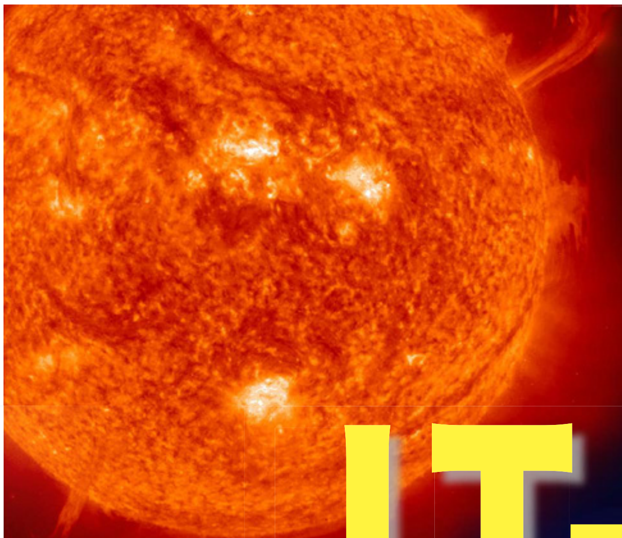
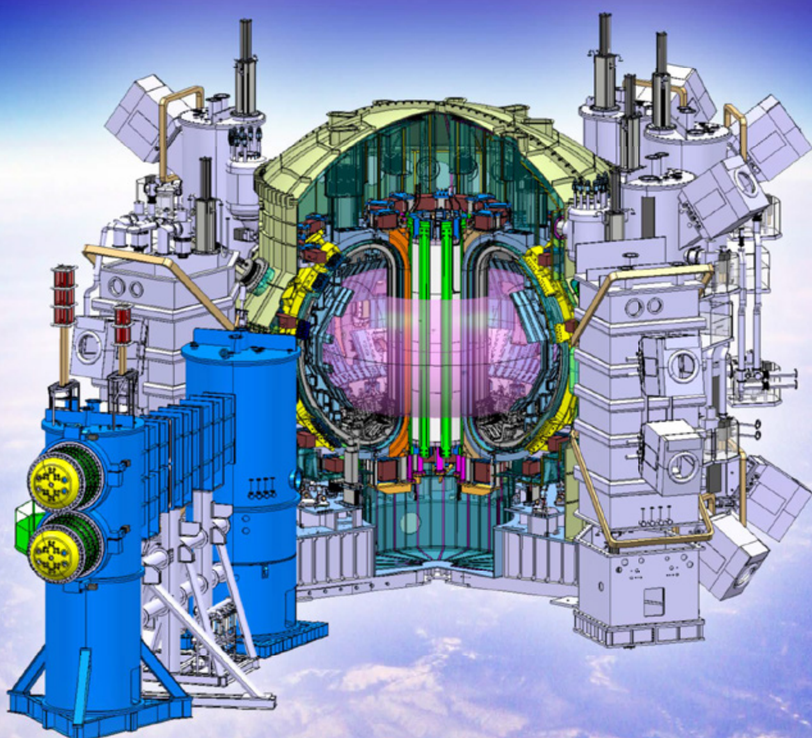


JT-60SA

— Toward the Realization of Fusion Energy —



Nuclear fusion is the energy source of the sun and stars,
in which light atomic nuclei fuse together, releasing a large amount of energy.

Fusion power can be generated on Earth using two isotopes of hydrogen,
deuterium and tritium, in the unique environment created in a fusion device.

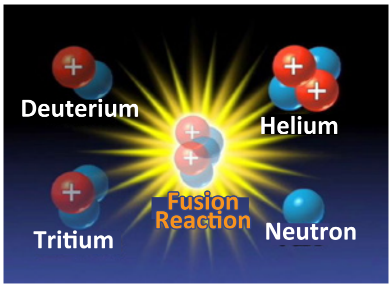
We are conducting research and development to create "A Sun on Earth",
which is favorable from the viewpoint of the environment and safety.

QST National Institutes for Quanatum and Radiological Science and Technology

JT-60SA: Core Device in Nuclear Fusion Research

Fusion reactor fuel is in a plasma state

The nuclear fusion reaction of deuterium and tritium produces helium and neutrons and releases a large amount of energy: 1 gram of deuterium and tritium releases energy equivalent to 8 tons of oil. However, it is necessary for nuclei to collide at the relatively high speed of 1000 km/s, beyond which the mutual repulsive force of two, positively charged nuclei is overcome. The most promising method to achieve fusion is to heat the fuel to a temperature exceeding 100 million degrees to facilitate the fusion of nuclei at high speeds. At such a high temperature, the fuel is fully ionized, and nuclei and electrons move freely. This is called a plasma state.



Progress in Nuclear Fusion Research

The study of stable confinement of ultra-high-temperature plasmas started in the 1950s. Tokamak devices prompted significant progress in magnetic confinement research. The tokamak features a nest of toroidal magnetic field lines produced by external magnets and an electric current in the plasma. In the 1990s, large tokamaks were constructed worldwide (JT-60 in Japan, TFTR in USA and JET in EU), reflecting intense, world-scale development in fusion research. Remarkable progress has raised expectations for realizing reactor-relevant, high-temperature and high-density plasmas. Based on these achievements, the ITER device is now under construction at Saint-Paul-lez-Durance in France to demonstrate the scientific and technological feasibility of fusion energy in a framework of international collaboration among Japan, EU, Russia, USA, China, Korea, and India.

Mission of JT-60SA

The JT-60 tokamak in the Naka Fusion Research Institute, the forerunner of JT-60SA, was one of the largest tokamak devices in the world. During operations from 1985 to 2008, JT-60 continued to produce remarkable scientific results in the form of world records and findings to become a global leader in fusion research. JT-60 made a particularly significant contribution to the design of ITER through its development of steady-state operations with a high fusion output. Building upon the results of steady-state research in JT-60, JT-60SA will play the following roles after modifying JT-60 to a superconducting device with an advanced control system for enhancing plasma stability.

Support ITER

JT-60SA will provide significant support to ITER research: prior to ITER experiments, JT-60SA will confine high-temperature deuterium plasmas at a break-even* level for long durations, the results of which will be incorporated into ITER experiments.

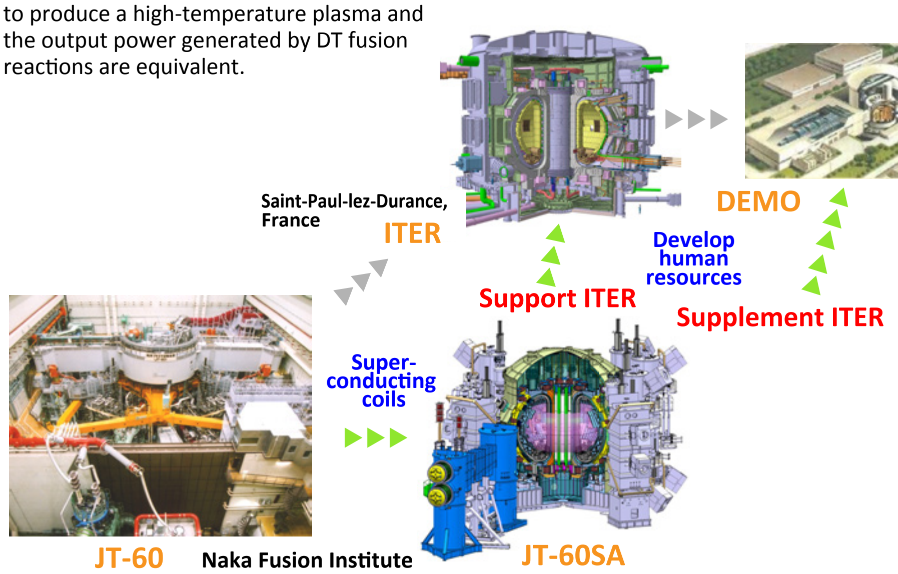
*Condition in which external heating power to produce a high-temperature plasma and the output power generated by DT fusion reactions are equivalent.

Supplement ITER toward DEMO

One of the missions of DEMO is to demonstrate that fusion can be an economically competitive and reliable energy source. JT-60SA will demonstrate a sustained (~100 s), high-pressure plasma which exceeds the target of ITER, thereby providing further evidence of the feasibility of fusion as an energy source for a competitive economy.

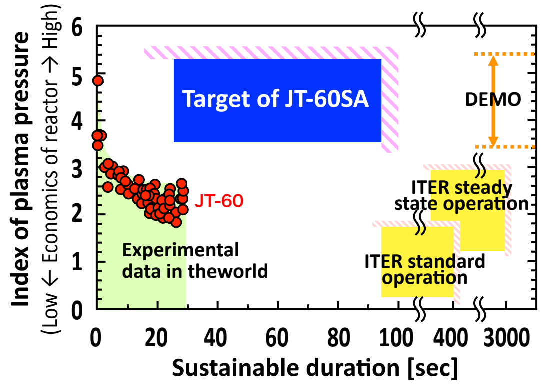
Develop human resources

As the only one large tokamak in Japan, JT-60SA will provide opportunities for researchers and engineers to cultivate their skills to become key contributors to global fusion research endeavors such as the ITER project.



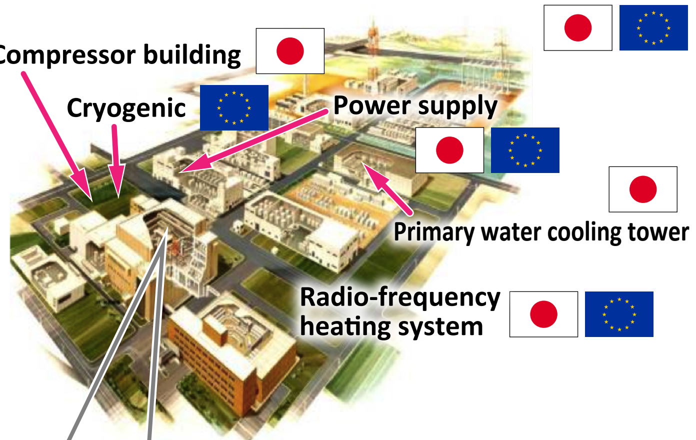
High-pressure plasma

- High-pressure plasma is a dense confinement of fuel ions in a fusion device, yielding a high rate of fusion reactions.
- Sustaining a stable, high-pressure plasma enhances the economic advantages of fusion reactors through reactor downsizing.



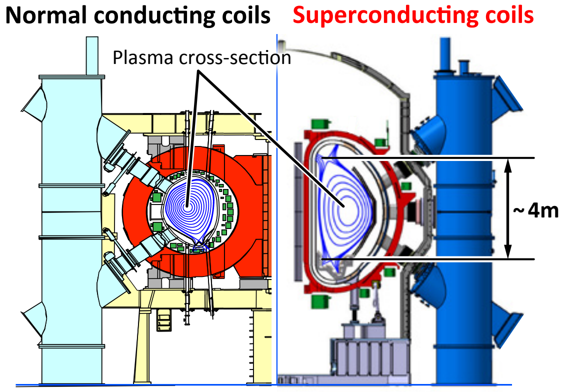
Large, Advanced Superconducting Tokamak for Stable Confinement of High Pressure Plasmas

Construction in Naka Fusion Institute
Optimized utilization of existing facilities
Components manufactured in Japan and EU



JT-60 ⇨ JT-60SA

Normal conducting coils — Superconducting coils



- Modification from a tokamak with normal conducting coils to one with superconducting coils
- Plasma cross-sectional shape suitable for sustaining a high-pressure plasma

Main Parameters of JT-60SA

Plasma Current	5.5 MA
Toroidal Magnetic Field	2.25 Tesla
Plasma Major Radius	3 m
Heating Power	40 MW × 100 sec
Weight of Tokamak Device	2600 tons

Radio-Frequency Resonance Heating System
Plasma heating device using electromagnetic waves in the electron cyclotron wave range

Neutral Beam Injector
Plasma heating device using high energy neutral beams

In-vessel Components
For control of high-pressure plasma:
- Passive stabilization by the surrounding conducting wall (stabilizing plate)
- Active stabilization using a wide variety of coils which produce offsetting magnetic fields based on detected plasma instabilities

Poloidal Field Coils
Superconducting coils for plasma production, positioning and shaping

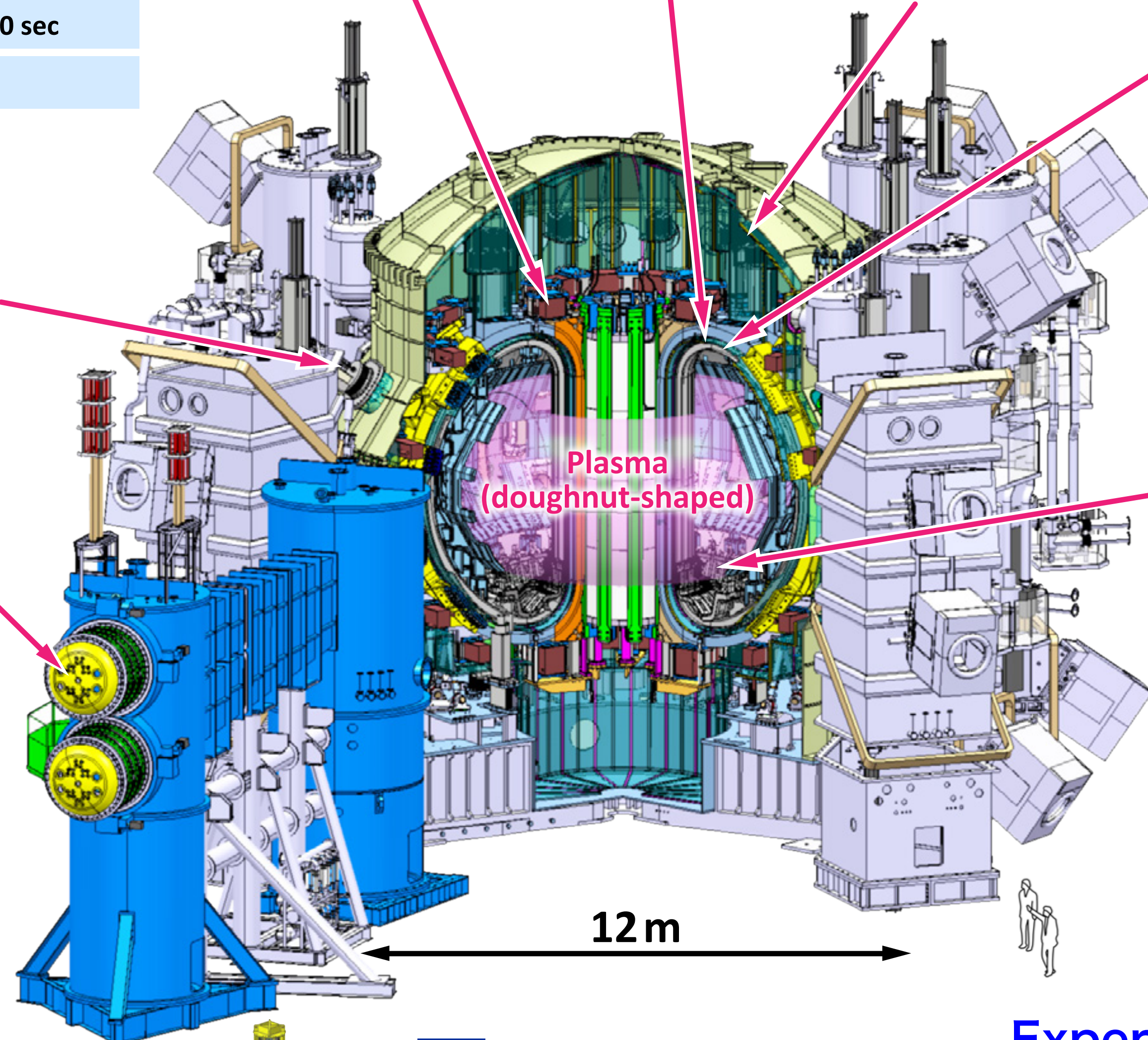
Toroidal Field Coils
Superconducting coils for confinement of the plasma

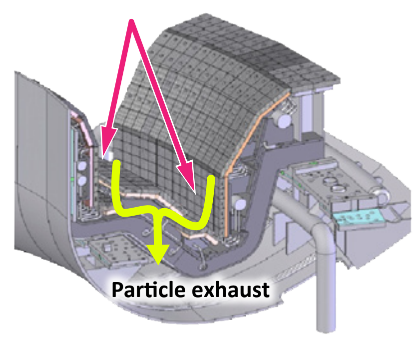
Cryostat
A large, stainless steel structure surrounding the vacuum vessel and superconducting magnets, providing a super-cool, vacuum environment

Vacuum Vessel
A doughnut-shaped vacuum chamber for production of high-purity plasmas by maintaining a stringent vacuum

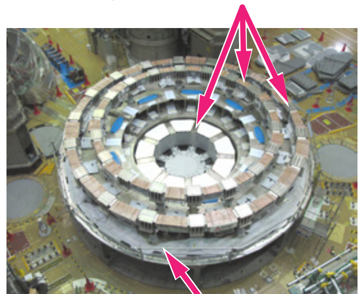
Diagnostics
Devices for measuring profiles of plasma density, temperature and neutron production

Divertor
Components for heat removal and exhaust of helium ash due to fusion reaction and impurities

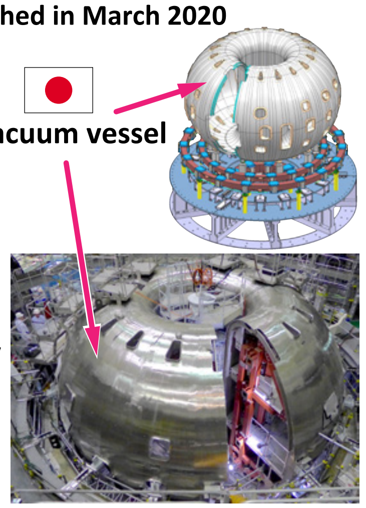


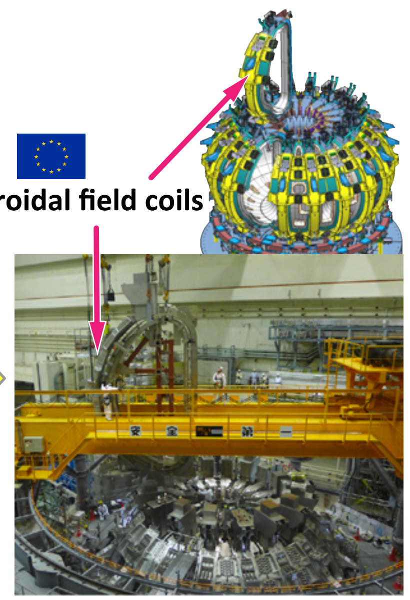


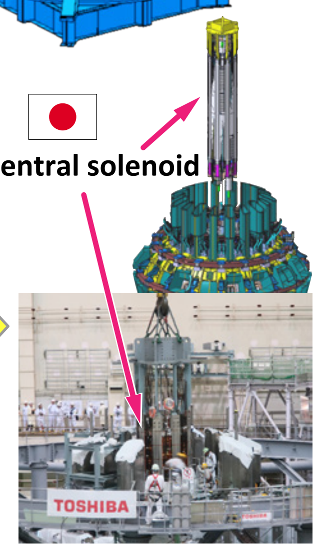
- Disassembly of JT-60 was completed in October 2012
- Assembly of JT-60SA was started in January 2013
- Assembly of JT-60SA was finished in March 2020

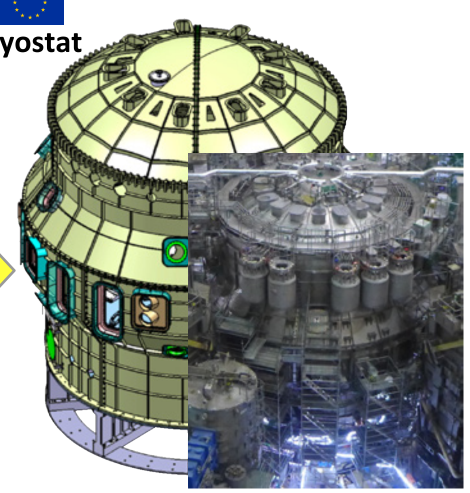


Assembly sequence

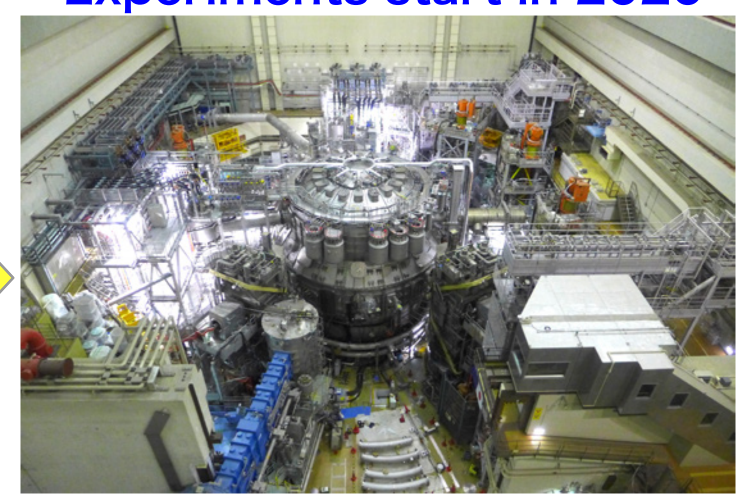








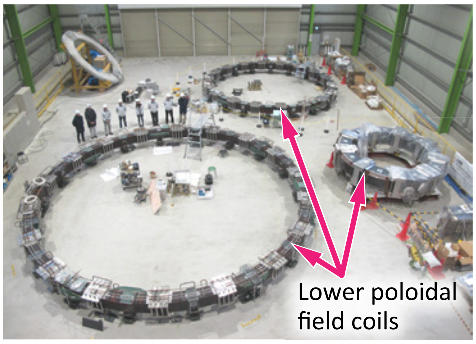
Experiments start in 2020



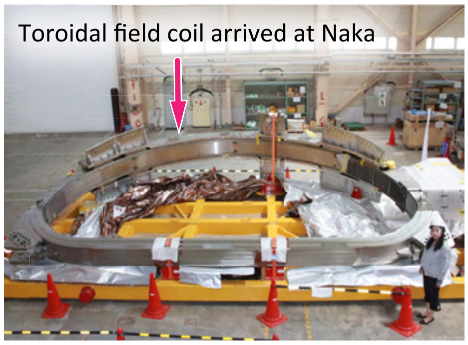
Synergy of technological development and physics research supporting JT-60SA

Manufacture of huge, superconducting magnets for confining high-temperature plasmas

Poloidal field coil (Japan)

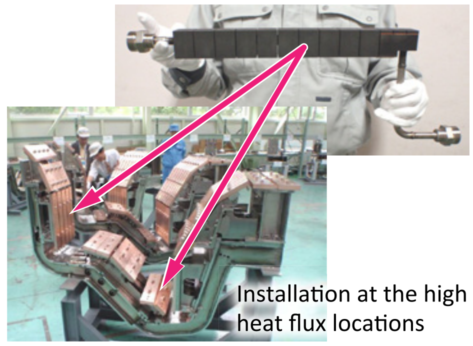


Toroidal field coil (EU)



Development of high heat-resistant components

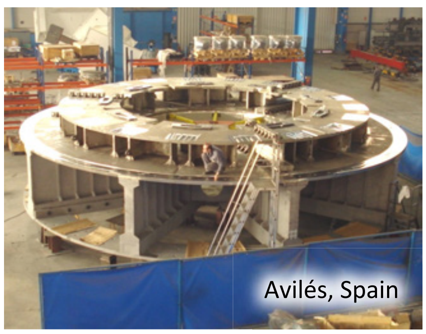
Heat resistance up to 15 MW/m^2 was demonstrated.



Manufacture of large components with high accuracy

Vacuum vessel (Japan)

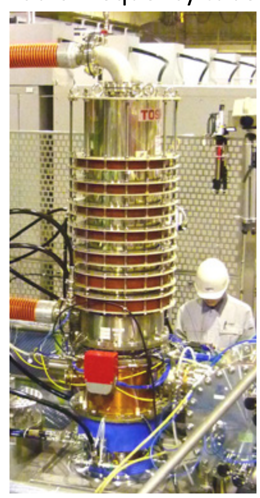
Cryostat base (EU)



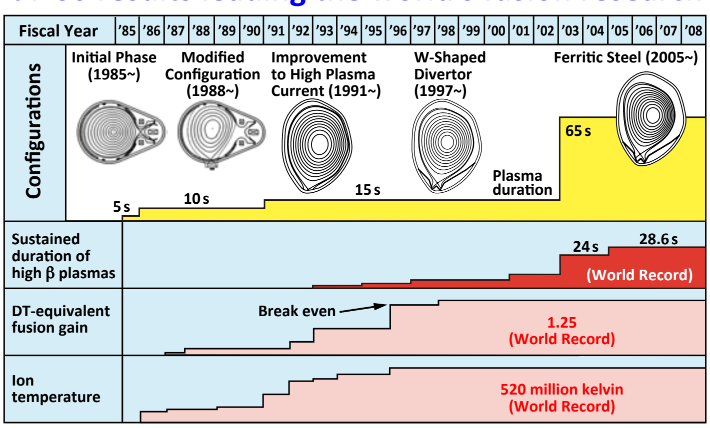
Development of systems for plasma heating to over 10 keV

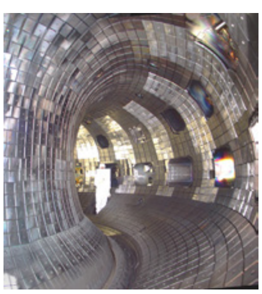
Neutral beam injector

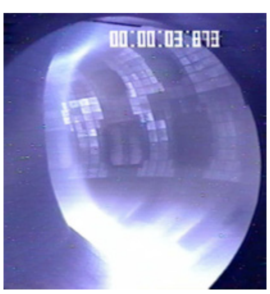
Radio-frequency tube



JT-60 results leading the world's fusion research



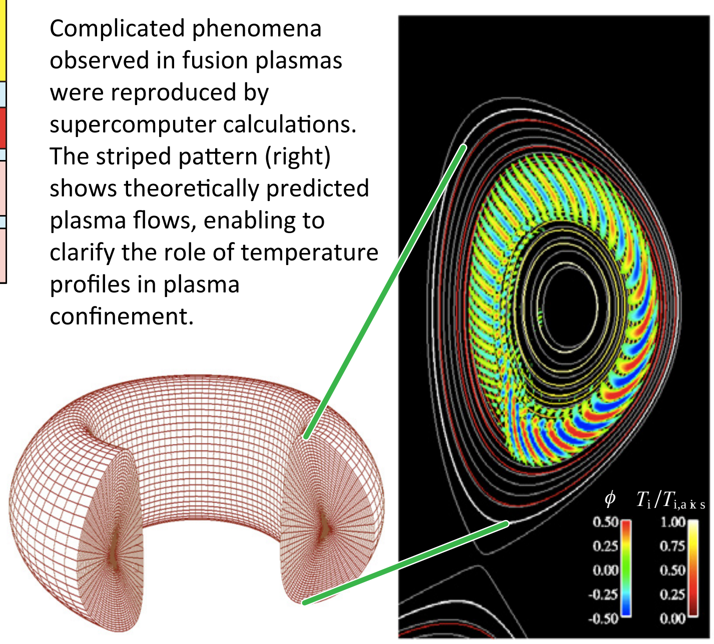




Inside of the JT-60U vacuum vessel during maintenance (left) and experiments (right)

Computational analyses of plasma behavior

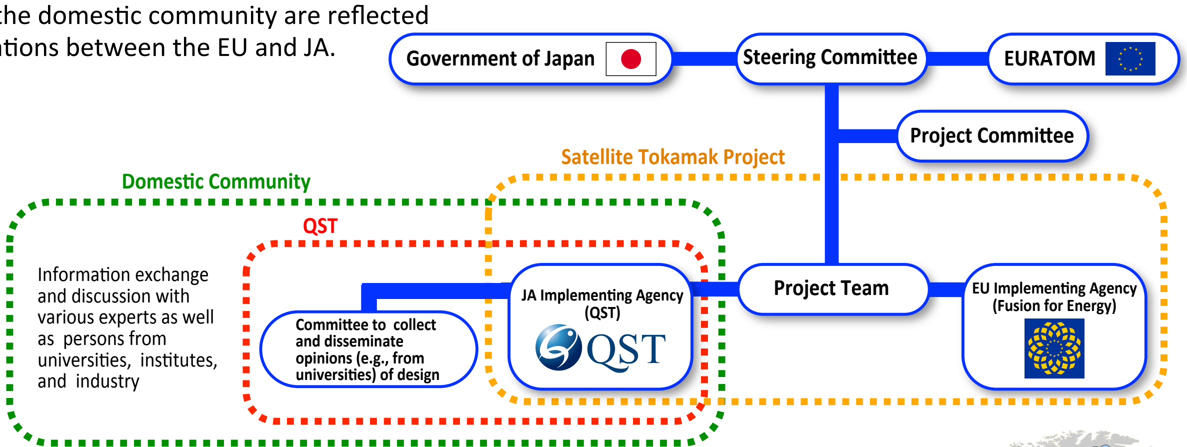
Complicated phenomena observed in fusion plasmas were reproduced by supercomputer calculations. The striped pattern (right) shows theoretically predicted plasma flows, enabling to clarify the role of temperature profiles in plasma confinement.



Center of Excellence for Domestic and Japan-Europe Collaboration on Fusion Research

Joint management by Japan and Europe

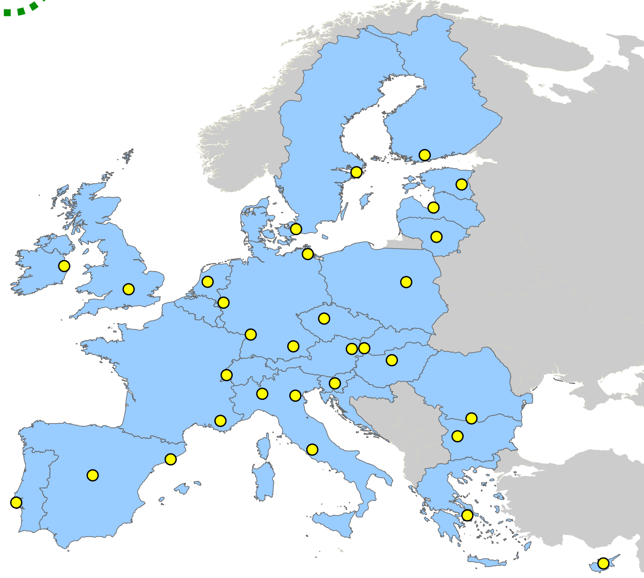
The JT-60SA project is a joint endeavor of the ITER Satellite Tokamak Program, part of the JA-EU Broader Approach, and the Japanese national program. The work program, approved by the steering committee formed by the governments of JA and EU, directs the JA and EU Implementing Agencies collaboratively to share responsibility for manufacturing components. Views of the domestic community are reflected in negotiations between the EU and JA.

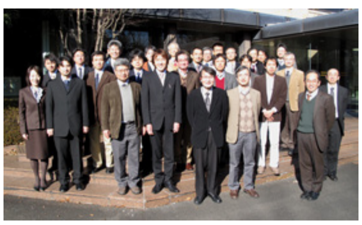


Development of JT-60SA Research Plan

More than 400 researchers in Japan and Europe, mainly young researchers who are in charge of experiments on JT-60SA and ITER, are formulating the JT-60SA Research Plan for ITER and DEMO.

Ver. 4.0 was completed in September 2018 by 435 coauthors : 174 from 18 research institutes including universities in Japan, and 261 from 33 research institutes in 14 countries in EU.





Domestic community

Naka Fusion Institute

EU-Japan Technical Coordination Meeting

National Institutes for Quantum and Radiological Science and Technology

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Photos of EU facility/component on page 5: Courtesy of F4E

Photos on front page: the Sun (NASA), M83 (Courtesy of Dr. K. Okano)

January 2021