Overview of Fusion Research Activities in Japan

Presented by Masayoshi SUGIMOTO (JAEA)

IAEA's Technical Meeting on Nuclear Data Libraries
for Advanced Systems: Fusion Devices (NuDL:FD)
31 October – 2 November 2007, Vienna

INTRODUCTION

- **To focus on perspective activities in Japan related to the fusion nuclear technology toward DEMO design and construction.**
- **To introduce a presentation made at ISFNT-8 on 3 October 2007.**
- **To summarize the expected cooperation with the Nuclear Data Community in the world.**

ISFNT-8
October 3, 2007
Heidelberg, Germany

Japanese Perspective of Fusion Nuclear Technology from ITER to DEMO

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Introduction

Fusion Technology

- **ITER Project:**
  - will start formal activities in a month - opening of a new 'ITER Era';
  - will demonstrate scientific and technological feasibility of fusion energy;
  - is a central element of the world fusion program.

- **BA Activities:**
  - will comprise three projects: IFMIF/EVEDA, IFERC and JT-60SA;
  - is complementary to or in support of ITER along the pathway toward DEMO.

- **New actions taken by the Japan Atomic Energy Commission, on the basis of 'Third Phase Basic Program of Fusion R&D' laid down in 1992:**
  - set up ad hoc committee, June 2003, to review the progress of fusion R&D and to investigate future basic program in view of the progress made in the last decade and recent moves of the world fusion program;
  - issued a Report entitled 'National Policy of Future Fusion R&D', Nov. 2005.

This presentation largely follows the line of this Report.

Key Points of the Report
'National Policy of Future Fusion R&D'

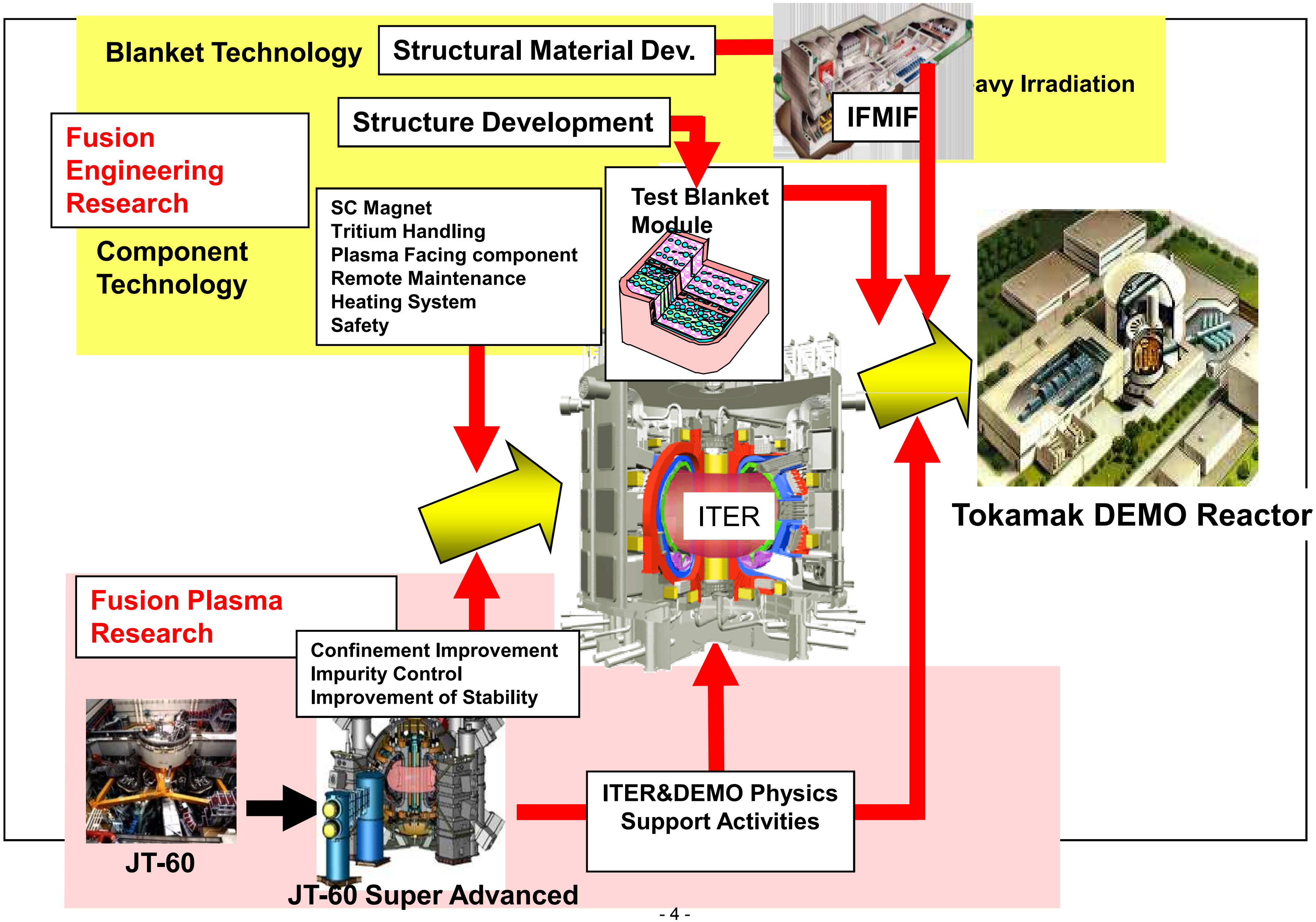
Fusion Technology

- **Early realization of fusion energy utilization:**
  - important to contribute to the resolution of global environmental problem and the energy supply;
  - necessary to make fusion system technically practical as a power generation system as well as to have economical competitiveness against other energy systems.

- **Three steps toward fusion energy utilization:**
  - ITER to demonstrate scientific and technological feasibility of fusion energy: namely, demonstration of control techniques of extended burning plasmas; demonstration of technologies essential to a reactor in an integrated system; and performing integrated testing of DEMO blankets.
  - DEMO to realize steady-state fusion core plasmas with high Q values and to demonstrate power generation in a plant scale, with possible upgrading during its operation phase so as to demonstrate to the utility and the public attractiveness as a power generation system
  - Commercial Reactor by the middle of this century

Comprehensive Fusion Program from ITER to DEMO

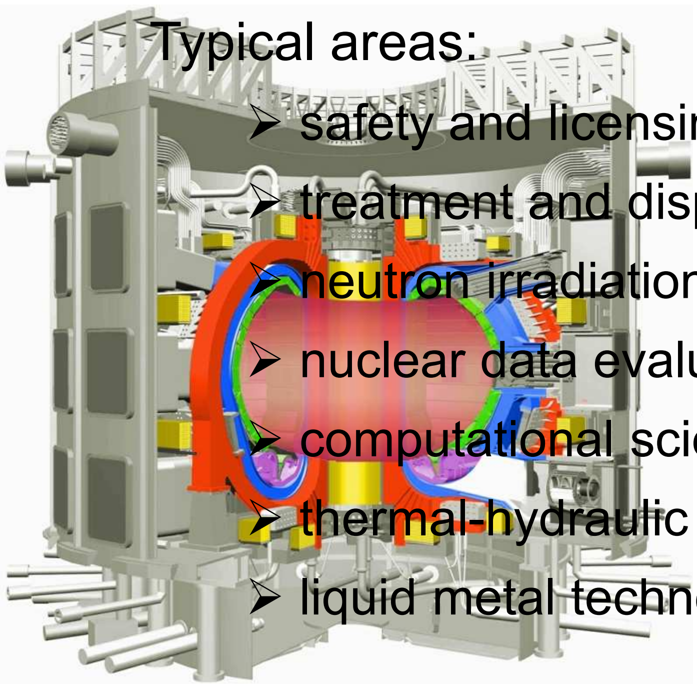
Fusion Technology



Fission-Fusion Synergy Effects

Fusion Technology

In the development of fusion energy system, collaborations with fission areas are getting more important. Expertise and knowledge available in the fission areas, in particular nuclear technology areas, are deemed of significant value and collaborations should be further strengthened.

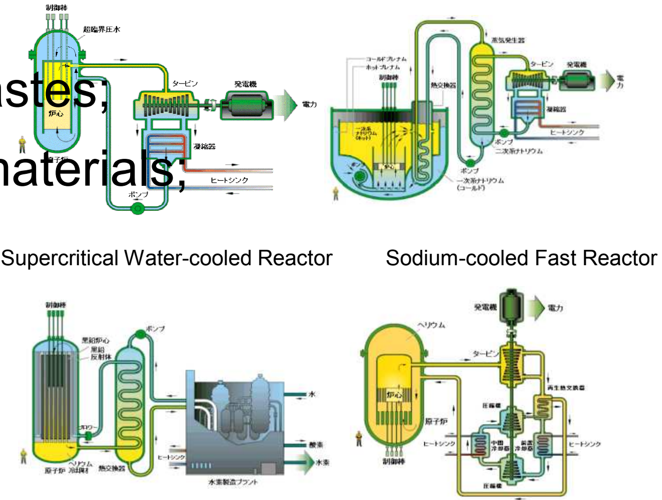


Typical areas:

- safety and licensing;
- treatment and disposal of rad-wastes;
- neutron irradiation damages of materials;
- nuclear data evaluations;
- computational science;
- thermal-hydraulic issues;
- liquid metal technology.

Fusion Programs

Moving Forward GENERATION IV nuclear energy systems



Supercritical Water-cooled Reactor | Sodium-cooled Fast Reactor

Very High Temperature Reactor | Gas-cooled Fast Reactor

Next Generation Fission Programs

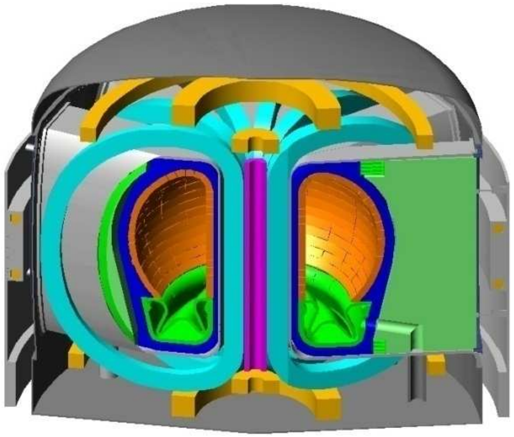
Scope of DEMO and DEMO Studies

Fusion Technology

Requirements for DEMO	• core dimension, comparable to ITER • steady state (year-long) • certain level of economic viability *AEC report, 2005*

Two conceptual DEMO designs proposed by JAEA and CRIEPI

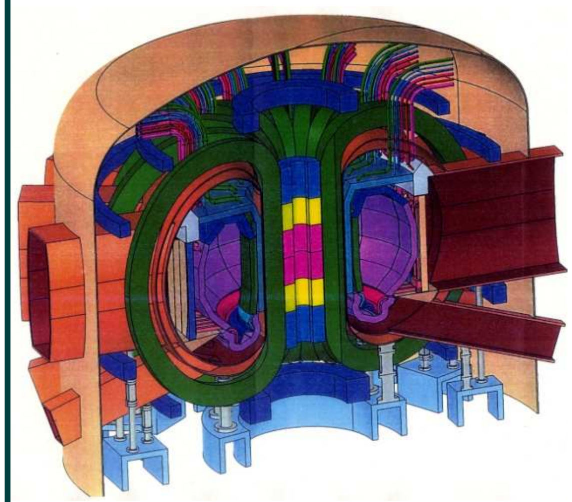
SlimCS *JAEA*



R_p = 5.6 m
a = 2.1 m
P_{fus} = 2.95 GW

- **compact low-A DEMO with reduced-size central solenoid**
- **potentially economic & low-A merit in design margins**

Demo-CREST *CRIEPI*



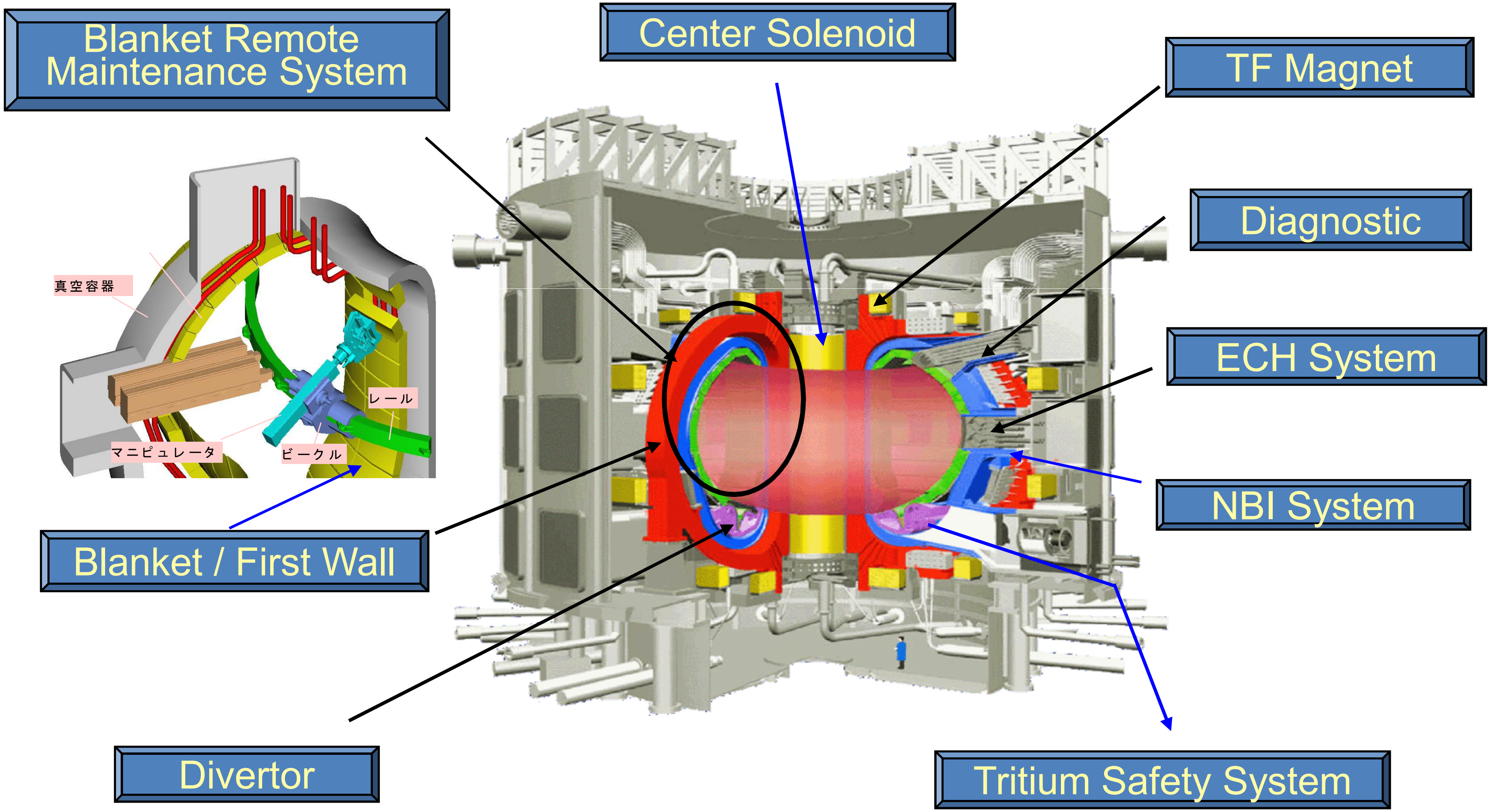
R_p = 7.25 m
a = 2.1 m
P_{fus} = 2.97 GW

- **in-life upgrade strategy to bridge the gap between ITER and economic CREST**

ITER Project - Procurement

Fusion Technology

Japanese DA is responsible for the procurement, partly, of high-tech components.



ITER Project - Construction and Operation

Fusion Technology

Key technologies to be demonstrated during ITER construction and operation will include:

- **Performances of Superconducting Magnet under neutron irradiations and compatible with plasma operations;**
- **Performances of remote maintenance equipments under radiation environments;**
- **Safe and reliable operation of tritium fuel processing and related safety systems;**
- **Performances of tokamak and plant control systems consistent with plasma operations;**
- **Performances of particle and heat rejection systems consistent with heat, particle and electromagnetic loads from plasmas.**

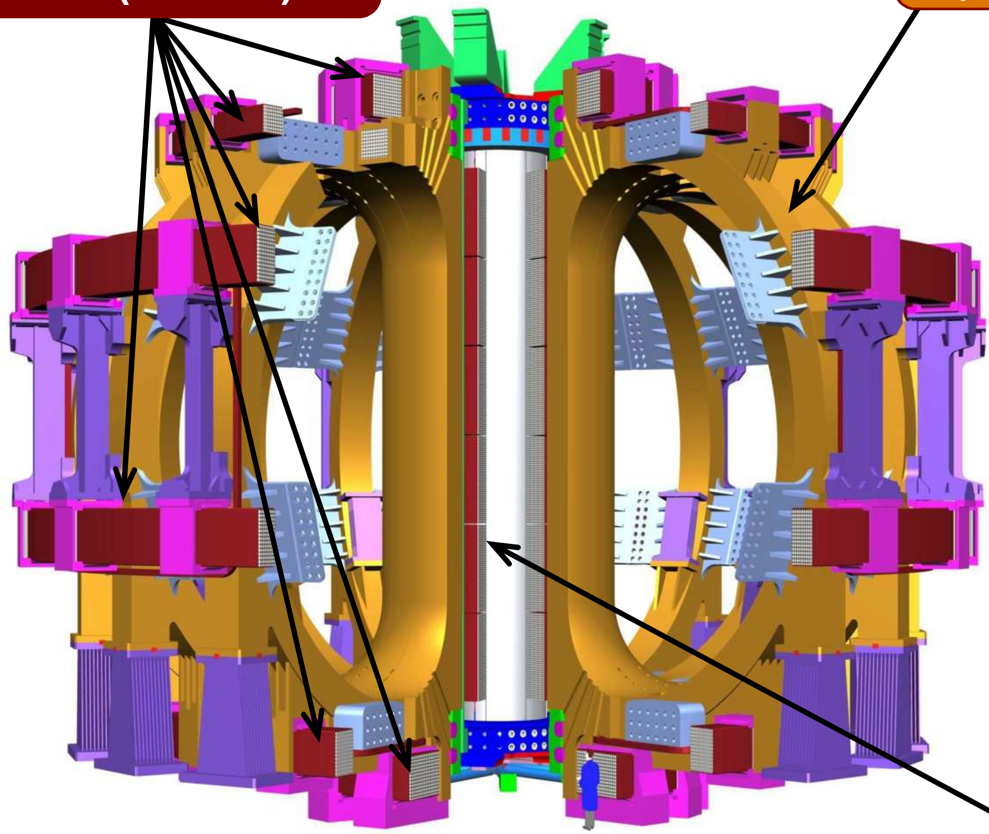
Technologies essential to the DEMO can be demonstrated during ITER construction and operation as an integrated system under fusion environments.

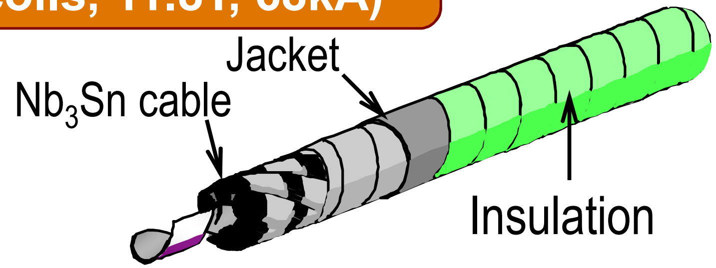
ITER Superconducting magnet system

Fusion Technology

Poloidal Field (PF) Coil (6 coils)

Toroidal Field (TF) Coil (18coils, 11.8T, 68kA)





- Neutron radiation; $1x10^{22}$ n/m^2

1) Demonstration of no significant degradation of superconducting performances,
2) Demonstration of insulation system of high radiation resistance, and
3) Stable operation of cryogenic system under nuclear heating (18kW at 4K).

Cutaway of ITER superconducting magnet system

Central Solenoid (CS) (6modules, 13T, 40kA, 1.2T/s)

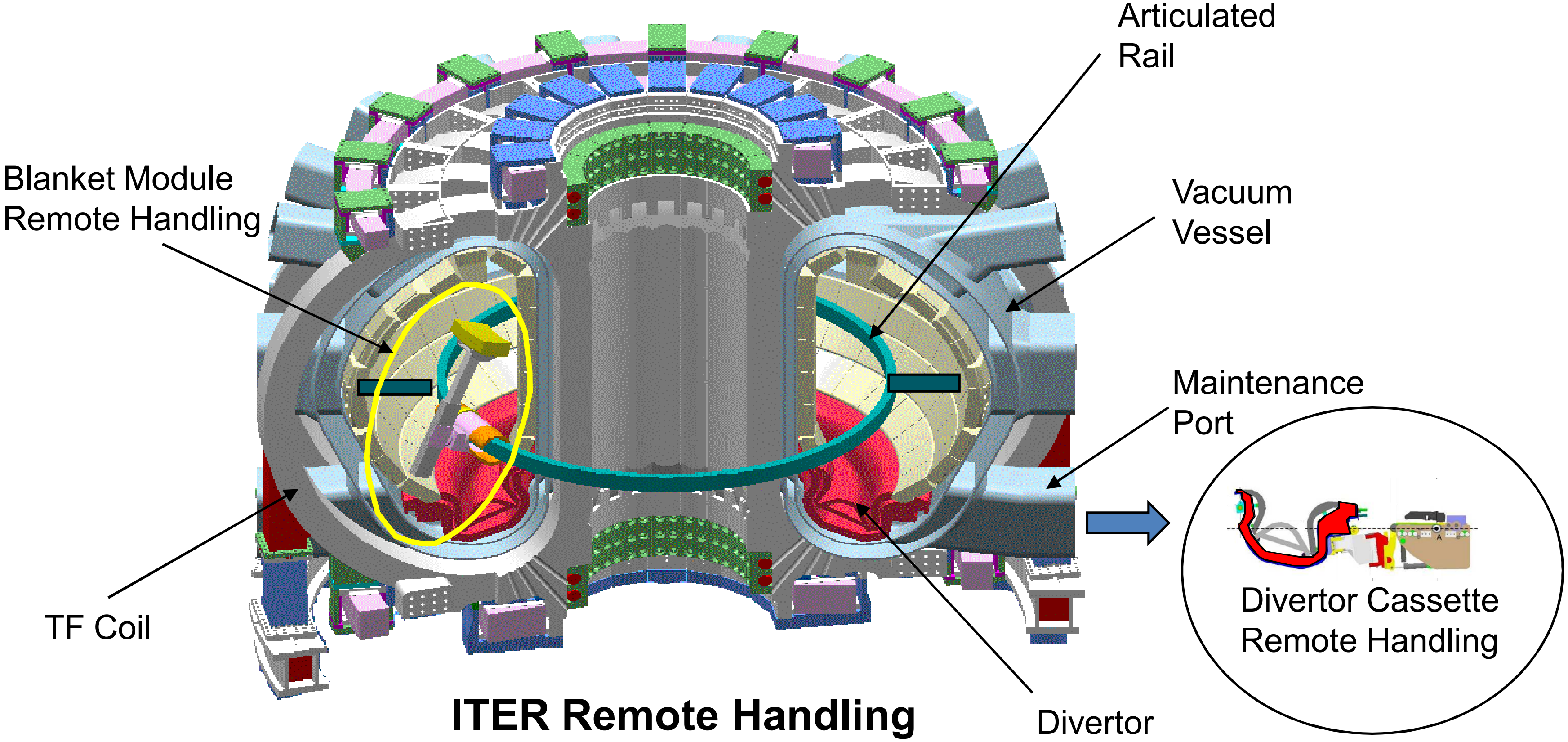
- Pulsed operation ; 1.2T/s (-2T/s)

1) Demonstration of low AC loss and stable conductor under pulsed field.

ITER Remote Handling System

Fusion Technology

Demonstration and improvements of remote maintenance technologies as an integrated system for components under real radiation environments and operational history, based on the experiences of ITER.

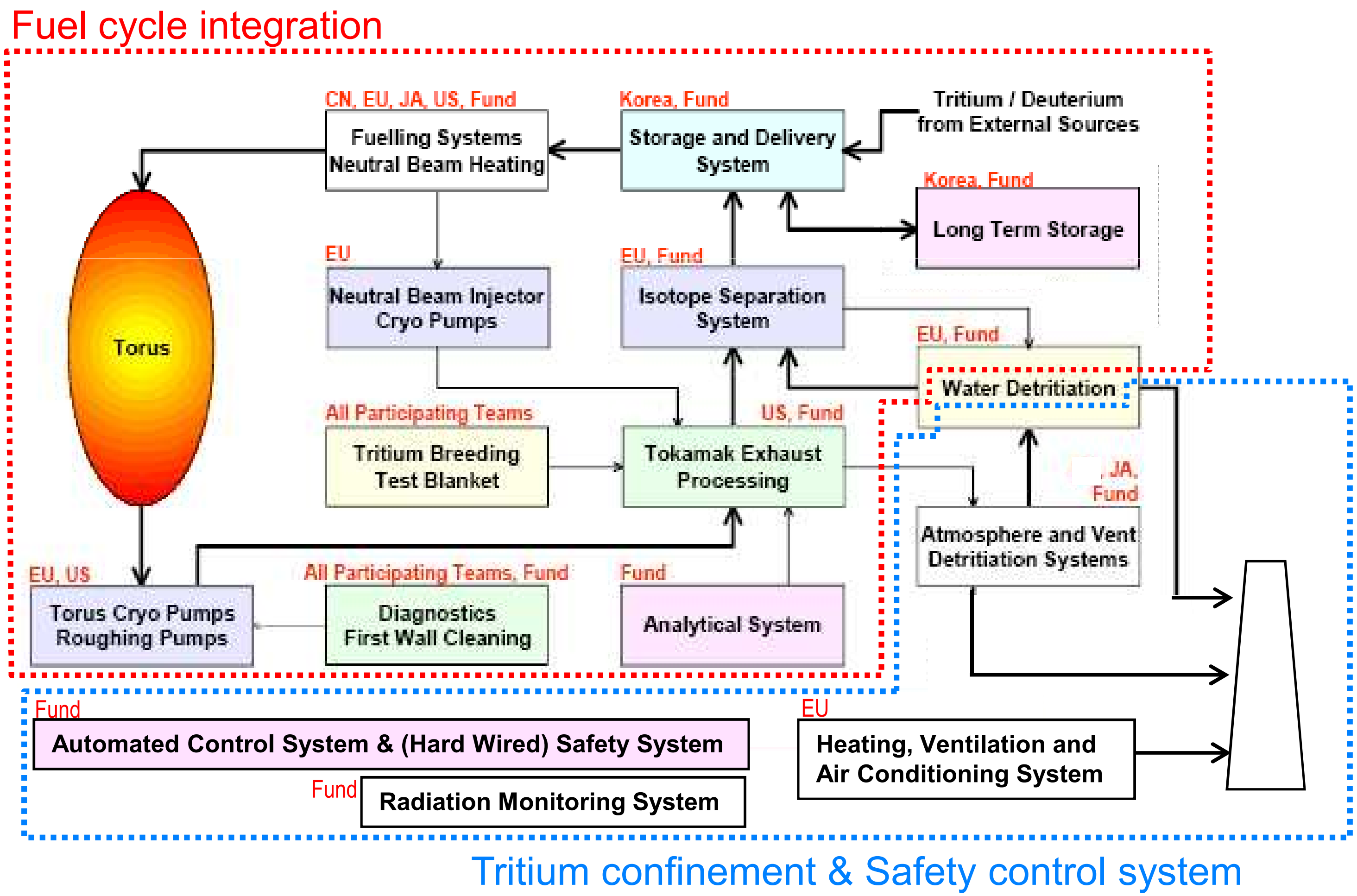


ITER Remote Handling System

ITER Fuel Cycle and Tritium Handling

Fusion Technology

1) **The first experience to operate tokamak system with kg of tritium.**
2) **The first operation experiences of of integrated tritium systems in tokamak, fuel processing, and test blanket systems. - Operation and control of the integrated tritium systems, tritium accountancy, and maintainability.**



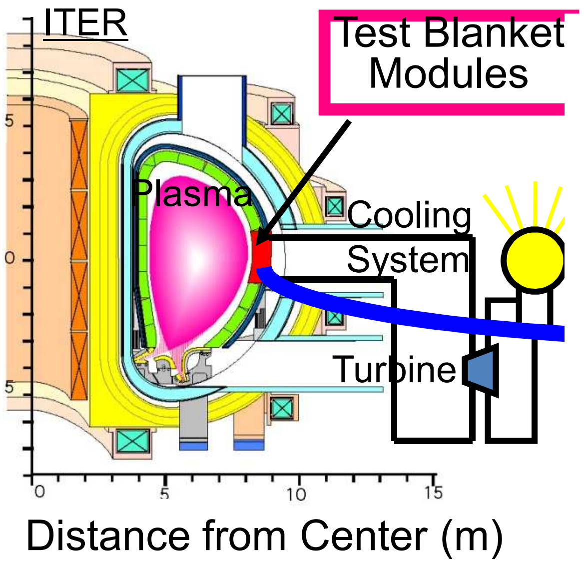
ITER Exploitation - TBM Program

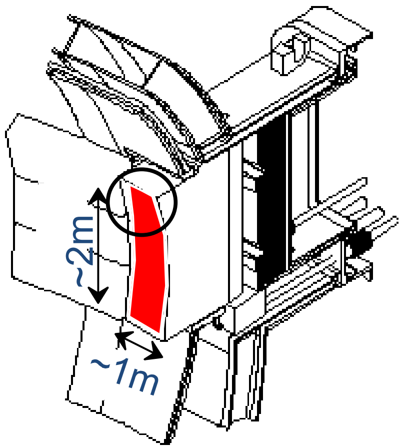
Fusion Technology

- ITER serves as a test bed for the Test Blanket Modules (TBM).
- JA has an intention to take a lead for the Water-Cooled Solid Breeder TBM concept, and to participate, as partner, in advanced concepts such as liquid breeder TBMs.

ITER Test Blanket Module Program

- ITER has 3 test ports for TBMs.
- Max. 6 TBMs can be tested in ITER, 2 TBMs/Port, simultaneously.





TBM Schedule

Year	2007	2010	2016
ITER	Construction		Opera-tion
TBM Program	R&Ds	TBM fabrication	

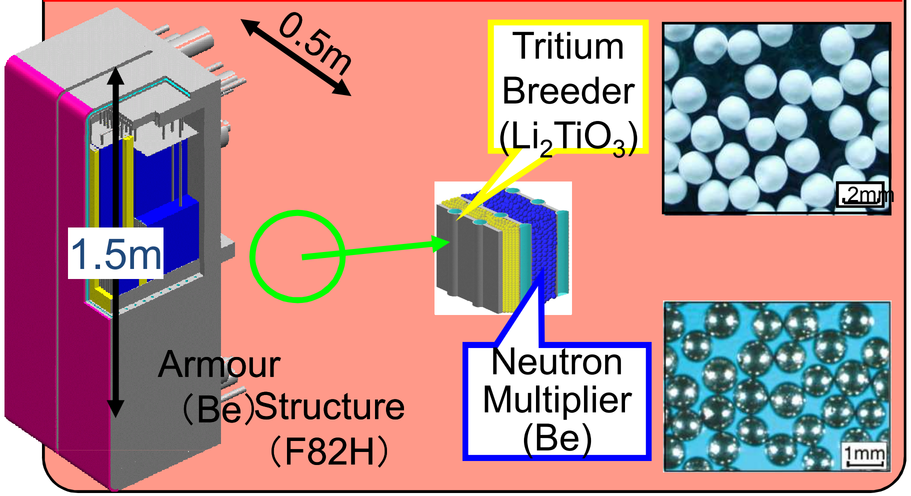
Framework of TBMs

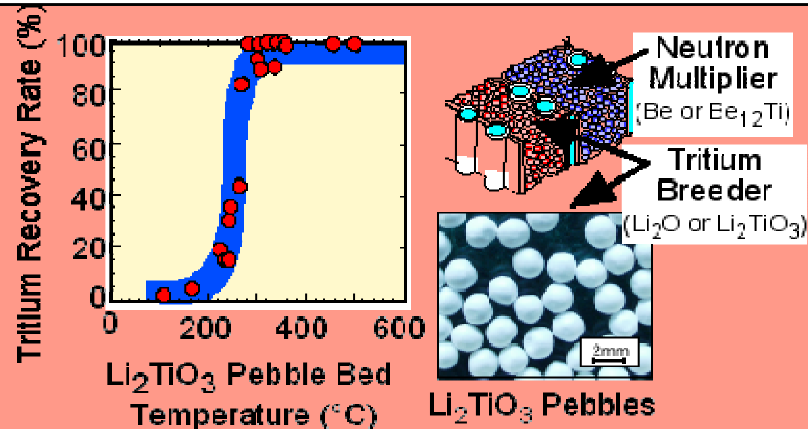
ITER TBM Program is an essential step toward DEMO and fusion reactors as an energy producing system.

R&D Progress in JA for Test Blanket Modules

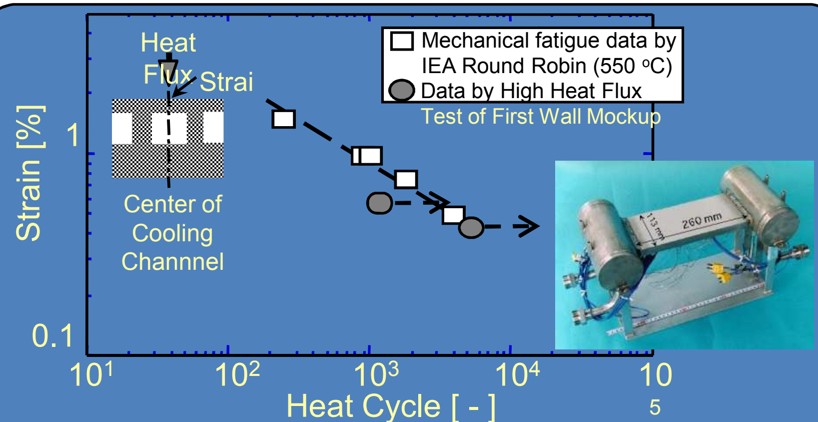
Fusion Technology

JA Water-Cooled Solid Breeder TBM

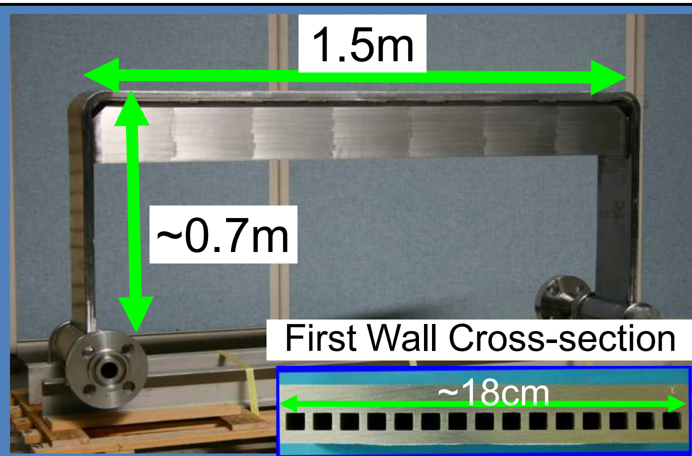




In-situ tritium release experiments in JMTR has shown that Tritium recovery rate becomes almost 100% over 300 ° C.



The F82H First Wall mock-up made by HIP has shown sufficient thermal fatigue lifetime.



Full-scale F82H First Wall mock-up has successfully fabricated by HIP.

TBM R&Ds have stepped up into Engineering-Scale R&Ds.

Broader Approach Activities by JA-EU cooperation in parallel with ITER Construction

Fusion Technology

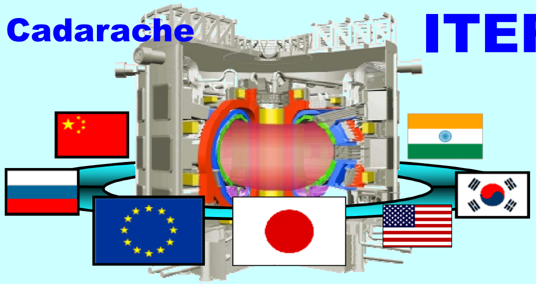
★ **In support of ITER or**
★ **Complementary to ITER toward DEMO**

DEMO

Electricity Production

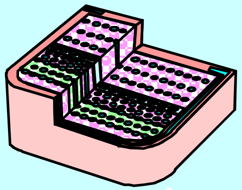
ITER

Cadarache



Fusion Energy Production

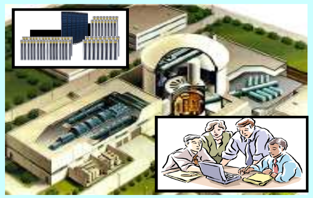
Fusion Plasma Research



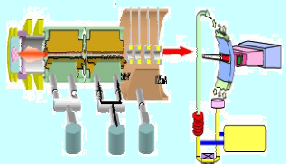
Fusion Engineering Research

Physics/Engineering Basis for ITER

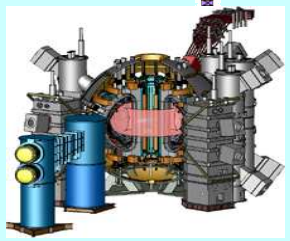
Broader Approach In Japan



IFERC (Rokkasho)
Strategic Approach with Supercomputer simulation, Demo Design+R&D coordination, Remote Experimentation



IFMIF-EVEDA (Rokkasho)
R&D and Comprehensive Design Hosting International Team



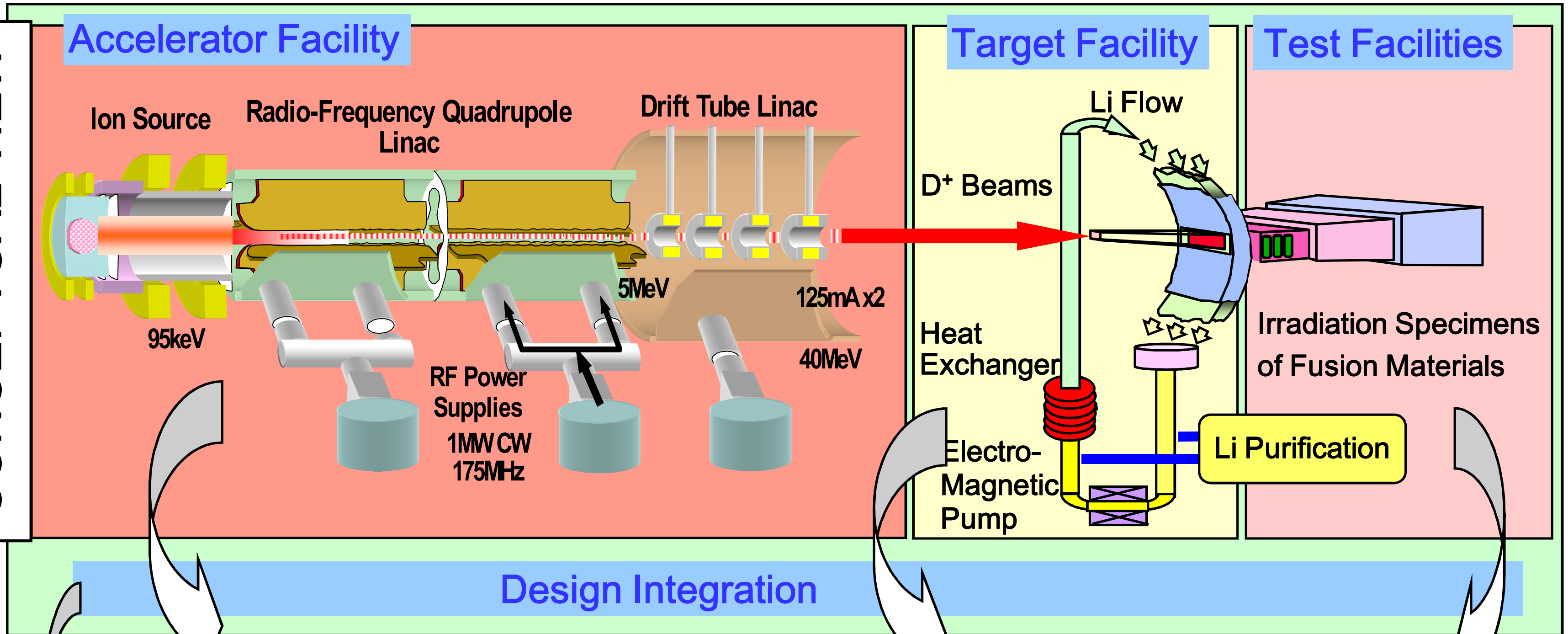
Satellite Tokamak (Naka)
Improve Core Plasma Training of Scientists/Engineers

Early Realization of DEMO

BA Activities - IFMIF / EVEDA Project

Fusion Technology

CONCEPTUAL VIEW



ACTIVITIES

- Prototype Accelerator- Full power Beam Test (low energy part from ion source up to the first section of drift tube linac)
- Accelerator Test Building

- Li Loop Fabrication/Test
- Diagnostics, Erosion/corrosion, Purification
- Remote Handling Technique
- System Engineering Design

- High Flux Test Module
- Fission Neutron Irradiation Test
- Small Specimen Test Technique
- System Engineering Design

Project Team • Design of Buildings and Utilities • Safety and Integration Issues

Complementary R&Ds – Materials Development

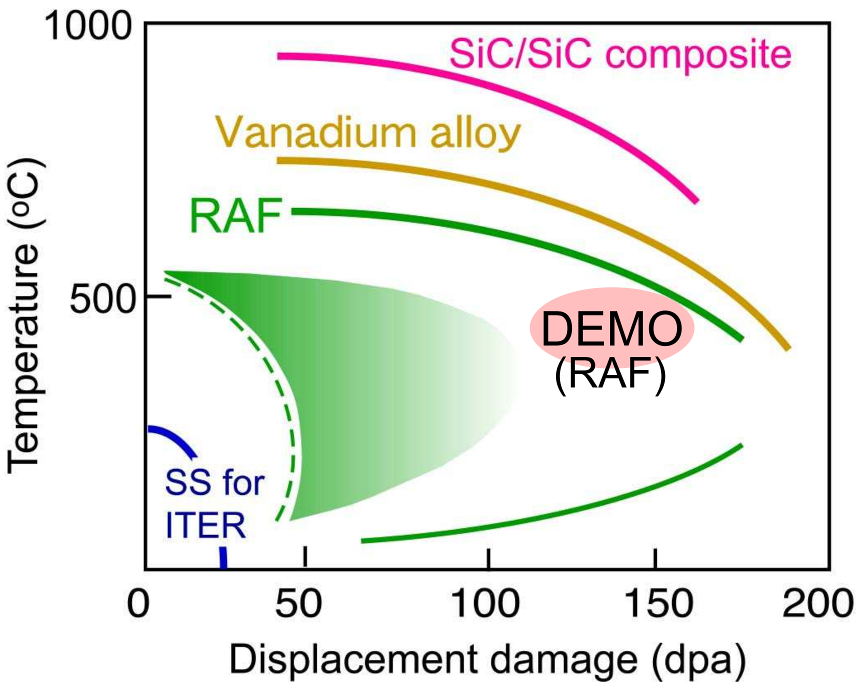
Fusion Technology

Data accumulation and analysis with fission reactor irradiation experiment is also necessary in addition to IFMIF project

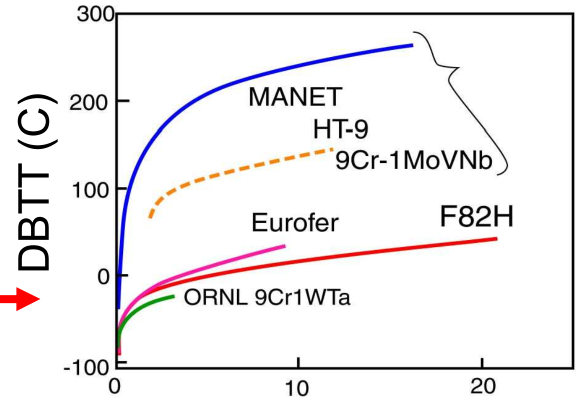
- Narrowing down materials specifications
- Development of structural design methodology/criteria
- Understanding of damage mechanisms for alloy improvement

(conclusions of IEA Sym. on fusion materials development in 2006)

Three candidate materials

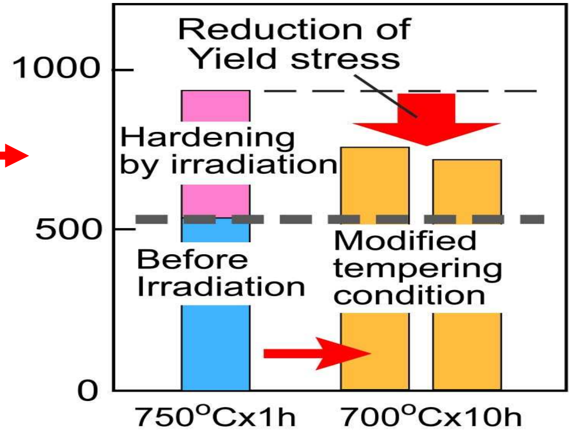


DBTT-shift (PIE results) Examined up to 20dpa.



Improvement of DBTT-shift

Reduction of irradiation hardening by heat treatment

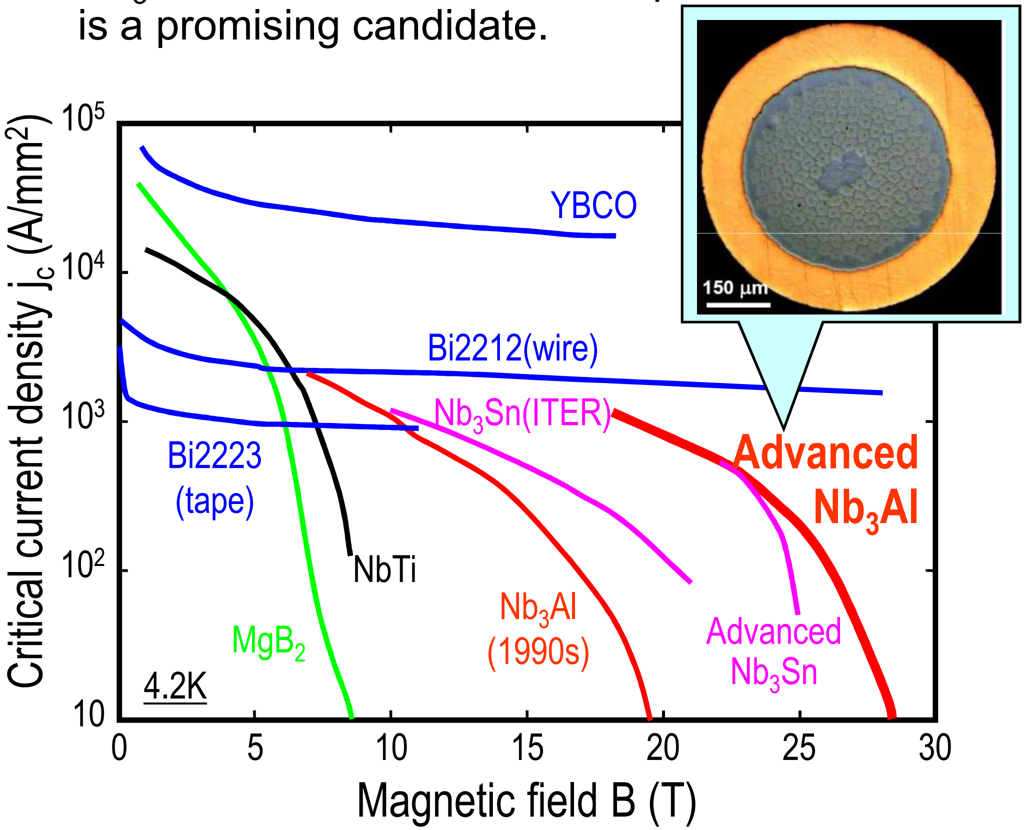


Complementary R&Ds – Upgrade of ITER Key Comp.

Fusion Technology

❑Superconducting Magnet

- High field and large current superconductor, at 16 -20T with 100kA, is essential to realize compact DEMO design.
- Nb_3Al conductor, under development at JAEA, is a promising candidate.



Critical current density of major superconductors

❑ H/CD system

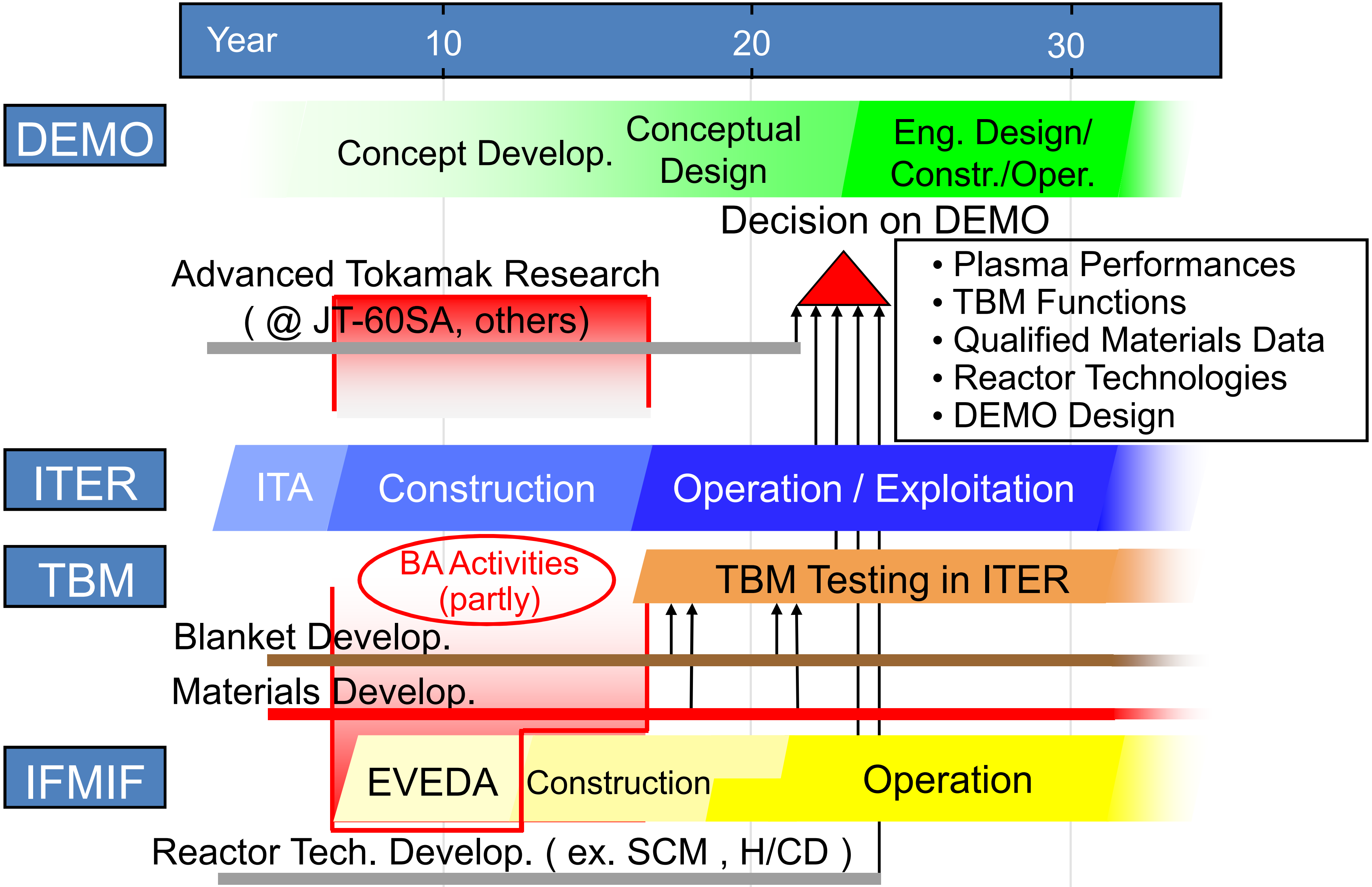
- higher beam energy (NB)
- higher system efficiency, higher reliability and CW-compatibility (NB/EC)

❑ Tritium system

- processing system compatible with high-T and high-P medium
- monitoring and control system of a large amount of tritium

A Possible Roadmap toward DEMO

Fusion Technology



Summary

Fusion Technology

On the basis of 'National Policy of Future Fusion R&D' issued by the ad-hoc Committee and endorsed by Japan Atomic Energy Commission, Nov. 2005, Japanese perspective of Fusion Nuclear Technology from ITER to DEMO was presented:

- Active participation in the ITER Project through component fabrication, construction and assembly, commissioning, operation, exploitation and decommissioning phases are essential to construct a sound technology basis for the design and construction of DEMO.
- In exploitation of ITER, Japanese leadership and active participation in the TBM program are of highest priority.
- The BA Activities are designed to be complementary to ITER toward DEMO, and smooth and effective implementation of the three BA Project are important for a timely start-up of the DEMO phase.
- The other key R&Ds on 1) reduced activation structural materials, 2) higher performances of superconducting magnet and heating/current drive systems and 3) upgrading of tritium processing and safe handling system should be pursued in parallel in a consistent manner with the development of DEMO design studies.

OVERVIEW SUMMARY

- ITER Test Blanket Module (TBM)
  - Water-cooled solid breeder as reference concept and liquid breeder as advanced concept.
  - Exact estimation of tritium breeding is required under the realistic condition of TBM.
- Broader Approach (BA) activities
  - IFMIF-EVEDA & IFERC at Rokkasho, Aomori and Satellite Tokamak at Naka, Ibaraki.
  - Accurate estimation of nuclear response in the tested materials, facility equipments and resultant environmental effects during operation and decommissioning of IFMIF is important.
  - DEMO design in IFERC project needs an intensive studies on neutronics.
  - Experimental or evaluation work on the radioactivity production in the candidate materials for DEMO is also helpful to complete the designs of DEMO itself and IFMIF.