integration simulator, cost evaluation, guidelines for ensuring safety, physics, engineering, and materials database) were submitted.	(3) Is it the request for development of reactor core and reactor engineering technology intended for the establishment of the technical basis of the conceptual design?	(3) R&D items requiring acceleration (high-intensity low-temperature steel, pellet injection, instrumentation control, etc.) were compiled.	
[7] Social relations	(1) Establish a headquarters for promoting social awareness.	(1) The outreach headquarters has been established and the activities have been started.	Has the outreach headquarters been established?	In February 2019, the outreach headquarters was established.	・According to the investigation results of the action plan progress state, goals by the time of CR1 were achieved.
	(2) Drawn up an awaraness activity promotion plan.	(2) According to strategies for PR and activity determined by the outreach headquarters, the outreach activity promotion plan has been drawn up.	Has the plan to promote fusion outreach activities been formulated?	In the outreach headquarters held in September 2020, the outreach activity promotion plan was formulated, and it was reported to the Science and Technology Committee on Fusion Energy in October in the same year.	