Research and Development Policy on Fusion Energy in Japan

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MEXT
MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

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Symposium for 2018 ITER/BA Activities
at Yurakucho Asahi Hall

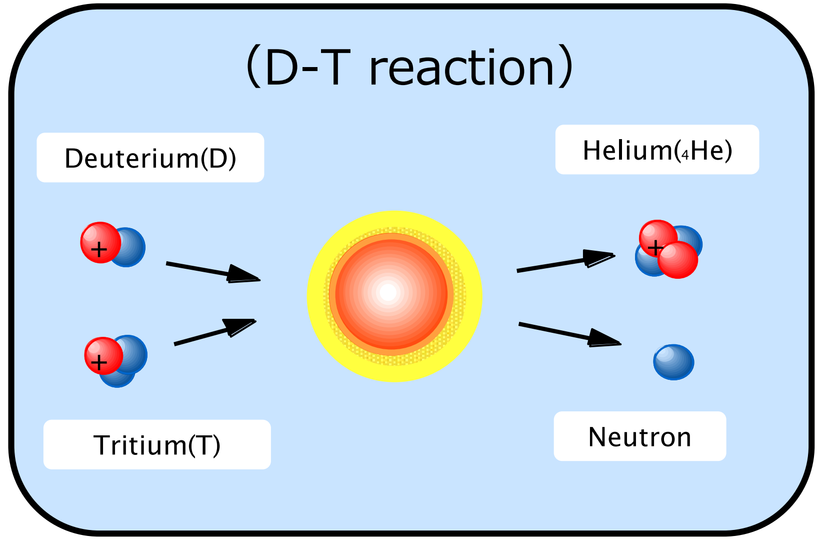
Contents

- Overview of Japanese Fusion Policy Status
- Policy on DEMO Development
- Projects Summary

Fusion Energy

Fusion energy

Nuclear Fusion is the energy source that powers the sun and stars in which light atomic nuclei fuse together by thermonuclear reactions, releasing a large amount of energy.

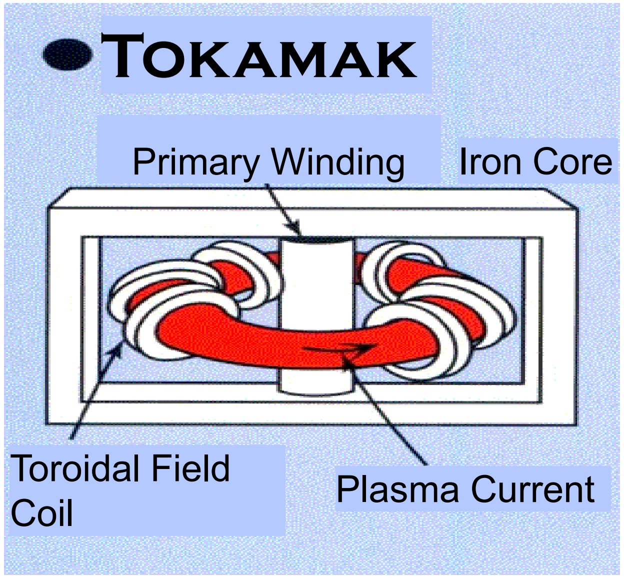


Features

- Deuterium exists in sea water and Tritium can be produced by nuclear reaction with lithium in the fusion reactor. Since this lithium exists as mineral resources and is included in sea water at approximately 0.2 grams per cubic meter, fusion has practically inexhaustible fuel resources.
- Carbon dioxide, nitric oxide and other gases which cause global environmental pollution are not generated in the reaction. Furthermore, the reaction can be easily stopped by closing the fuel supply valve.

Confining the plasma

● TOKAMAK



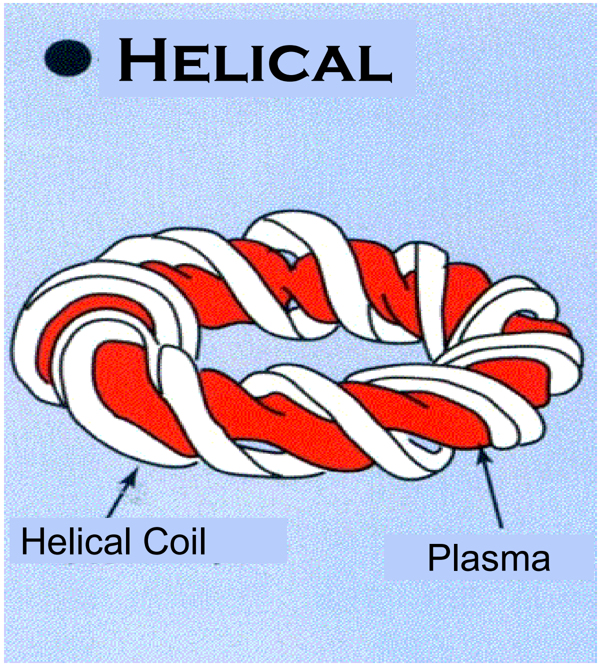
- ◆Plasma is confined by doughnut-shaped magnetic cage which is formed by driving plasma current.
- ◆Tokamak is originated in former Soviet Union and adopted world-wide.

→ Presently most developed

- ◆JT-60 marked the world record of ion temperature of 5.2 hundred million K.

ITER
JT-60
National Institutes for Quantum and Radiological Science and Technology

● HELICAL



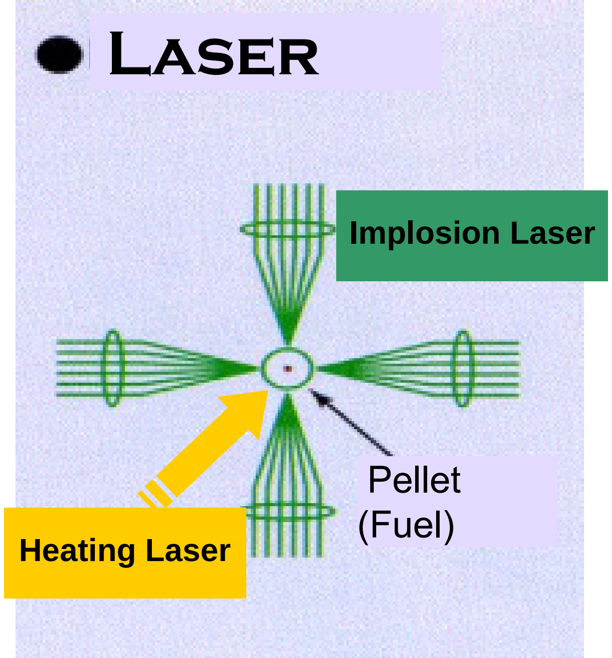
- ◆Similar to tokamak, but helical coil is used.
- ◆Driving plasma current is not necessary.

→Suitable to long pulse operation

- ◆LHD marked the world record of longest operation of 1 hour.

Large Helical Device（LHD）
National Institute for Fusion Science

● LASER



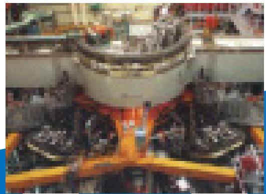
- ◆Fuel is explosively compressed and heated by high-intensity laser. Plasma is confined by pressure of implosion.
- ◆Alternative approach for fusion energy.

GEKKO-XII･LFEX
Osaka University

Steady promotion of research in the current phase as "Scientific and Technological Feasibility" of the fusion research and development

Scientific Feasibility

-To achieve break-even plasma condition

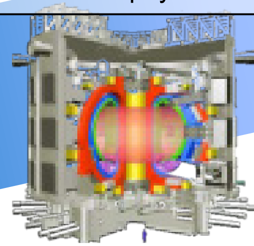


JT-60 (QST)

- 7 Members (EU, JA, CN, IN, KO, RF, US) collaboration
- Demonstrate burning plasma (Q>10, 300-500sec)
- ITER Organization assembles components as in-kind contribution by 7 Members (JA: Toroidal Field Coils etc.)

Scientific & Technological Feasibility

-To realize burning plasma and long-duration burning
-To establish physical and technological basis for DEMO



ITER
(ITER Organization)

ITER Project

JT-60SA (QST)

BA Activities

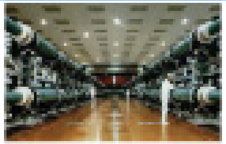
- EU – Japan Bilateral Collaboration in Japan supporting ITER and DEMO R&D comprising following activities:
  - IFERC (DEMO design and R&D)
  - IFMIF/EVEDA (Engineering Validation for fusion material irradiation facility)
  - Satellite Tokamak Programme (JT-60SA)
- Discussing activities from 2020 onwards

Technological Demonstration & Economic Feasibility

-To demonstrate electric power generation
-To Improve economic efficiency

DEMO Reactor

Academic Research



FIREX (Osaka Univ.)

LHD(NIFS)

QST: National Institutes for Quantum and Radiological Science and Technology
NIFS: National Institute for Fusion Science

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Fusion Science in National Policy

5th Science and Technology Basic Plan （Cabinet Decision in January 2016)

◇Chapter 3 Addressing economic and social issues

(1) Sustainable growth and self-sustaining regional development

① ⅰ）Ensuring stable energy and improving energy efficiency

・・・Furthermore, we will work on R&D aimed at establishing important energy technologies for the future, such as innovative nuclear fusion and nuclear fuel cycle technologies.

◇Chapter 4 Reinforcing the “fundamentals” for science, technology, and innovation

(2) Promoting excellence in knowledge creation

① ⅲ）Promoting joint international research and forming world-class research centers

・・・ As a nation, we are making advances in such areas as planning the use and operation of facilities in Japan and overseas for big science projects such as nuclear fusion, particle acceleration, and space development and utilization, as well as constructing mechanisms to stimulate international joint research with a variety of overseas partners. In addition, in order to strengthen bilateral and multilateral collaboration and build mutually beneficial relationships, we are working to enhance fund-matching partnerships and the operation of jointly managed overseas research centers while cooperating strategically with partner nations with regard to the identification of common problems and similar matters.

5th Strategic Energy Plan （ Cabinet Decision in July 2018 ）

◇Chapter 2 Basic Policies and Measures towards 2030

Section 3 Promotion of technology development

2. Technical challenges to be addressed

・・・The ITER project, which uses the tokamak and is being implemented through international cooperation, and the Broader Approach Activities aimed at realizing energy from nuclear fusion, there has been progress in on-site construction and the production of the equipment. GOJ will continue to steadily promote these activities from the long-term viewpoint. It will also promote parallel research on the helical and laser types as well as innovative concepts from the perspective of securing technological diversity.

Policy on DEMO Development

New Policy on DEMO Development has just been compiled in Dec. 2017 as the revision of the policy set by Atomic Energy Commission in 2005.
Summary of the New Policy is as follows.

Development Strategy

- ✓ Common target for entire community is to achieve technological solution for DEMO with tokamak.
- ✓ Promote balanced research on helical and laser fusion as alternative or complimentary option in parallel.

Basic Concept Required for DEMO

- ✓ Steady and stable electric output (Hundreds MWe).
- ✓ Availability sufficient for commercialization.
- ✓ Tritium breeding that fulfills self-sufficiency in fuel.
- ✓ Inherent safety leveraged by merit of fusion (No chain reaction).

Approach for Development for Resolution of Technological Issues

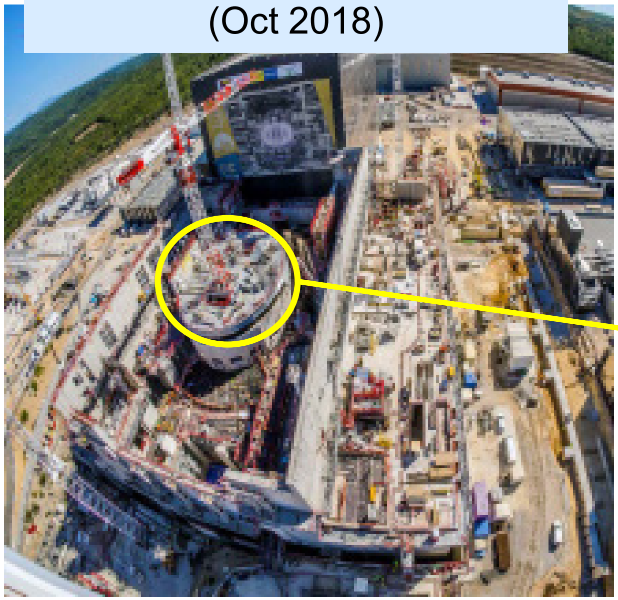
- ✓ Development plan taken into account construction cost, operation scenario etc. as well as technical consistence.
- ✓ Technological issues classified under 15 elements as “Action Plan” .
- ✓ Building all-Japan framework comprising industry, academia and government.
- ✓ Nurturing human resources necessary for long-term R&D.

“A Roadmap toward Fusion DEMO Reactor”

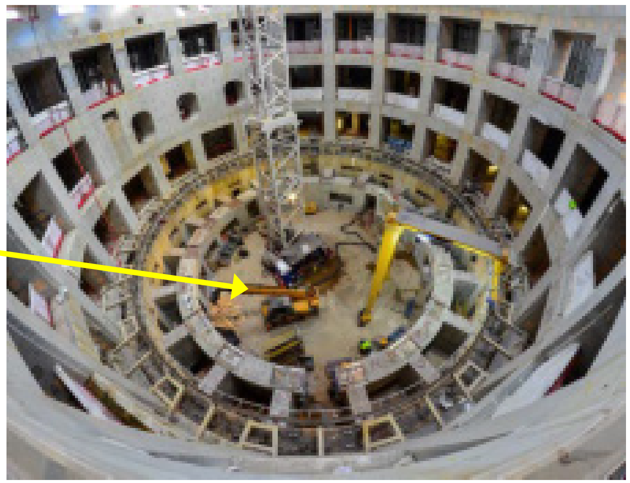
In terms of the implementation of “Action Plan” for DEMO development, “Roadmap” shows priority, major milestones, relation between items of Action Plan, role and responsibility of QST and NIFS as main development bodies, international cooperation, funding scheme etc.

ITER Site

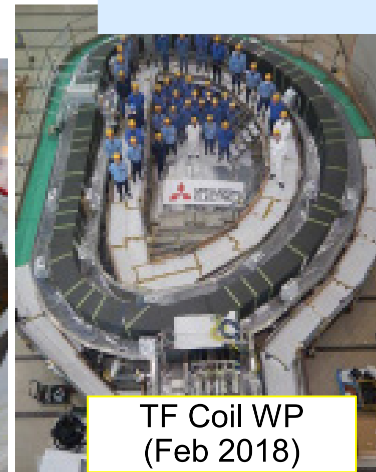
Tokamak Construction (Oct 2018)



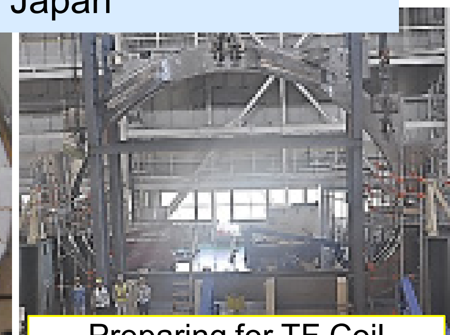
Tokamak Pit (Aug 2018)



Manufacturing of components in Japan



TF Coil WP (Feb 2018)

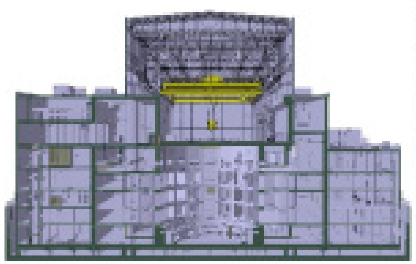


Preparing for TF Coil (Aug 2018)

CS Coil Conductor (Oct 2017)

Commissioning of JA components in the NBTF Site (Sep 2018)

(Apr 2015)



(Apr 2016)

The 23th ITER Council Meeting

(2) Final approval of Baseline 2016

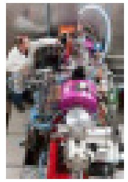
- Several members finalized their domestic process.
- As for Japan, Science and Technology Committee on Fusion Energy reviewed Baseline 2016 and the Committee decided that Baseline 2016 is valid.

(3) Next meeting

- 19 and 20 June 2019 at Cadarache ,France

Progress in BA Activities

IFMIF/EVEDA (Rokkasho, Aomori)

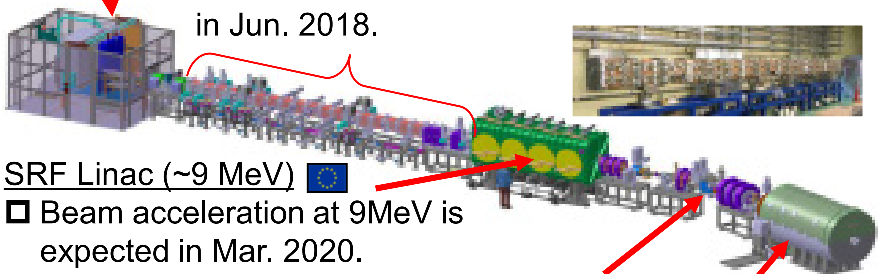


Injector (~0.1 keV)

- The Injector achieved 135 mA beam with sufficient beam quality in 2016.

RFQ (~5 MeV), RF Power

- The first beam acceleration test was succeeded in Jun. 2018.



SRF Linac (~9 MeV)

- Beam acceleration at 9MeV is expected in Mar. 2020.

Installation

- RFQ was installed in July 2017.
- Assembly of SRF Linac will start in 2018 and installed in 2019.

HEBT

Beam Dump

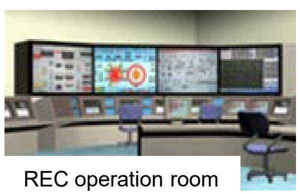
Building

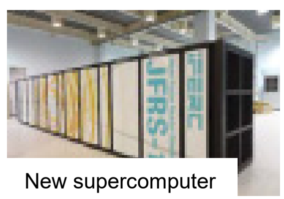
Auxiary System

IFERC project (Rokkasho, Aomori)

- Interim report of DEMO design activity was finalized in 2017.
- The infrastructure of the Remote Experiment Center was completed in Mar. 2017.
- new supercomputer started operation in Jun. 2018.


Demo


REC operation room


New supercomputer

JT-60SA (Naka, Ibaraki)

In Satellite Tokamak Project (JT-60SA), Japan procures key components for DEMO ; Vacuum Vessel, CS, PF coil, and Assembly & Installation (those are not procured in ITER Project).

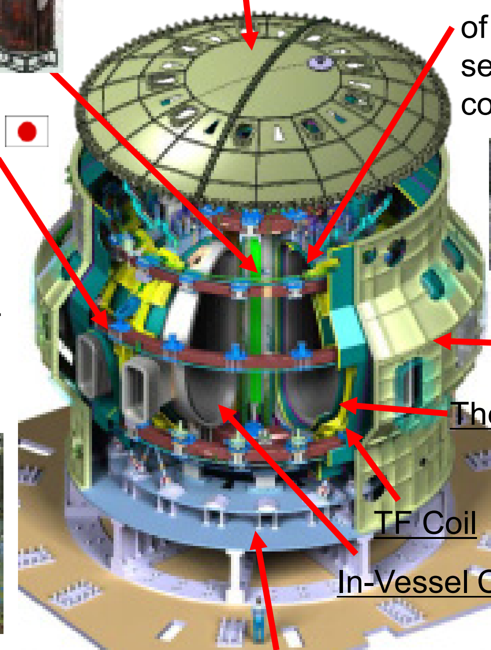
CS Coil

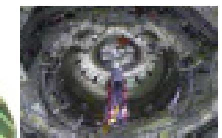
- Fabrication of 4 CS modules completed in Mar. 2018.

Cryostat Top Lid

Vacuum Vessel

- Manufacturing of 10 VV sectors were completed.





PF Coil

- Fabrication of 6 PF coils were completed in 2016.
- At present, 3 PF coils were pre-installed.

Thermal Shield

TF Coil

In-Vessel Components

Cryostat Base

Assembly and Installation

- Assembly and installation of Vacuum Vessel was completed in Aug. 2015.
- Installation of Toroidal Field Coil completed in Apr. 2018.

Summary report of BASC-23

IFERC

③Satellite Tokamak Programme (JT-60SA)

- CEA and ENEA completed the manufacturing and cold test of all superconducting Toroidal Field coils.
- Three upper Equilibrium Field Coils were installed and welding of the final 20 degree sector of the Vacuum Vessel was also completed.

④the report from the BA Phase II Task Group

- The SC approved each Project Plan ad referendum as a working basis for further consideration, and subject to follow-up political decision by both Parties before March 2020.

⑤other

- The SC expressed appreciation for the great efforts of the Aomori Prefecture and Rokkasho Village for the high-quality living and educational support for the EU researchers and engineers as well as their families in Rokkasho.
- BASC-24 will be hosted by Japan in Rokkasho on 11 April 2019.

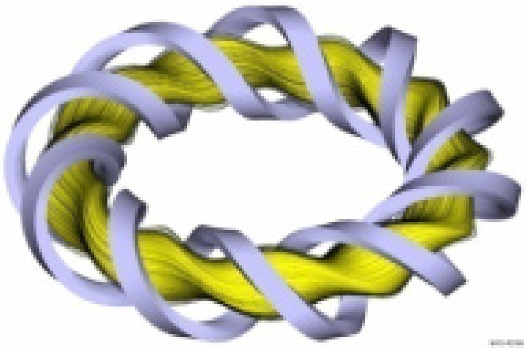
BASC-23 Group photo

Visit of CEA Cryogenics Laboratory

Research on large helical devices

Helical type

Twisting the external coils：
Helical type (LHD)



◆ Allow Steady State Operation for more than one year in principle

◆ Issue
To realize High Performance Plasma capable of ignition
→ Ion temperature of 120 million ℃

National Institute for Fusion Science Large Helical Devices（LHD）

Outer diameter of the machine : 13.5m
Height (including ports) : 9.1m
Net weight : approx. 1,500t
Toroidal plasma diameter : approx. 8m
Poloidal plasma diameter : 1.0 to 1.2

Results

Advantage of Helical type：
The adopted confining configuration “heliotron" for the LHD is the Japanese original idea, and the devices have the advantages of controllability and Steady State Operation in comparison with the devices which rely on the current inside the plasma, such as a tokamak.

Summary of Experimental Achievements :
- Long pulse operation of 54min. (world record) in 2005
- 12×10^{14}/cc (world record) in 2008
- 120 million℃ of Electron Temperature in 2014
- 120 million ℃ of Ion Temperature in 2017

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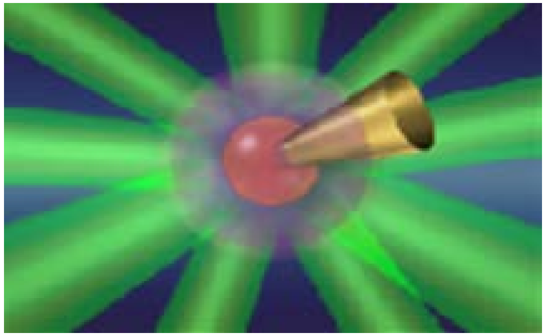
Research with High-power lasers

High-power lasers

Advantage of Fast ignition type: Fast ignition type is the method that realizes fusion ignition by compressing the fuel with high - power laser and heat it with high intensity laser.



It is expected that Fast ignition may make possible an ignition with one-tenth of the energy compared to central ignition, which realizes ignition only by implosion.

Research with High-power lasers

Mainly in Institute of Laser engineering (ILE), Osaka University

Lawrence Livermore National Laboratory

OSAKA UNIVERSITY

Background and current situation

- Started FIREX-I Project in 2008 for demonstrating the principle of Fast ignition with implosion laser (Gekko-XII) and Heating laser (LFEX).
- Achieved electron temperature of higher than 22 million degrees.
- Cooperation with the Lawrence Livermore National Laboratory such as exchanging of researchers and collaborative research using large laser devices.

The next steps

- Aim to demonstrate the ignition temperature as the original goal of FIREX-I Project.
- Strengthen international partnerships in anticipation of FIREX-II Project which will aim to demonstrate self-ignition.
- Promote the research in the field of High Energy Density Science including laser fusion science with a view of application to a wide range of fields such as academic, medical, and industrial fields. (ex. new Project Arrangement with DoE).

Summary of A Roadmap toward Fusion DEMO Rector

Importance and urgency of development
International collaboration

- Important milestones: First Plasma in 2025, “deuterium-tritium(DT) burning and ignition” in 2035.
- Necessary to achieve the way for long plasma control tests.
- Preceding research with JT-60SA.

- the second intermediate check and review will be required to decide upon the transition to the construction of A-FNS.
- it is desirable to materialize the construction of A-FNS by taking advantage of the experiences and results obtained in the IFMIF/EVEDA, while seeking for international cooperation.

Summary of A Roadmap toward Fusion DEMO Rector

Development of human resources

➢ Developing and Securing Human Resources

・ In order to promote DEMO development based on a long-term plan, the environment should be conducive for the training of such personnel, who will be involved in the developments in the fusion field, as well as for the securing and further training such personnel.

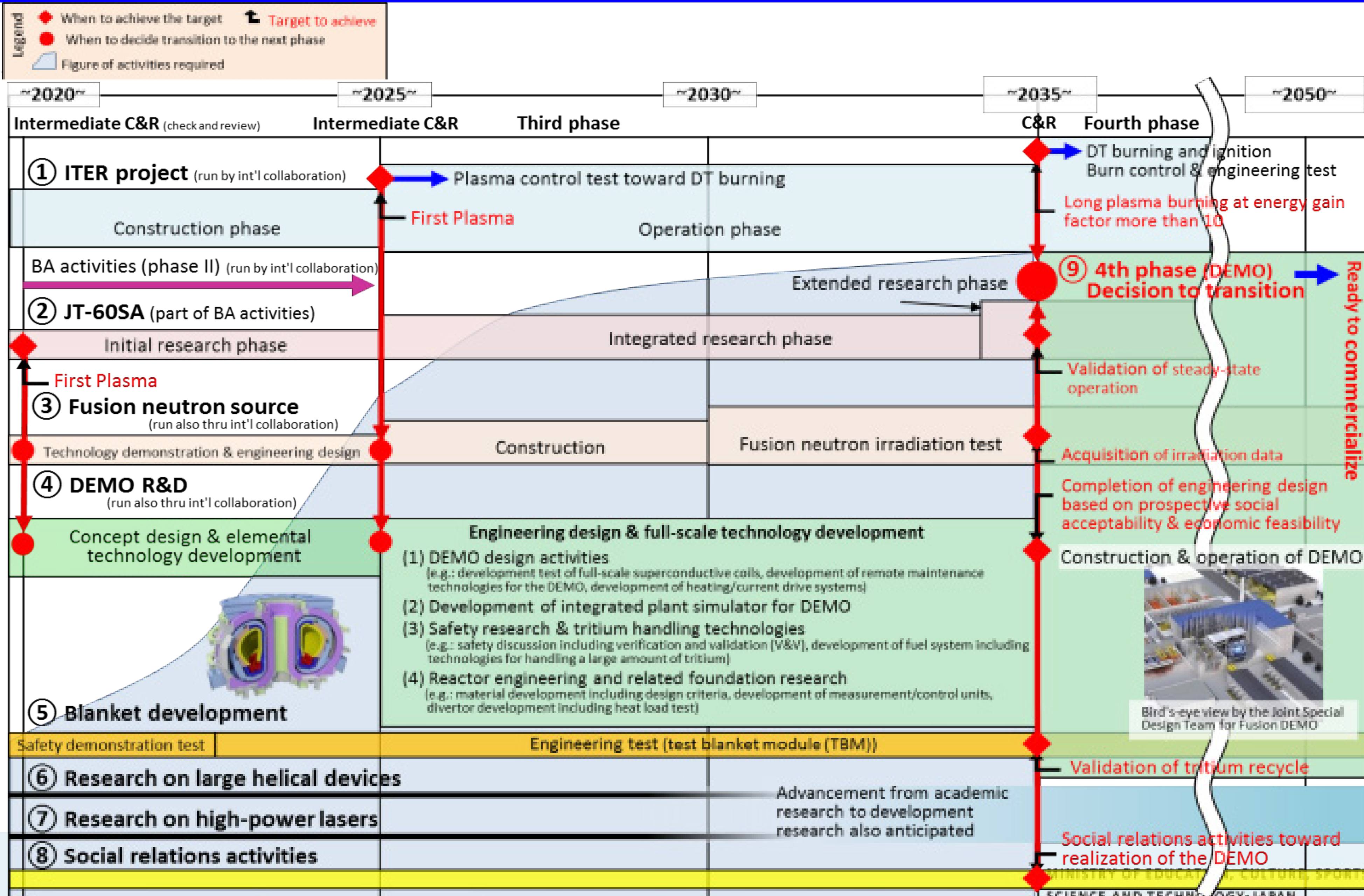
➢ Closer Relations with Universities

・ In order to encourage universities to autonomously and independently conduct great activities, it is necessary to build a new framework for universities that organizes collaborative research toward the DEMO, apart from the existing framework in which the National Institutes for Quantum and Radiological Science and Technology is playing a central role.

Outreach Activities

➢ For fusion energy to become the public's energy source of choice, it is necessary to share information and engage in continuous dialogue with society about the special characteristics, usefulness and safety of fusion energy.

A Roadmap toward Fusion DEMO Rector



All-Japan framework for Fusion DEMO

Science and Technology Committee on Fusion Energy

Discuss and decide the policy on fusion R&D, including Road-map

Power Generation

DEMO Reactor

Review

Draw up/Formulate an Action Plan

Show the policy

Task Force on DEMO comprehensive strategy

-grasp the situation of elemental technologies as a whole
-Optimize the overall strategy

Sharing information etc.

Grasp the situation of each elemental technology

DEMO Concept Design

"Joint Special Design Team for Fusion DEMO" of Rokkasho Fusion Research Center

-Plan and implement R&D to address issues
- Organize Work Shops

QST,NIFS,Univ.,Industry

Total 97 persons
*As of July 2018

QST	28
NIFS	3
Univ.	31
NIMS	1
Industry	34

Providing collaboration

Scientific Associations

Material

Plant engineering

Theoretical Analysis

Superconducting

Divertor, Blanket

Tritium

Fusion reactor Plasma

Heating

application of fusion science to industry

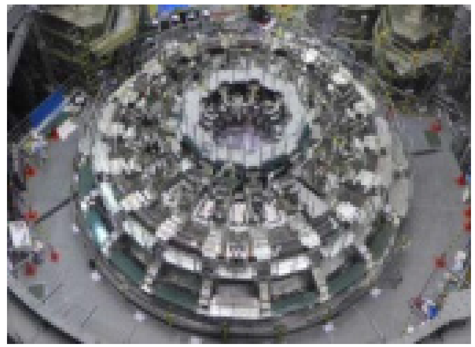
Cutting edge technologies pioneered by fusion research and development are applicable as industrial bases in various fields

High Precision Machining Technology

Establishment of general-purpose machining technology for large structural components with high precision that has never been achieved.

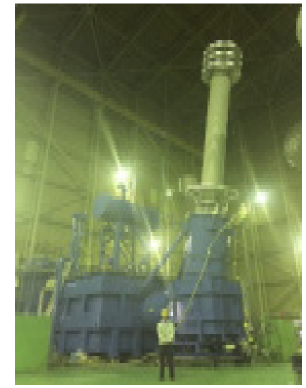
Assembly Technologies of Large Components

Leading the world by assembly Technologies with ultrahigh accuracy.



High Voltage and High Power Technology

Application to electric power transmission system and transportation power facility.



Superconducting Magnet Technology

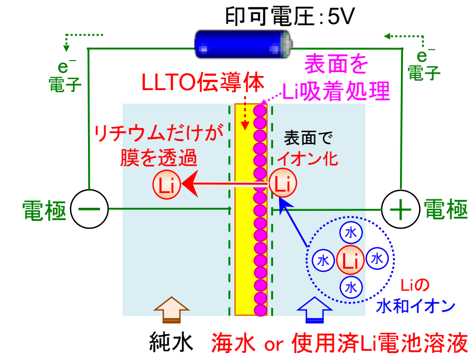
Development of radiation resistance insulation tape and application to TF coils in EU as well.

Diagnostic Technology

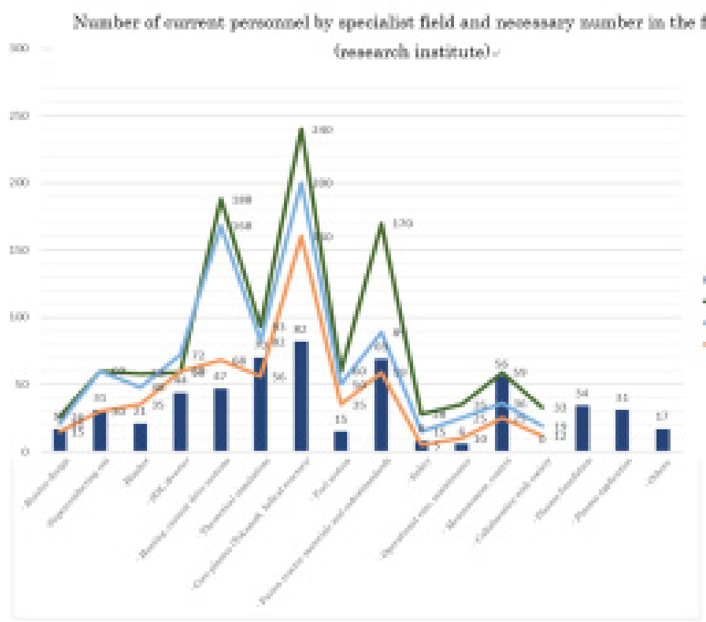
CO_2 laser profile monitor was commercialized.

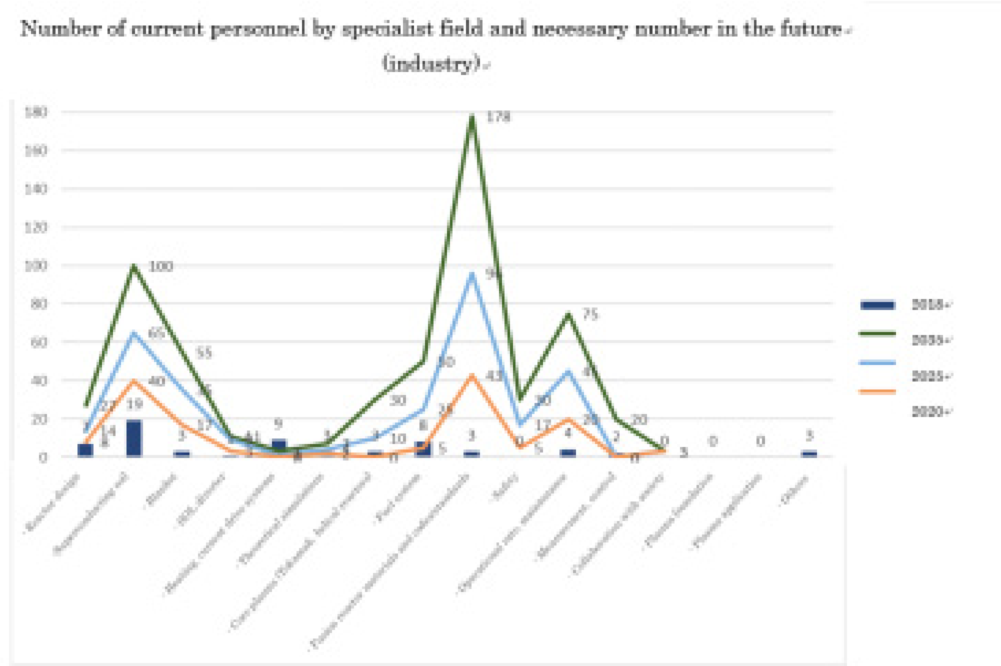
Lithium Recovery Technology

Performance improvement achieved towards pilot plant construction.



Current Situation Surrounding Fostering of Human Resources





Japanese Staff in ITER Organization

1. Current Situation

- ITER Organization Staff; 838 (the end of Aug 2018)
- Japanese Staff in ITER Organization; 26 (3.1%; the bottom of ITER Members)

EU	CN	IN	JA	KO	RF	US	Total
583	77	34	26	33	36	49	838
69.6%	9.2%	4.1%	3.1%	3.9%	4.3%	5.8%	100%

- For increasing the number of Japanese staff, QST established the section in April 2017. The section has worked with staff recruitment company and enforced measures.

2. Recruitment（2017.9～2018.8）

- ITER Organization staff：

  9 persons employed （total 26 (+5 from the end of Aug 2017)）

- IPA（ITER Project Associates）：

  3 persons employed (total 4（+3 from the end of Aug 2017）

3. Internship in ITER Organization（from Jan to Sep 2018）:

5 persons employed

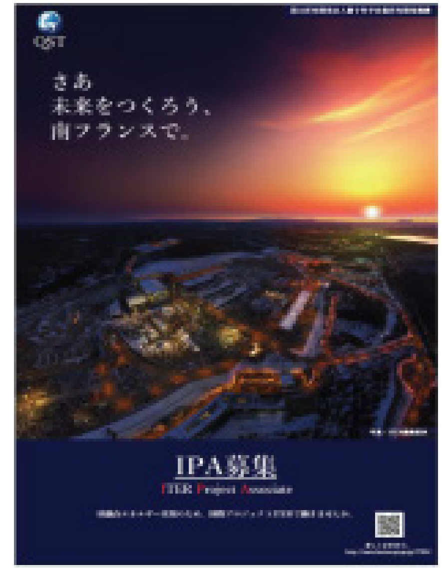
ITER Project Associates（IPA）

1. Over View

IPA is the framework that workers engage in tasks about ITER as a seconded employee of QST.

The chance to experience state-of-the-art technology and have a relationship with a variety of engineers and market. In addition, the chance to experience international negotiation and management in the multicultural environment.

- ･Skills：Plant engineering, HR, PR, Procurement, Legal, IP
- ･Period：Less than 4 years
- ･Support from IO：Installation allowance,
  Access to the local international school in Manosque (EIPACA)
- ･Support from QST：salary, support to application and stay



2. Application method

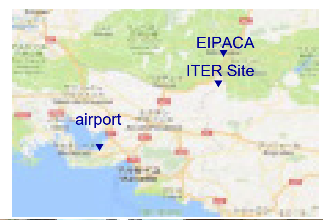
Contact to ITER Japan(QST) with resume

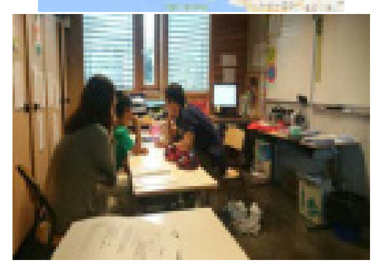
※(ITER Japan) E-mail：jada-recruiting@iter.jp TEL：029-270-7739

3. Ecole Internationale de PACA (EIPACA)

Over view：EIPACA is the international school FR established based on ITER agreement for children from ITER Members.

- ･FR public school (fees are free)
- ･Nursery, Elementary, Junior high, High
- ･1 Sep～31 Aug
- ･French + Japanese





Students in Japanese section（in Sep 2018）

	Nursery（3～5）	Elementary（6～10）	Junior high（11～14）	High（15～18）	Total
students	4	8	6	0	18

Training and securing of personnel for the promotion of fusion energy developments

Science and Technology Committee on Fusion Energy: 28 March 2018

Purpose of this proposal

- Consistent, long-term R&D will be needed to achieve fusion energy, necessitating the training and finding of personnel who will be able to stay working on such a project for the long haul. We propose sorting out the challenges and taking specific, urgent, and long-term actions.

Professional development today

- A large disparity exists between the number of personnel that will be required and the number currently focusing their efforts on fusion energy development.
- The weight given to fusion research within overall plasma research at universities is declining. Rates of advance to doctoral programs are also on a downward trend in comparison with 2006.
- Although Japan is expected to make great contributions internationally to the ITER project, only a small percentage(~3%) of ITER Organization staff are Japanese.

Required skills and abilities

- The basic ability to develop individual techniques; high expertise in problem solving; and the skill to apply those in a practical manner.
- A broad perspective capable of taking in the big picture; the ability to integrate various individual techniques.
- Leadership and the ability to work in international co-creation on international projects such as ITER.
- Dialog and outreach ability – to explain to society at large in an easy-to-understood manner.
- Humanities and social sciences knowledge needed for precise analysis of social situation.

Preferable environment

- It will be necessary to create an environment conducive to training and turning out personnel who will be responsible for the DEMO reactor on a continuous and steady basis, with a long-term plan; as well as one conducive to securing and further training such personnel.

Graduate school education

We need to promote academic research, maintain and bolster an environment for basic research in order to increase the number of doctoral candidates.

Personnel mobility

We need to partner domestic R&D with ITER project and BA activities; and to develop such partnerships as a system for knowledge circulation.

Outreach

We need to promote mutual understanding on and inspire interest in fusion R&D among all ages, including children.

Challenges

- Building an educational program to teach a broad and varied range of specialization; and bringing together industry and academia in order to gain experience with manufacturing and system integration.
- Creating broad personnel mobility among industry and academia, including the ITER Organization and establishing appealing career paths.
- Social partnership work, including outreach, incorporating the need to recruit work-ready personnel and to secure future personnel, and promoting public acceptance.

The Way Forward

➢ Success of the ITER Project and BA activities(phase Ⅱ)

- Secure First Plasma in 2025 and steady construction for DT operation.
- The BA activity from FY 2020 to FY 2025 will be defined as "BA phase Ⅱ", which will be implemented under the current BA agreement.

➢ Nurturing human resources

- Mid-long term approach for fostering young researchers and engineers.
- Diversity on disciplines including socio-economic field.
- Stimulate fusion community by increasing human resources mobility both internal and external community.

➢ Foster socio—economic acceptability for DEMO development

- Expand outreach activities.
- Expand technology exchange with and spin-off to other technological field.

Thank you for your kind attention.