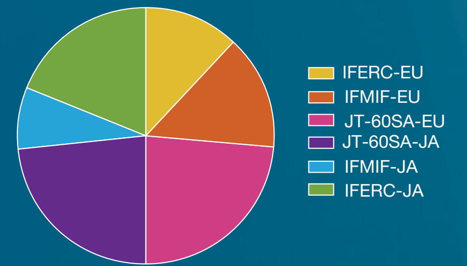
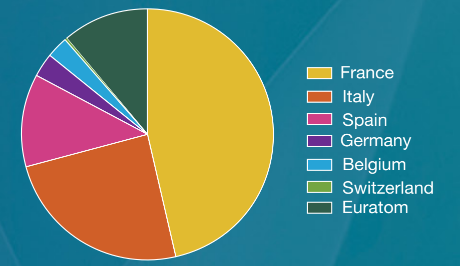
Budget

Japan and Europe contribute equally a fixed amount to the Broader Approach Activities. The European contribution has a nominal value of €339M, and that of Japan ¥46B, both in June 2005 values. For convenience, this total budget volume is set equal to 1 million "BA units of account" (BAUA). Each Party receives credit in BAUA for work, services or hardware provided, according to a breakdown agreed by the BA Steering Committee. The scope of work is divided amongst the projects as shown below left. The European part of this scope is mostly provided by voluntary contributions from the Governments of France, Spain, Italy, Germany, Belgium and Switzerland, with the remainder being provided by Euratom, as shown below right.





Project Management

"Procurement Arrangements" (PAs) between the two Implementing Agencies detail the scope of the procurement or service, including its technical specifications, time schedule and credit. For Europe, if the work is not carried out directly by F4E, each PA is matched by one or more "Agreements of Collaboration" between F4E and Voluntary Contributor Designated Institutions (VCDIs). Ultimately the institutions - JAEA, F4E, and the VCDIs - place contracts with suppliers from their institutional budgets.

Each project has a common quality management system (common across each Integrated Project Team) which has significant common elements between the three projects. Management decision-making is by consensus of the Project Leader and the heads of the Home Teams. Regular technical coordination meetings involving all responsible officers ensure continuous integration of the various projects or subprojects. The projects rely on a dedicated common set of tools (e.g. document management system) for sharing and tracking of information, separate from those of their institutional systems.

To utilise the Broader Approach facilities, different agreements are sometimes needed. For instance, in the case of IFERC, the time available for projects running on the Helios simulation computer is shared equally amongst researchers from the wider European and Japanese fusion programmes.

Messages from the Project Leaders

IFMIF is indispensable for the worldwide nuclear fusion programme to learn the effect of the neutrons generated in deuterium-tritium fusion reactions in order to build a sound reactor. The technical difficulties are surmountable, and given the quality of the IFMIF family there can only be success ahead. We have the privilege of partaking in the common human endeavour to tame fire for the second time in our short history, this time the fire of the stars.

Juan Knaster, IFMIF/EVEDA Project Leader

Most of the procurement contracts have been placed, and machine assembly in Naka has begun. The detailed research programme to be carried out once JT-60SA is operating is being developed jointly by all physicists involved in the fusion programmes of Europe and Japan. Despite the long distance between Europe and Japan, there is enthusiasm and dedication to try to maintain the schedule and quality of the delivery of components and the eventual machine assembly, commissioning and operation. This is very encouraging for the successful outcome of this project.

Shinichi Ishida, JT-60SA Project Leader

Joint work on the DEMO design has been started, covering studies on system codes, divertor, in-vessel components, tokamak operation modes and maintenance schemes. DEMO R&D activities are being performed by using the excellent R&D facilities now established at the Rokkasho IFERC site. The high performance 1.5 Pflops Helios computer has started operation, exploiting the new research field at the forefront of magnetic fusion simulations. These activities indicate that the IFERC project is now shifting from the preparatory research phase into the actual research.

Noriyoshi Nakajima, IFERC Project Leader

Implementing Agencies and European Voluntary Contributors

For Europe — FUSION FOR ENERGY

Fusion for Energy

For Japan — JAEA

Japan Atomic Energy Agency

European Voluntary Contributors

French Alternative Energies and Atomic Energy Commission

Ciemat — Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Spanish Research Centre for Energy, Environment and Technology

CONSORZIO RFX — Ricerca Formazione Innovazione

CNR - Italian National Research Council / Consorzio RFX

CRPP

Swiss Plasma Physics Research Centre

ENEA

Italian National Agency for New Technologies, Energy and Sustainable Economic Development

INFN — Istituto Nazionale di Fisica Nucleare

Italian National Institute for Nuclear Physics

KIT — Karlsruhe Institute of Technology

Karlsruhe Institute of Technology, Germany

SCK•CEN — STUDIECENTRUM VOOR KERNENERGIE CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Belgian Nuclear Research Centre

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Project Websites

www.ba-fusion.org www.iferc.org www.ifmif.org www.jt60sa.org

Publications Office

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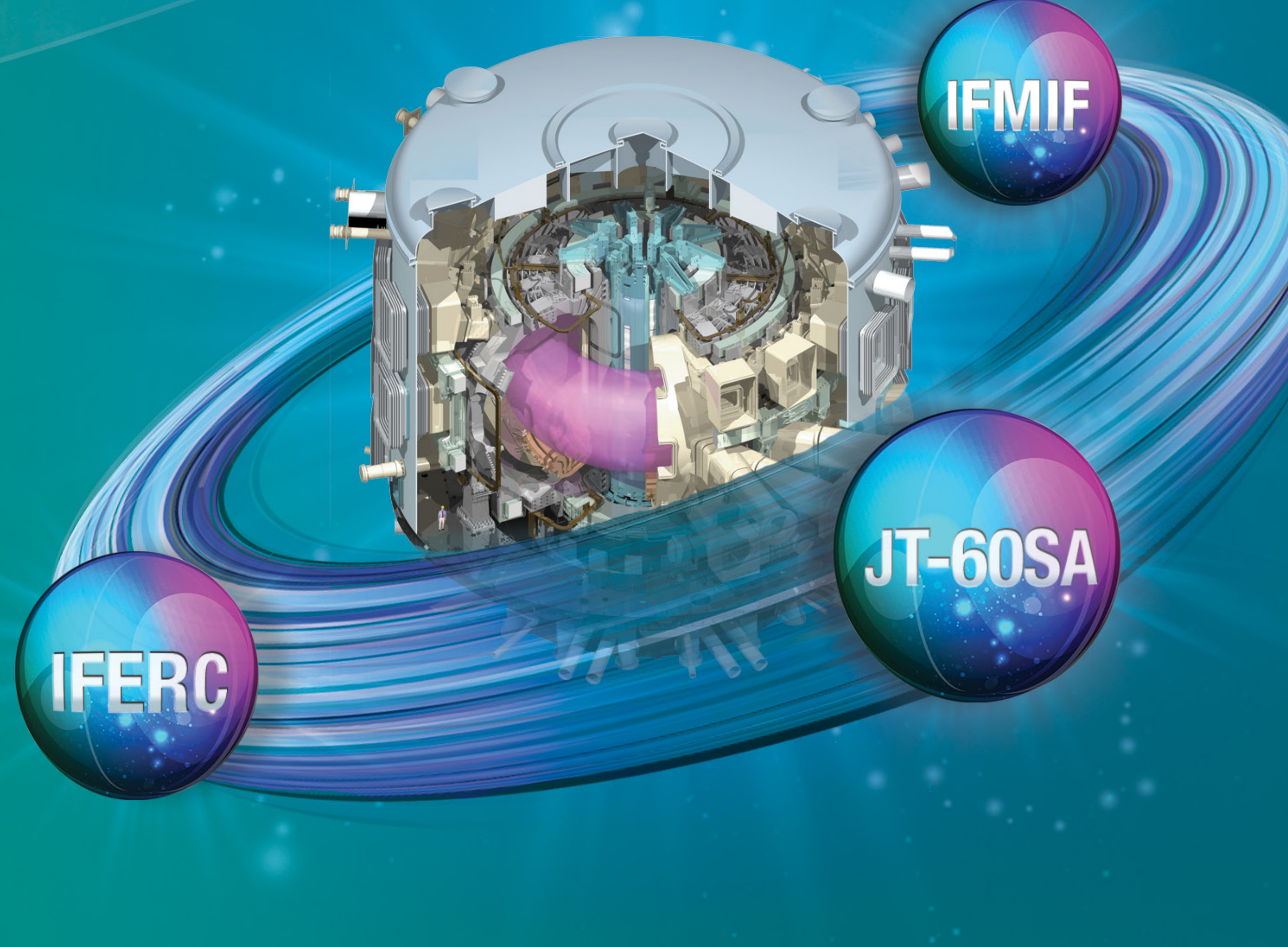
BROADER APPROACH

Activities in the Field of Fusion Energy Research

Projects which complement the ITER project and accelerate the realisation of fusion energy by carrying out R&D and developing advanced technologies for future demonstration power reactors.



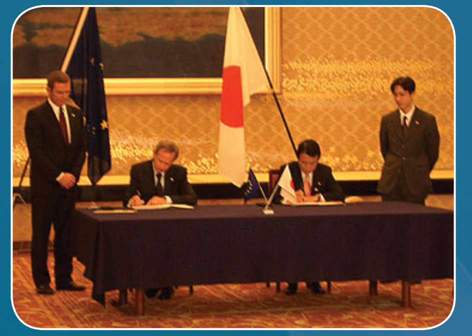
Broader Approach and its Projects

The Objectives

During the ITER negotiations in 2005, the decision to site ITER in Cadarache was reached through an agreement between Europe and Japan. This forged a privileged partnership in the ITER project and on a set of activities, to be performed jointly in Japan - the Broader Approach Activities (BA Activities). In Brussels on November 22nd 2006, at the same time as the signature of the ITER Agreement, the representatives of the Government of Japan and EURATOM signed the Brussels Joint Declaration agreeing *"to jointly implement the Broader Approach Activities in support of the ITER Project and an early realisation of fusion energy for peaceful purposes on a time frame compatible with the ITER construction phase."* The "Broader Approach Agreement" was signed on February 5th 2007 in Tokyo and the activities started on June 1st 2007 after ratification of the Agreement by both Parties. It remains in force for a period of 10 years and continues in force thereafter unless terminated by either Party.

The agreed joint programme consists of three projects: the Engineering Validation and Engineering Design Activities for the International Fusion Materials Irradiation Facility (IFMIF/EVEDA), the Satellite Tokamak Programme Project JT-60SA, and the International Fusion Energy Research Centre (IFERC).

The main objective of these three projects is to provide information, complementary to that from ITER, in the fields of physics and technology, needed to proceed to DEMO, the next step in the quest for fusion power. The three Broader Approach projects represent a well-integrated approach to support ITER, and to prepare to undertake the engineering design and construction of DEMO.



Taro Aso, Minister for Foreign Affairs of Japan and Hugh Richardson, the Ambassador of the Delegation of the European Commission to Japan, signing the Agreement between the Government of Japan and EURATOM for the Joint Implementation of the Broader Approach Activities.

Organisation

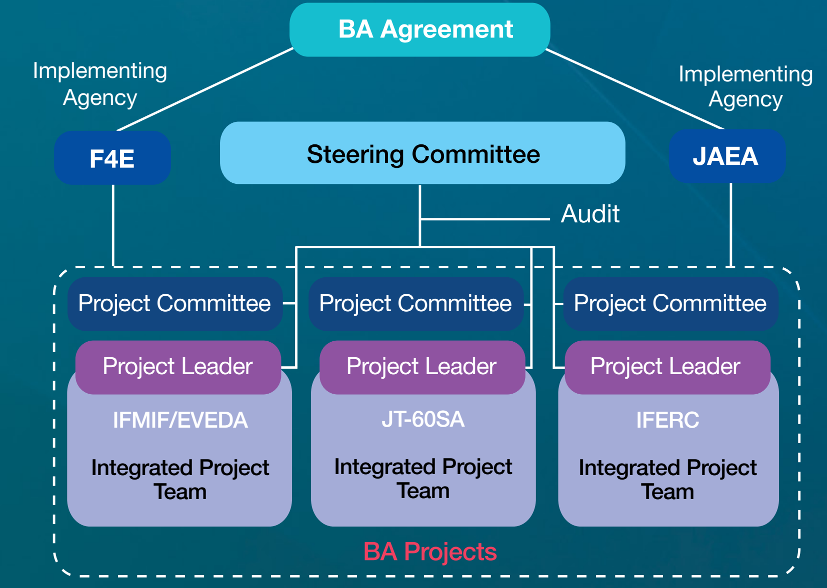
Project Governance

Steering Committee
The Steering Committee, where both Parties are equally represented, is responsible for the overall direction and supervision of the implementation of the activities. In particular, for each of the three projects, it appoints the Project Leader and the Project Team staff, approves the structure of the Project Team, the project plan, work programmes and annual reports, and decides on the participation of any other ITER parties.

Project Committees
In addition to giving advice, the function of each Project Committee is to monitor and report on the progress of each project to the Steering Committee.

Implementing Agencies
Each Party has designated an Implementing Agency to discharge its obligations to the Broader Approach Activities. The Japan Atomic Energy Agency (JAEA) in Japan and the European Joint Undertaking for ITER and the Development of Fusion Energy, "Fusion for Energy" (F4E) in Europe have been assigned this role. They undertake this by the creation of Japanese and European Home Teams, led by these agencies, and in the case of Europe including staff members of the designated institutions of the voluntary contributors providing the European contributions.

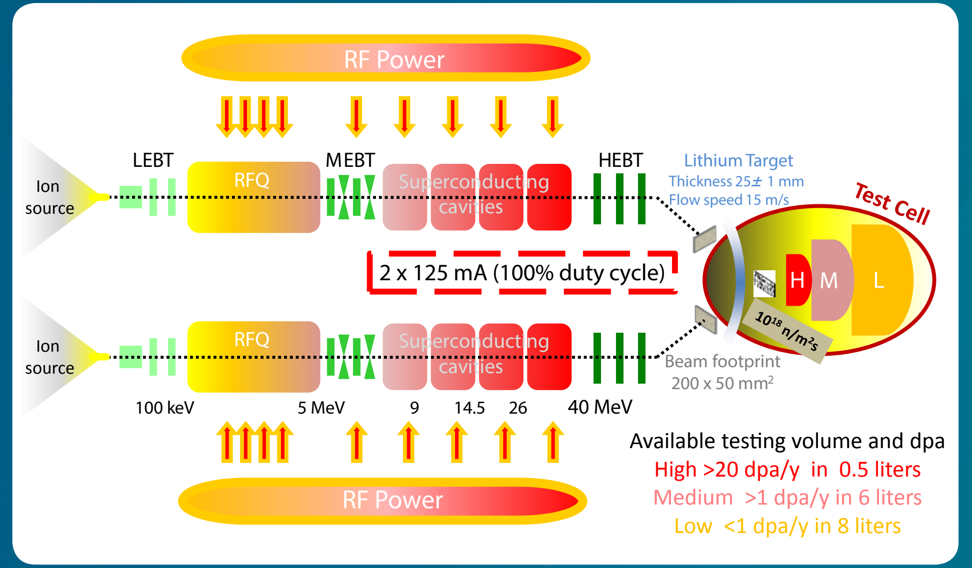
Project Leaders and Integrated Project Teams
A Project Leader, supported by the respective Project Team and Home Teams together forming each Integrated Project Team, is responsible for the co-ordination of the implementation of each project, including preparation of reports to the Project and Steering Committees. The total number of people involved in the three Integrated Project Teams is around 500 (at a level of effort on these projects equivalent to about 400 full-time people).



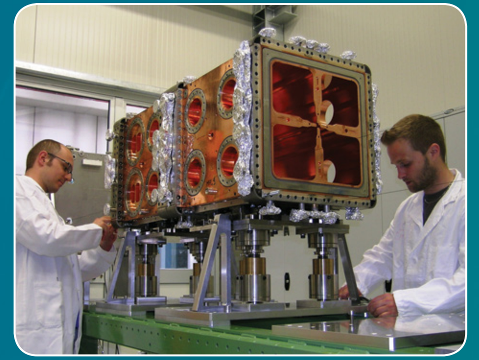
Arrangement of the main bodies forming the BA organisation

IFMIF/EVEDA

IFMIF, the International Fusion Materials Irradiation Facility, will generate neutrons with an energy spectrum similar to those occurring in a DT (deuterium-tritium) fuelled nuclear fusion reactor. A commercial fusion reactor will require materials capable of withstanding 150 dpa (dpa is the typical unit used to describe neutron-induced materials degradation, indicating average displacements per atom in the bombarded material), which nowadays is an unexplored region. The design of a reactor demands an understanding of which materials can be used and what mechanical properties they will retain after years of operation. IFMIF is a unique tool to learn this. In IFMIF neutrons will be generated by bombarding liquid lithium with accelerated deuterium ions (deuterons). There will be sufficient to cause damage equivalent to that in the first wall of a fusion power plant (see bottom right of figure).



Overview of main IFMIF systems


Assembly of modules for the high power testing of RF quadrupole elements at INFN

Three main facilities will form IFMIF: two accelerators, a target, and a test cell. All three are under validation and design refinement in the current Engineering Validation and Engineering Design Activities (EVEDA) phase, which is due to be completed in 2017. Two additional facilities complete the IFMIF plant: a post-irradiation and examination facility, and a set of conventional facilities.

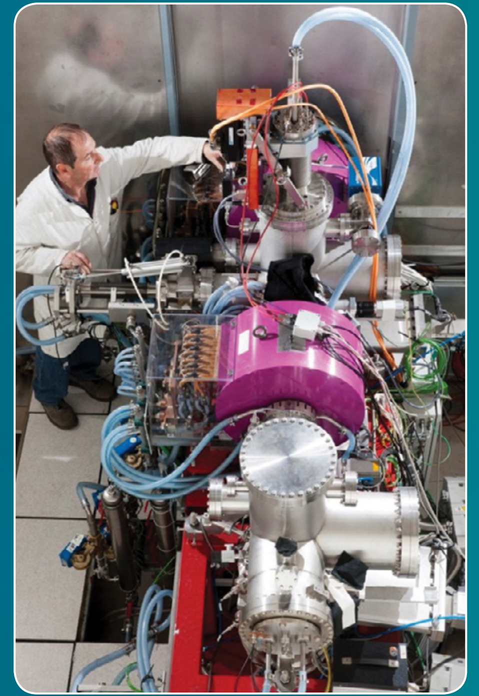
LIPAc, the prototype of the IFMIF accelerators, presently being installed in Rokkasho, Japan, will demonstrate technologically that the IFMIF 40 MeV deuteron accelerators are feasible.

The EVEDA Lithium Test Loop (ELTL) under operation in Oarai, Japan, with the development of needed diagnostics and purification systems, will demonstrate that IFMIF's liquid lithium loop is achievable.

Mechanical testing of small irradiated specimens is a well-known technology for fission reactor materials, but special requirements are placed on IFMIF if it is to provide the conditions matching those of the most exposed materials of a fusion reactor vessel. The highest exposed test module (High Flux Test Module) will allow the testing of around 1000 small specimens with an accurate control of the irradiation temperature thanks to a cooling system with helium gas that has also been demonstrated in the full scale HELOKA loop. The validation of the design under neutron irradiation will be performed in the high flux BR2 reactor.

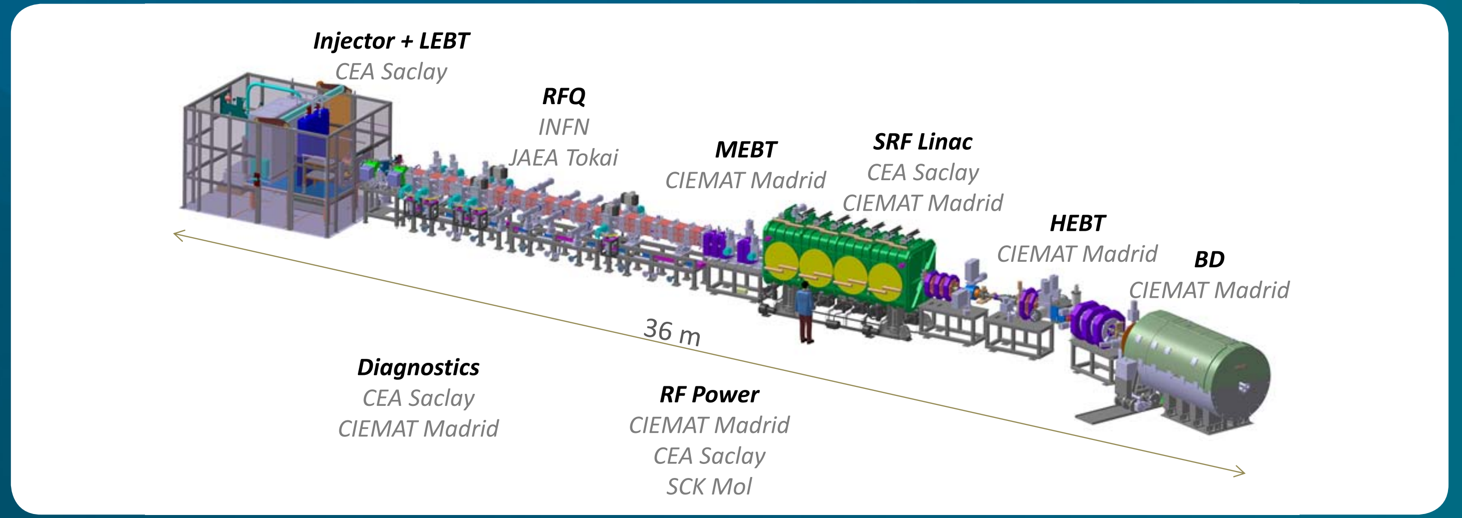
All the information gleaned from the validation activities is contributing towards the comprehensive design of IFMIF. The results of the work are documented in an IFMIF Intermediate Design Report, completed in mid-2013, which is sufficiently detailed to allow decisions to be made on future IFMIF siting, construction schedule, and cost breakdown.


Flowing lithium in the ELTL facility (Oarai)


Injector under test at CEA Saclay


Half-wave resonator prototype (CEA)


Small specimen tray (4 x 8 cm) for test irradiation (KIT, SCK-CEN)

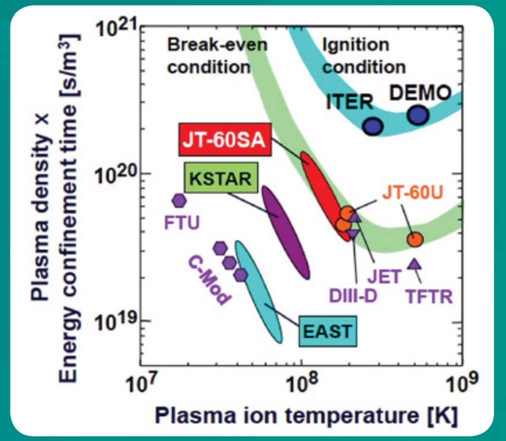


Details of the Linear IFMIF Prototype Accelerator (LIPAc)

JT-60SA

The Mission

The mission of JT-60SA is to contribute to the early realisation of fusion energy by addressing key physics issues relevant for ITER and DEMO. JT-60SA is a fully superconducting tokamak capable of confining high-temperature (100 million degree) deuterium plasmas under conditions equivalent to those where a 50% deuterium – 50% tritium plasma would generate as much energy as is required to maintain it ("break-even"). Because JT-60SA uses only deuterium as a fuel, it can help optimise the plasma configurations for ITER and DEMO without generating large amounts of heat or neutrons. It is therefore perfect for supporting ITER operation by being able to more quickly explore options. JT-60SA nevertheless slowly will become radioactive in use, and remote handling of systems near the plasma must be planned. JT-60SA has a large amount of power available for plasma heating and current drive, from both positive and negative ion neutral beams, as well as electron cyclotron resonance radio-frequency (RF) heating. It will typically operate for 100 s pulses once per hour, subjecting watercooled divertors to maximum heat fluxes of 15MW/m². The machine will be able to explore full non-inductive steady-state operation.

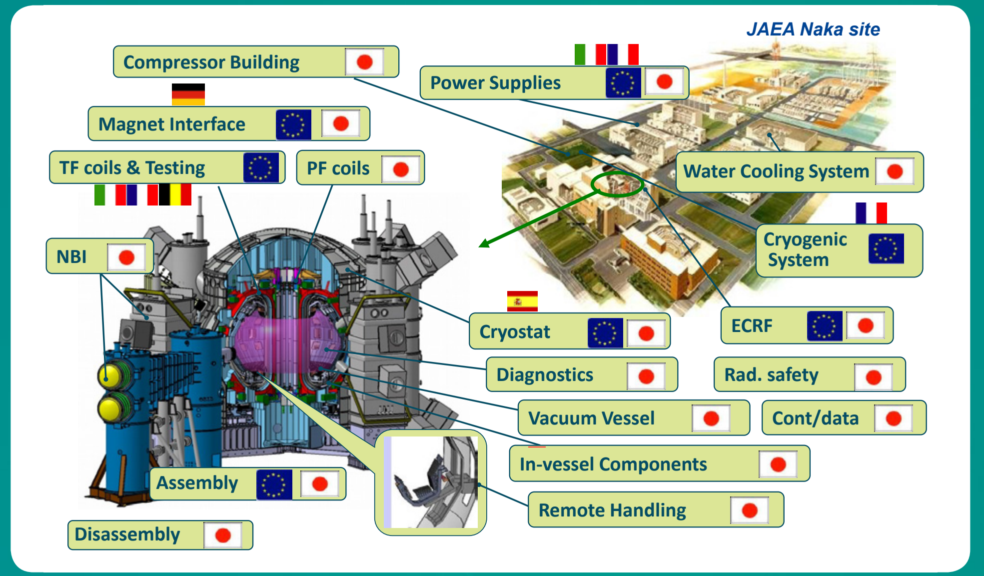


Operation space of JT-60SA

The JT-60SA Integrated Project Team, EFDA and the Fusion Energy Forum of Japan are collaborating as the JT-60SA Research Unit to establish the research plan of JT-60SA. This research plan will continue to evolve as the fusion communities in Japan and Europe deepen and sharpen the research strategy of JT-60SA. The plasma performance range expected for JT-60SA is shown on the diagram, in comparison with existing experiments worldwide as well as with expected ITER and DEMO operation.

The Machine

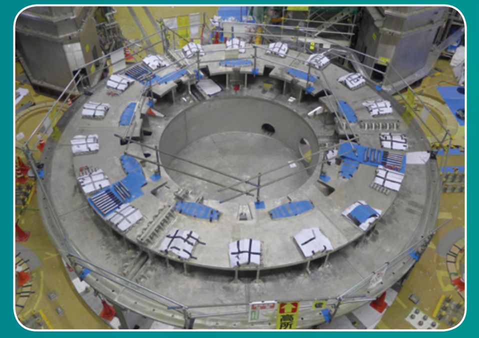
JT-60SA is being constructed at the Japan Atomic Energy Agency Naka Fusion Institute in Japan. The machine combines a plasma similar in size to that of JET (Joint European Torus), using superconducting magnets, as in ITER, to reduce power consumption. The JT-60SA tokamak consists of the magnets and vacuum vessel. The vessel houses components dedicated to vessel protection, plasma impurity control, plasma position control and fuelling, vacuum pumping and cooling. Diagnostics and heating systems utilise the vessel ports. A cryostat and thermal shield surround the tokamak and protect the superconducting magnets operating at ~4K from heat inleak from the environment and hotter structures. Services are provided for water cooling, cryogenics, power supplies, the control system, as well as heating, ventilation and air conditioning of the building. A remote handling system is included, and is used also to assist in construction. The JT-60SA tokamak is located in the building previously occupied by the JT-60U tokamak, involving disassembly and recommissioning of some equipment before assembly of the JT-60SA tokamak. Additional safety features are also being added.

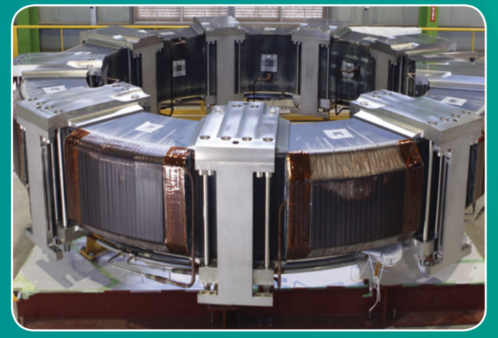


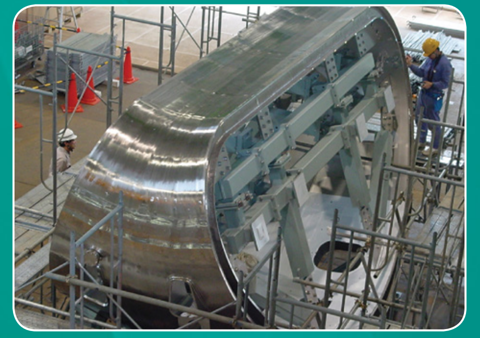
Sharing of procurement between Europe and Japan

Most of the procurement is currently underway in Europe and Japan, particularly the Toroidal Field (TF) coils, Poloidal Field (PF) coils, vacuum vessel, thermal shield, in-vessel components, and cryostat, and JT-60U machine disassembly has been completed during 2012, enabling the start of construction of the new machine at the beginning of 2013.

Recent Achievements


Completion of assembly of cryostat base in the Torus Hall at the Naka Fusion Institute


Completed equilibrium field coil No. 4 in the PF Coil Manufacturing Building at the Naka Fusion Institute


40° sector of vacuum vessel, in the Vacuum Vessel Assembly Building at the Naka Fusion Institute


Divertor cassette bodies before mounting with plasma-facing components

IFERC

In order to implement the mission to contribute to ITER and to an early realisation of DEMO, the International Fusion Energy Research Centre (IFERC) promotes three sub-projects: DEMO Design and R&D Coordination Centre, Computational Simulation Centre (CSC), and ITER Remote Experimentation Centre (REC).

DEMO Design and R&D Coordination Centre

This Centre in Rokkasho plays an important role in co-ordinating scientific and technological activities necessary for DEMO including design activities and technology R&D on key issues of common interest. The objective includes the assessment of pre-conceptual design options for DEMO, reflecting the outcome of R&D activities. It is expected that this design activity will also suggest specific research activities, some of which would have to be carried out on ITER. Others would have to be carried out on JT-60SA or other facilities.

The DEMO R&D Building in Rokkasho has been completed recently as a radioisotope (RI) handling facility, which consists of an RI experimental room, beryllium handling room, microstructure analysis room, and material test room.

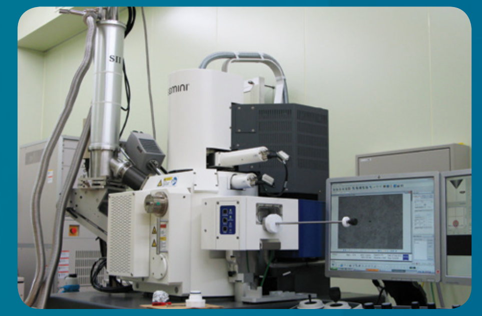
RI Experimental Room
This consists of a 370 GBq hood for development of tritium accountancy technology, basic tritium safety research, and tritium durability tests.


Tritium handling equipment

Beryllium Handling Room
The beryllium handling room has been set up for the development of beryllium intermetallic compounds (beryllides) as advanced neutron multipliers.


Plasma sintering device

Microstructure Analysis Room
This room is for high-resolution micro/nano-structural observations, nano-scale surface analysis, and nano-scale mechanical tests.

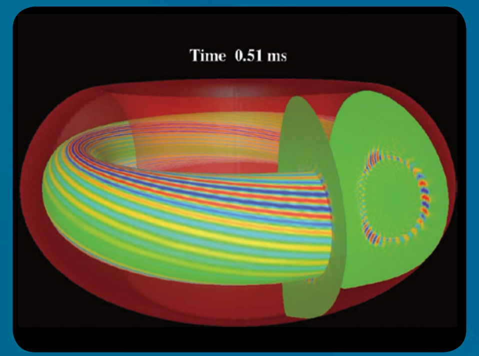

Field emission scanning electron microscope

Material Test Room
Mechanical tests, fracture surface observation and sample preparation for low-activated materials (reduced-activation materials, ceramic composites, tungsten and beryllium alloys, etc.) can be performed in this room at the highest quality level. The mini hot cell has been equipped with shielding and manipulators for post-irradiation experiments.

Computational Simulation Centre (CSC)

The objective of the CSC is to provide a state-of-the-art supercomputer and to exploit large-scale and high-performance simulations to analyse experimental data on fusion plasmas, prepare scenarios for ITER operation, predict the performance of ITER, and contribute to the DEMO design.

The "Helios" supercomputer, which has more than 4000 nodes, was installed at the end of 2011 and has achieved 1,237 petaflops in the LINPACK test. In its initial operation in the first quarter of 2012 "Lighthouse Projects" (which are expected to shed light on plasma calculations) were performed using four selected codes, in order to confirm its capability in exploring the frontier of magnetic fusion confinement. Between April and November 2012, a first cycle of production with 58 selected projects addressed issues related to plasma turbulence and reactor technology. The second cycle of calculations and simulations up to November 2013 is now well underway.



This simulation of the spatial distribution of a particular type of instability in an ITER steady-state plasma shows that it would not degrade the confinement of alpha particles


Helios supercomputer

ITER Remote Experimentation Centre (REC)

The REC will be developed as a remote experimentation room for experimental campaign preparation and data analysis for ITER, and will be able in the future to monitor the ITER plant status, prepare and transfer pulse parameter request files to the ITER CODAC, present the main machine and plasma parameters in real time, and access promptly the experimental data for further analysis at the REC. Prior to the demonstration of ITER remote experimentation, the REC will be tested on JT-60SA and/or other existing tokamaks.


Artist's impression of the REC in action