Role of JT60SA in Fusion Development

S. Ide for the JT-60SA Team
QST: National Institutes for Quantum and Radiological Science and Technology

FUSION POWER ASSOCIATES
37th ANNUAL MEETING AND SYMPOSIUM
13-14, December 2016
HYATT REGENCY CAPITOL HILL HOTEL, Washington DC, USA

JT-60SA, the Project

The mission of the JT-60SA project is to contribute to the early realization of fusion energy to support the exploitation of ITER and research towards DEMO, by addressing key physics issues for ITER and DEMO.

Conducted under both the ITER Satellite Tokamak Program in Broader Approach agreement between JA and EU and the Japanese national programme.

Three main objectives of the project

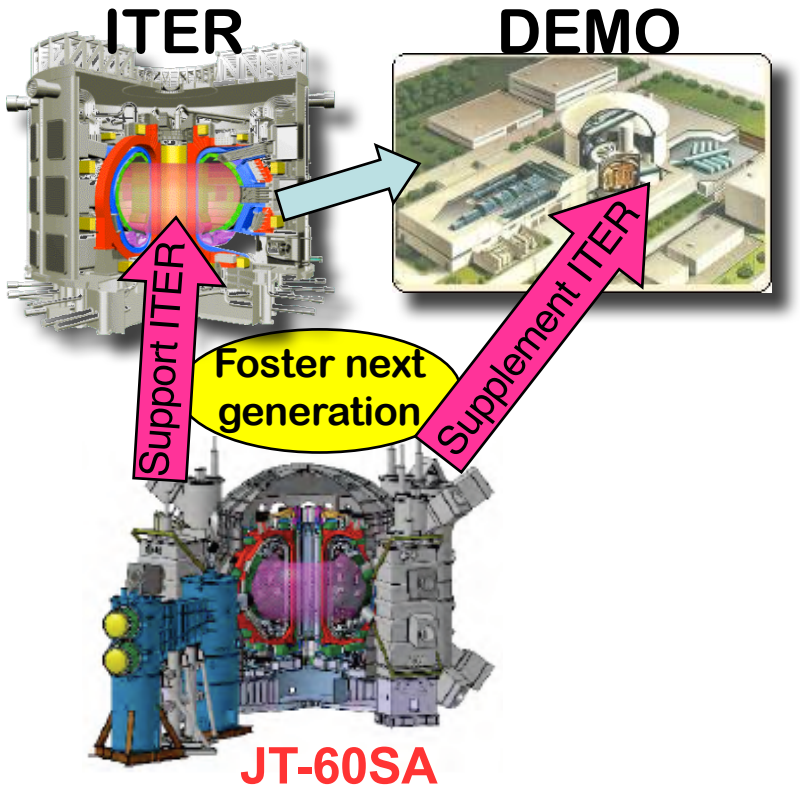
- **Support ITER**

  using break-even-equivalent class high-temperature deuterium plasmas lasting for a duration (typically 100 s) for optimization of ITER operation scenarios.

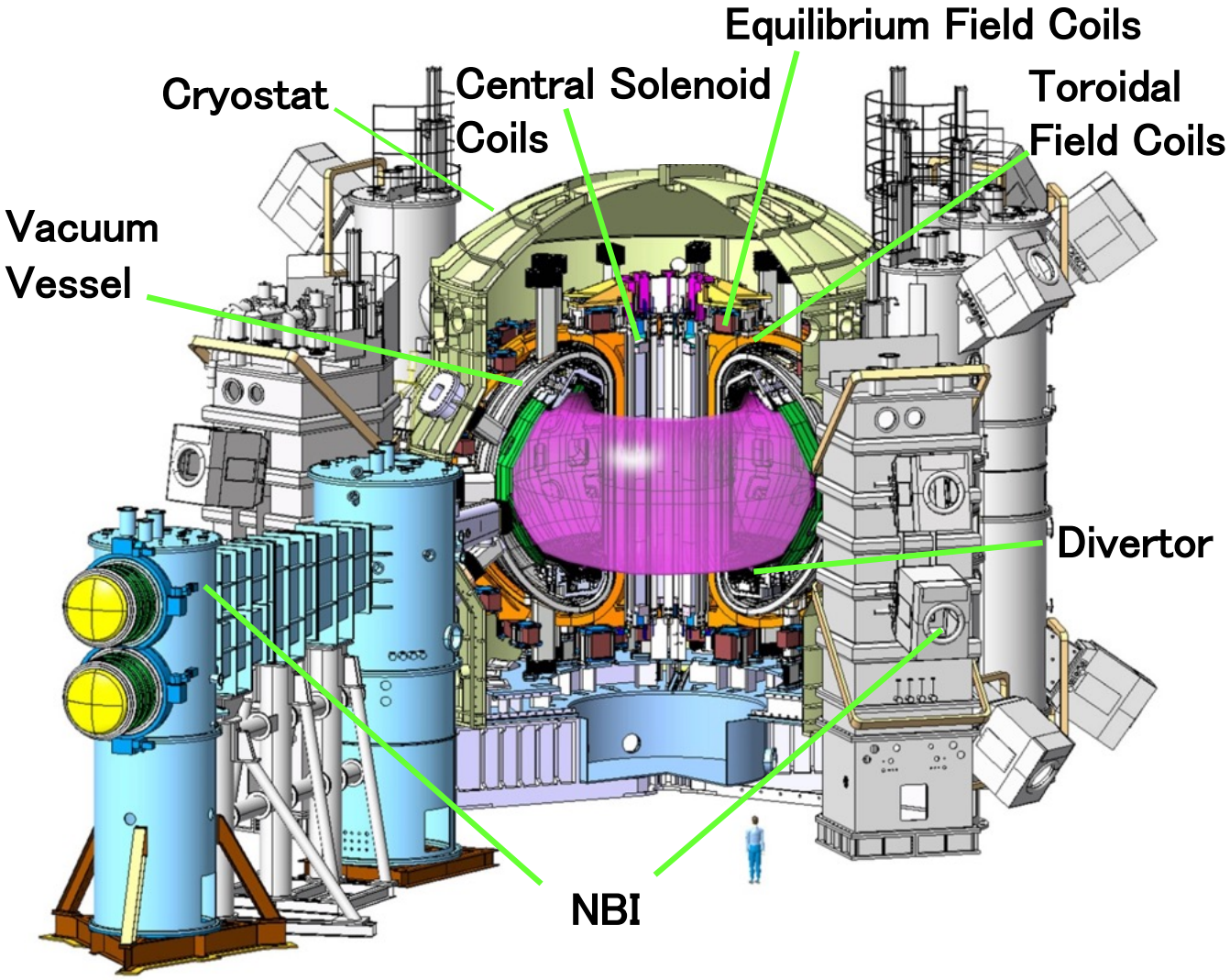
- **Supplement ITER towards DEMO**

  with long sustainment (~100 s) of high pressure plasmas necessary in DEMO for establishment of DEMO operation scenarios.

- **Foster the next generation for ITER & DEMO**



Major parameters of JT-60SA

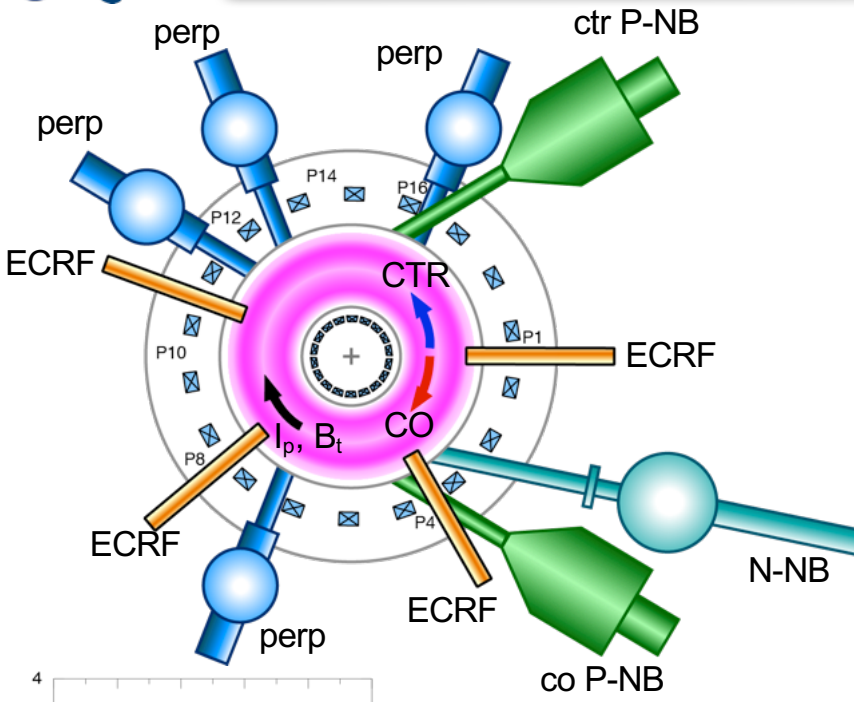


Plasma Current I_p	5.5MA
Toroidal Field B_t	2.25T
Major Radius R_p	2.97m
Minor Radius a_p	1.18m
Elongation κ_x	1.93
Triangularity δ_x	0.5
Safety Factor q_{95}	3
Plasma Volume V_p	133m^3
Flat Top	100 s

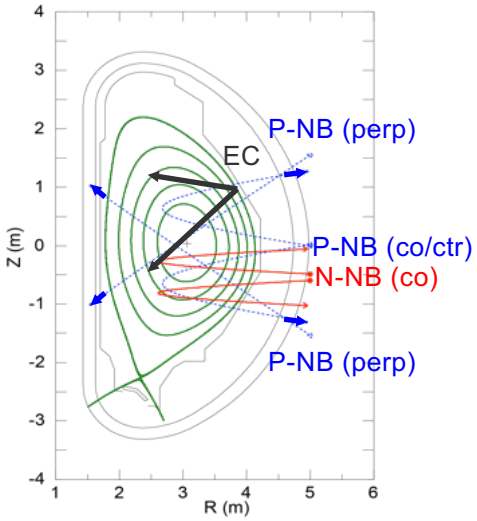
super conducting coils

Toroidal Field Coil	NbTi
Equilibrium Field Coil	NbTi
Central Solenoid Coil	Nb_3Sn

The heating and current drive systems



NB (14 units)		ECRF
N-NB: 500keV	P-NB: 85keV	(9 gyrotrons)
cox2 10MW	cox2 4MW ctrx2 4MW perpx8 16MW	7 MW 110 & 138 GHz (dual frequencies)
functions: heating (N-NB: more electron heating, P-NB: more ion heating) current drive toroidal torque drive fueling		functions: heating (pure electron heating) current drive
total 41 MW, duration 100s		



- Variety in NB injection (direction, energy) maintained from JT-60U ⇒ Energy, Current and Torque control
- N-NB = the main Current Driver
- ECRF by dual frequency gyrotron ⇒ flexibility for various B_t

JT-60SA is a flexible 'Test Stand' for ITER

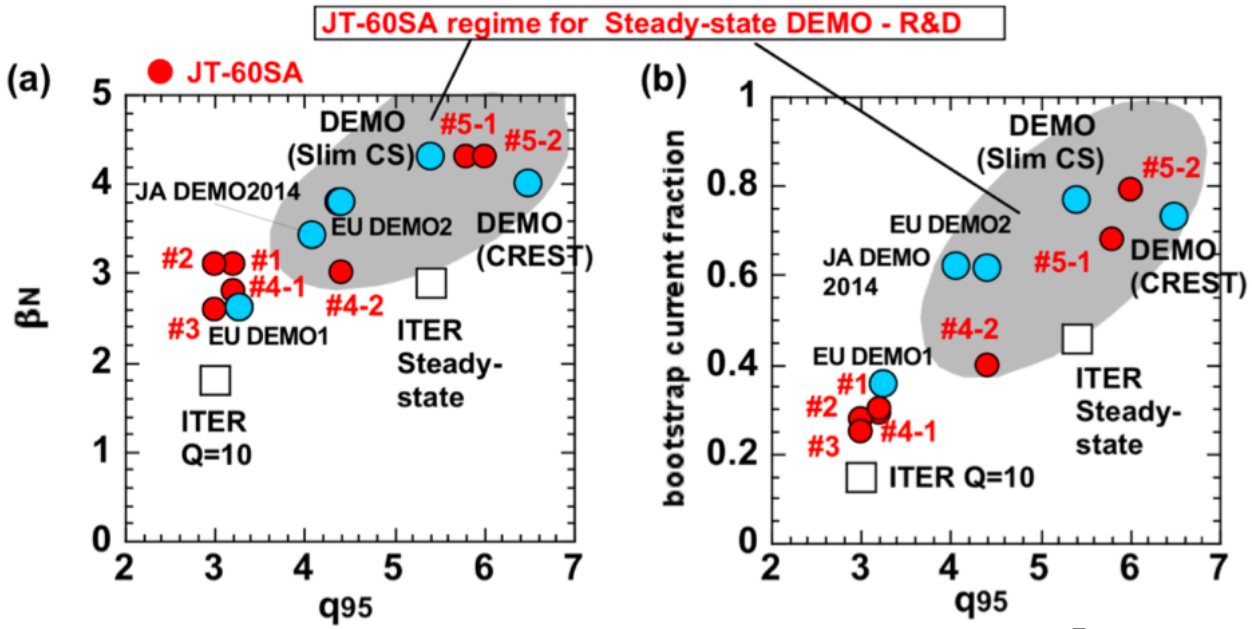
Having ITER like non-dimensional parameters, ITER like conditions: small-torque input, electron heating, … and ITER like shaped divertor, JT-60SA is a flexible Test Stand for ITER in eg.;

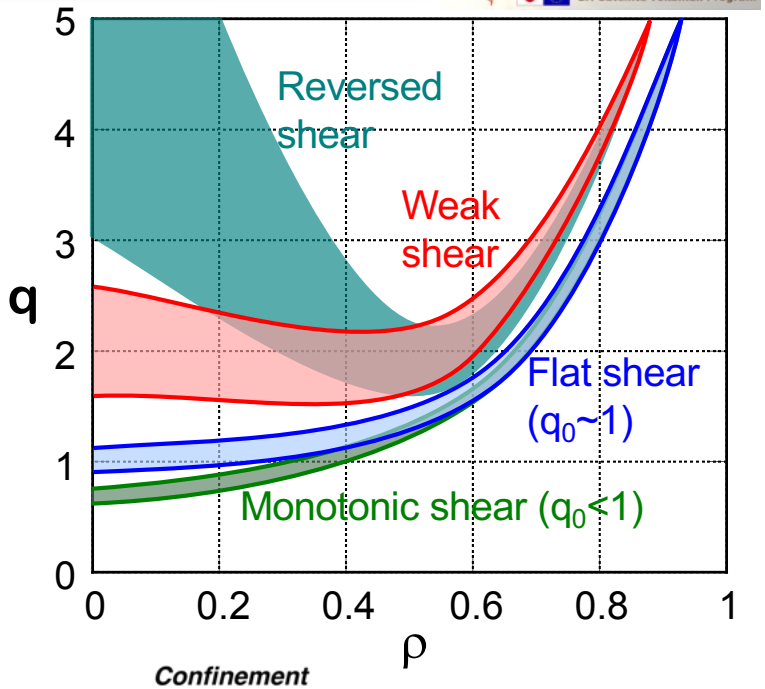
- H-mode operations (H, He, D) towards Q=10, @ Ip ~ 5.5 MA
- MHD stability at small ~ zero rotation
- Improved H-mode (Hybrid) Operation with ITER-like shape @ Ip ~ 4 MA
- ELM mitigation (RMP, pellet pacing, …) & small / no ELM regime at low-ν^*
- Disruption avoidance & mitigation R&D at high current (tests of MGI, SPI etc.)
- Divertor Heat Load reduction with ITER-like-shaped divertor & Steady-State
- Effects of Error Field / noise
- Integrated Operation scenario optimization with superconducting PF coils.
- High Energy particle physics at ITER-relevant conditions using 500 keV N-NB
- Operation Experience of the large superconducting tokamak

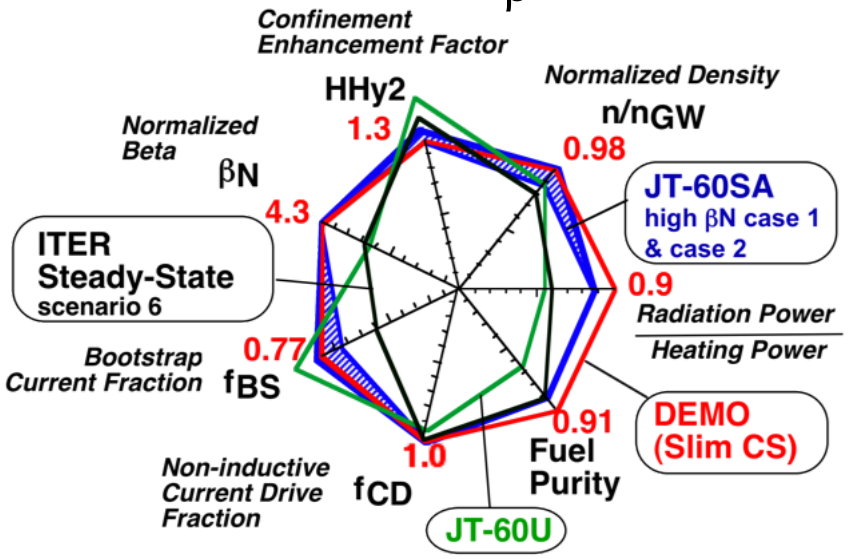
JT-60SA Research Regime for DEMO

Goal of JT-60SA: 'Simultaneous & steady-state sustainment of the key performances required for DEMO' (= highly self regulating)

- JT-60SA should decide the practically acceptable DEMO parameters, and develop & demonstrate a practical set of DEMO plasma controls.







Research Phases of JT-60SA:

Full Metal Wall from ~2028 is under investigation

	Phase	Expected Duration		Annual Neutron Limit	Remote Handling	Divertor	P-NB 85keV	N-NB 500keV	ECRF 110 GHz & 138GHz	Max Power	Power x Time
Initial Research Phase	phase I	1-2y	H	-	R&D	LSN partial-monoblock Carbon Div.Pumping	10MW	10MW	1.5MW x100s + 1.5MW x5s	23MW	NB: 20MW x 100s 30MW x 60s duty = 1/30 ECRF: 100s
	phase II	2-3y	D	4E19			Perp. 13MW Tang. 7MW			33MW	
Integrated Research Phase	phase I	2-3y	D	4E20		LSN full-monoblock Carbon Div. Pumping			7MW	37MW	
	phase II	>2y	D	1E21	Use						
Extended Research Phase		>5y	D	1.5E21		DN/SN full-monoblock Metal or Carbon Advanced Structure	24MW			41MW	41MW x 100s

ITER H / He heating exp.

Possibility of W-coated full monoblock CFC (partially bulk W) divertor + full W-coated first wall + fully water-cooled installation ~2028

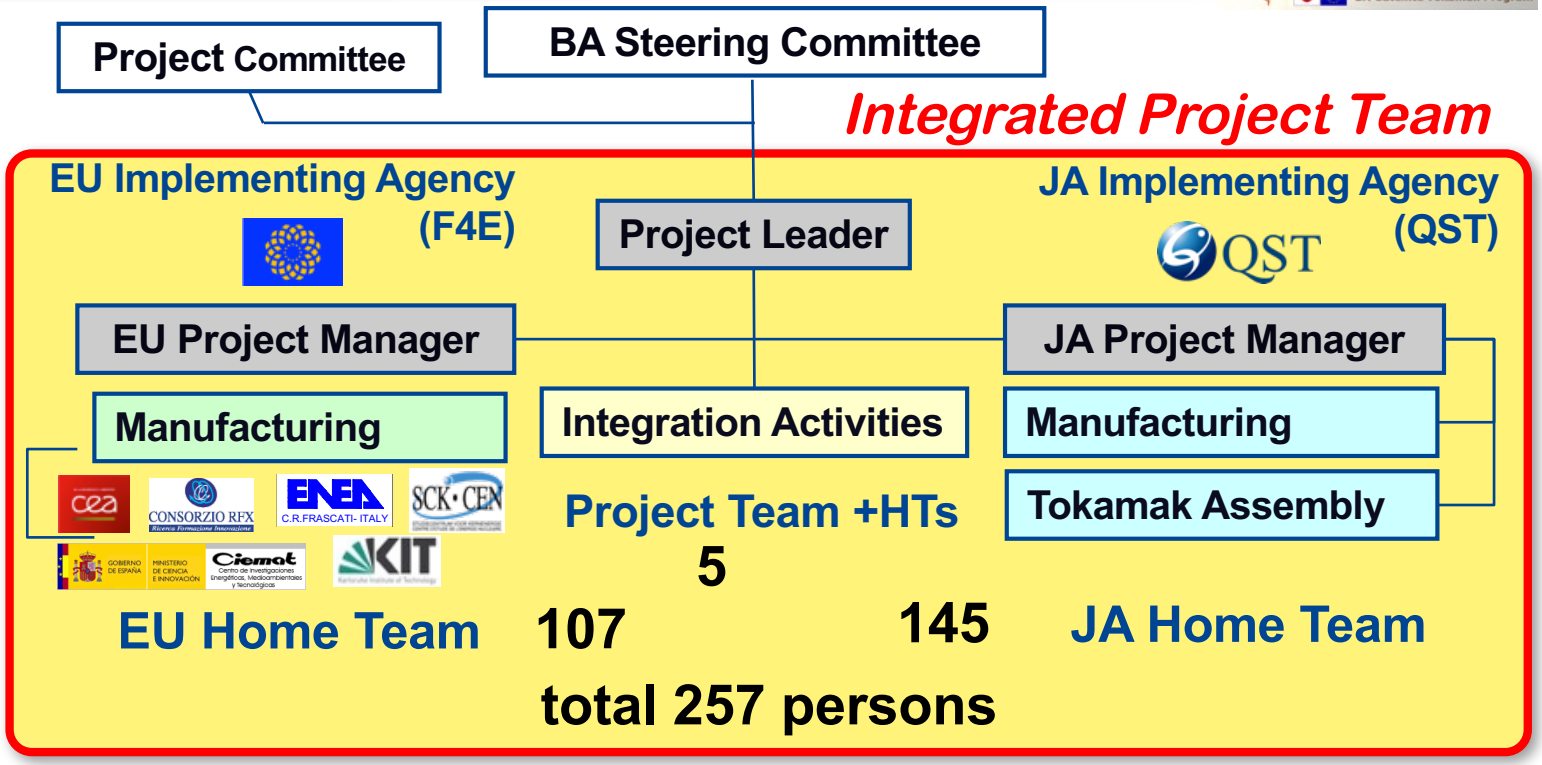
Partially W (or W-coated CFC) divertor tiles.

The JT-60SA Integrated Project Team

Project Coordination Meeting (PCM):
Remote meeting
176 times
(every 2-3 weeks)

Technical Coordination Meeting (TCM):
Face to Face meeting
26 times
(~ 3 times / year)

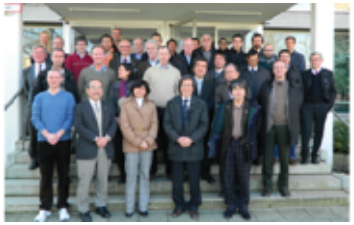
Research Coordination Meeting (RCM):
Face to Face meeting
5 times
(since 2011, every year)



TCM-15 (Padva, Sep. 2012)

TCM-17 (Grenoble, May. 2013)

TCM-19 (Garching,Feb. 2014)

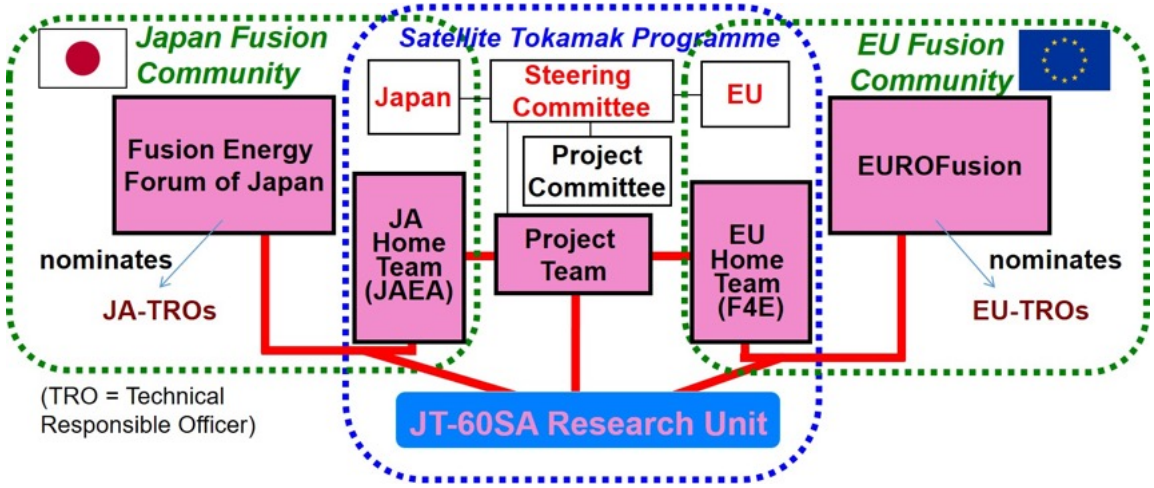


TCM-21 (Saclay, Nov. 2014)

JT-60SA Research Unit

JA and EU fusion community members join "JT-60SA Research Unit" to study key physics and engineering issues of ITER and DEMO.

5th. EU&JA Research Coordination Meeting
(May 2016, Naka)



JT-60SA Research Plan (ver. 3.3) written by 378 authors from JA/EU was open to public in March 2016.

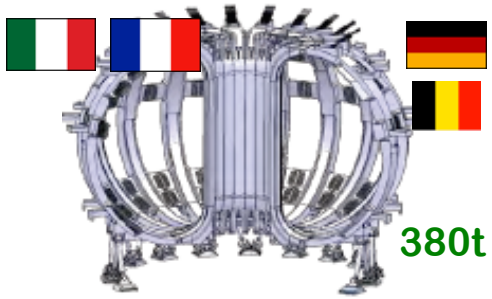
EU diagnostics: EDICAM (camera), etc.

http://www.jt60sa.org/pdfs/JT-60SA_Res_Plan.pdf

International collaboration is open

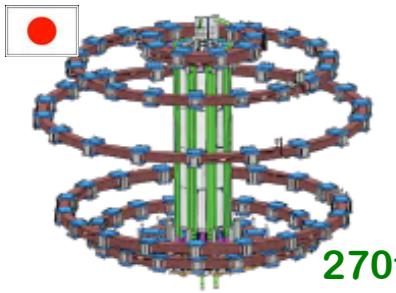
- International collaboration with third parties
  - *Party – level* collaboration: In order to join the JT-60SA project as a party, its integrated contribution shall be approximately the same as that of EU. The process to accept this level of collaboration follows Article 25 of the BA Agreement (ref.3)
  - *Institute – level* collaboration: This category includes in-kind contributions, such as specific components, equipments, materials and other goods and services, and financial contributions. For these collaborations, the procedure follows the 'Guidelines on participation of other ITER Parties in Broader Approach Activities at the level of Research Institutes'.
  - *Researcher-level* collaboration: The JT-60SA team is collaborating with teams of other devices or institutes by exchanging researchers. The inter-machine experiments and code-benchmarking under the ITPA are included.
- US: Ongoing discussion of possible Institute-level diagnostic collaboration, which QST/JT-60SA supports.

JA and EU share manufacture of JT-60SA components



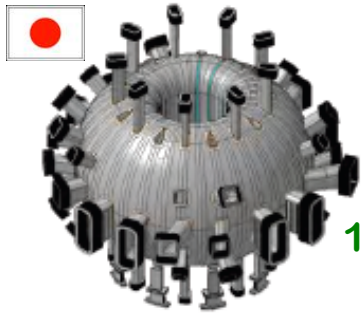
380t

Toroidal Field Coils



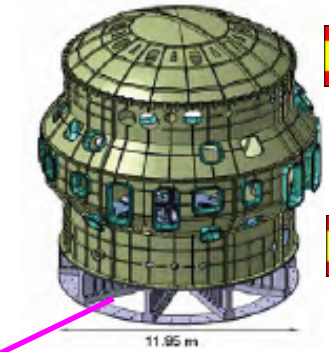
270t

Poloidal Field Coils



150t

Vacuum Vessel



440t

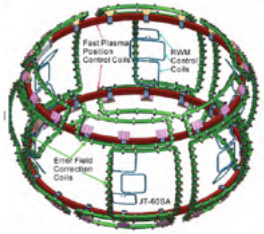
Cryostat Body

260t

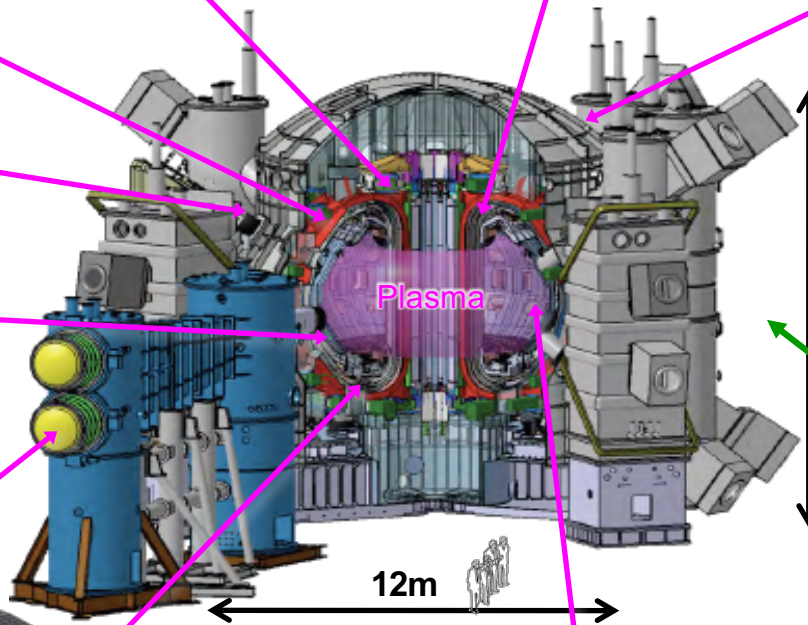
Cryostat Base

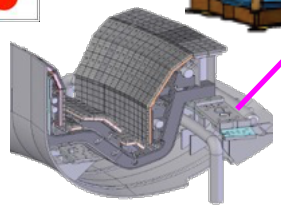
Electron Cyclotron Range of Frequency System

In-vessel Components



Neutral Beam System



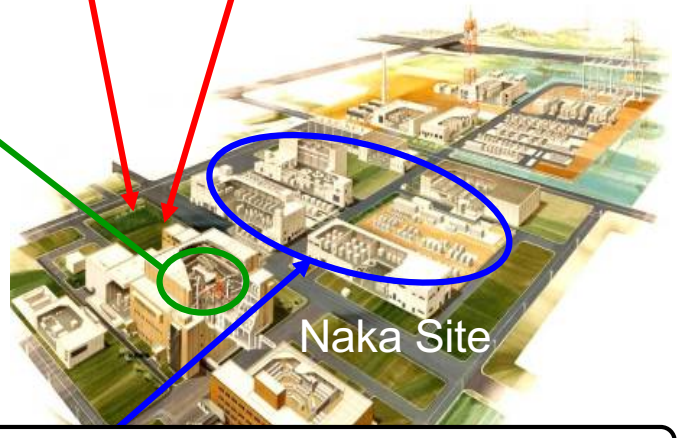


Divertor

Plasma Diagnostics

Compressor Building

Cryogenic System

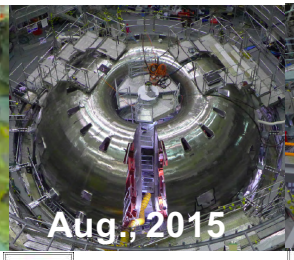


Power Supplies

JT-60SA Project is in full assembly phase

Cryostat Base

Lower Poloidal Field Coils



Vacuum Vessel

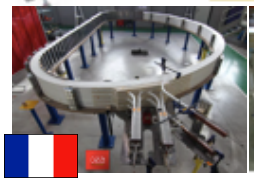
VV thermal shield

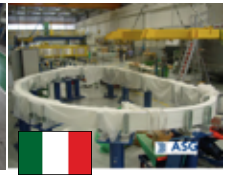
TF Coils

Upper Poloidal Field Coils and Central Solenoid

Cryostat

TF Coil Cold Test Facility

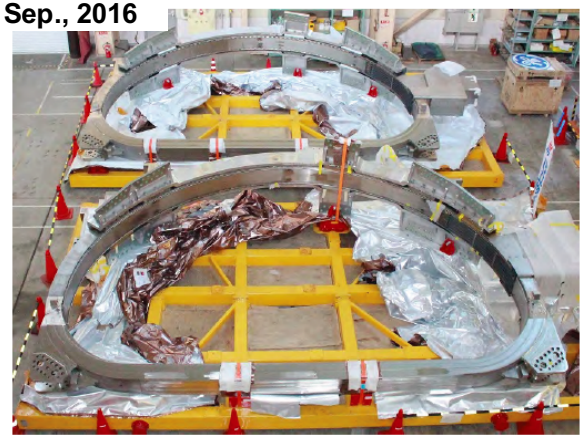




Current Lead

TF Coils

Sep., 2016

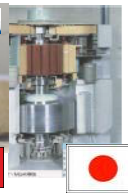


Start Operation 2019

power supplies

QPC

MG-set



SCMP

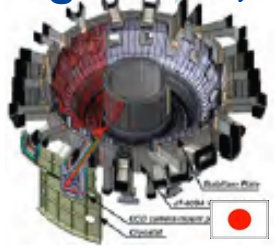
SN

cryoplant

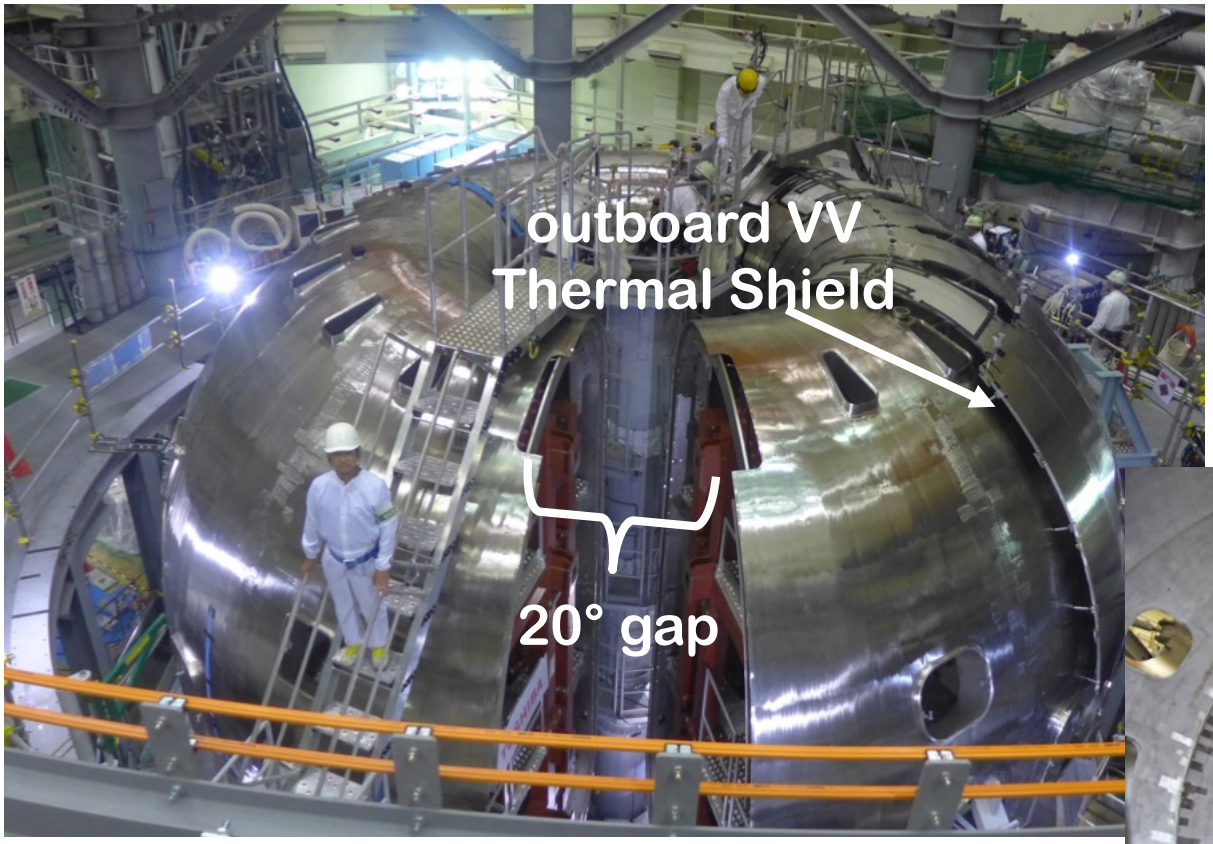
NBI

ECRF

diagnostics, etc

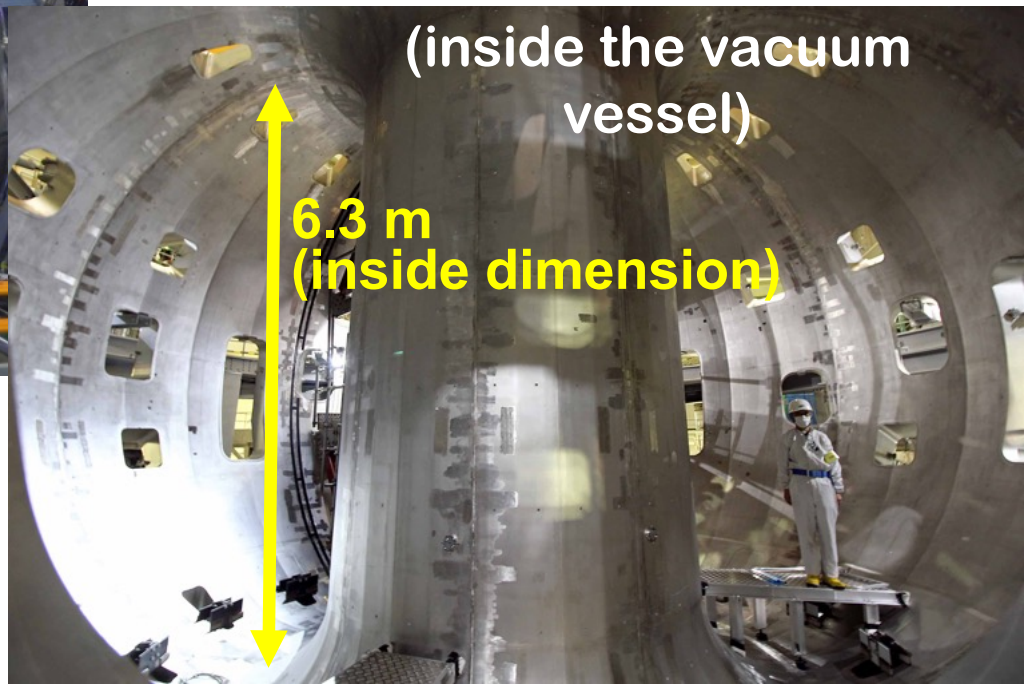


Vacuum Vessel completed up to 340°



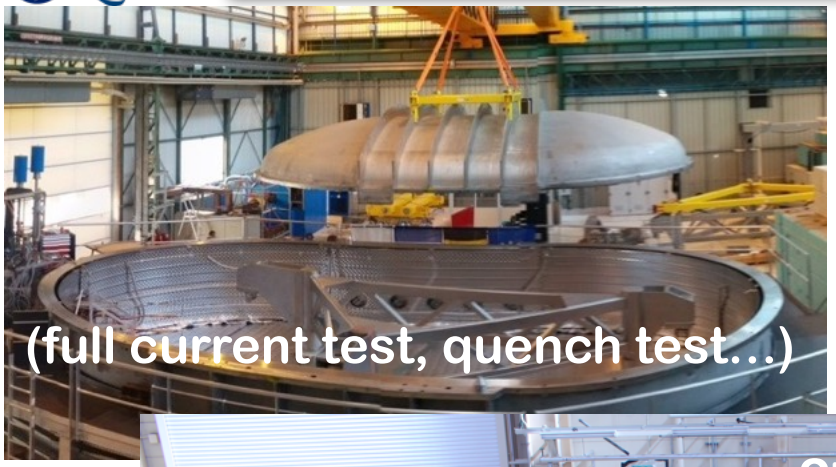
High dimensional accuracy was achieved by careful welding work.

	requirement	achieved
horizontal	≤ ±30 mm	±5 mm
vertical	≤ +6/-4 mm	-4 mm



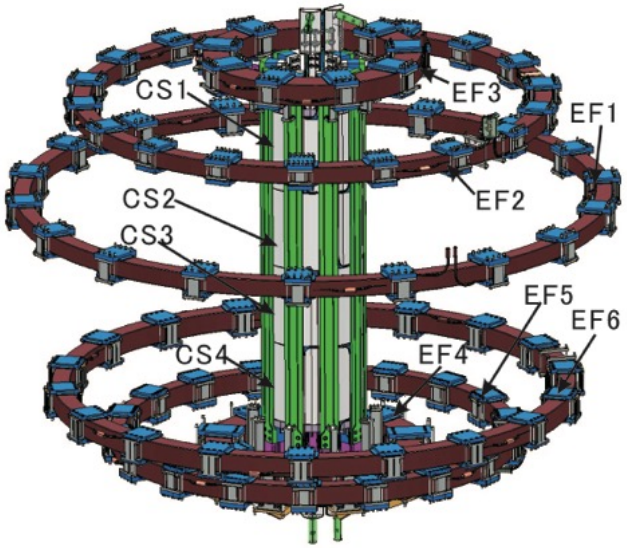
20° gap is to install TF coils.

Three TF coils now in Naka Site



All coils tested at cryogenic temperature at CEA Saclay.

Manufacturing of EF coils was successfully finished with very high accuracy.



	diameter	requirement	Achieved
EF1	12.0m	≤ 8 mm	0.3 mm
EF2	9.6m	≤ 7 mm	0.4 mm
EF3	4.4m	≤ 6 mm	0.2 mm
EF4	4.4m	≤ 6 mm	0.6 mm
EF5	8.1m	≤ 7 mm	0.6 mm
EF6	10.4m	≤ 8 mm	1.3 mm

Deviation of current center from exact circle

Summary

- JT-60SA project is advancing with objectives:
  - Support ITER
  - Supplement ITER towards DEMO
  - Foster the next generation for ITER & DEMO

- Collaboration is open for the third parties.

- Construction at Naka site is progressing towards operation starting 2019.
  - Vacuum Vessel is formed up to 340°.
  - Three TF coils are already at the site. Installation of the 1st TF starts soon.
  - Other components, both tokamak and facilities, are also getting ready.