Next steps after the integrated commissioning in JT-60SA and participation in the experiment team

J. Garcia on behalf of the JT-60SA Experiment Team Leaders

Contents

JT-60SA
Advanced Superconducting Tokamak
BA-Satellite Tokamak Program

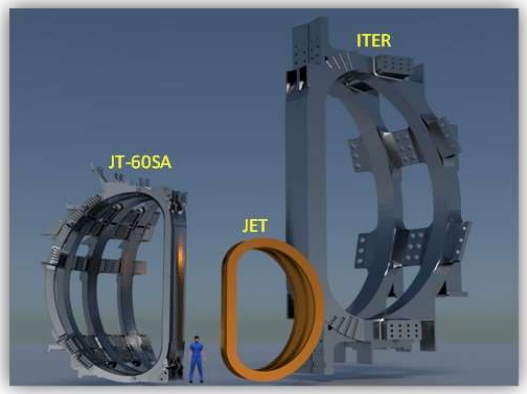
1. Mission of JT-60SA
2. Experiment team organization
3. Scientific priorities and call for participation
4. Conclusions

Contents

JT-60SA Project for ITER and DEMO

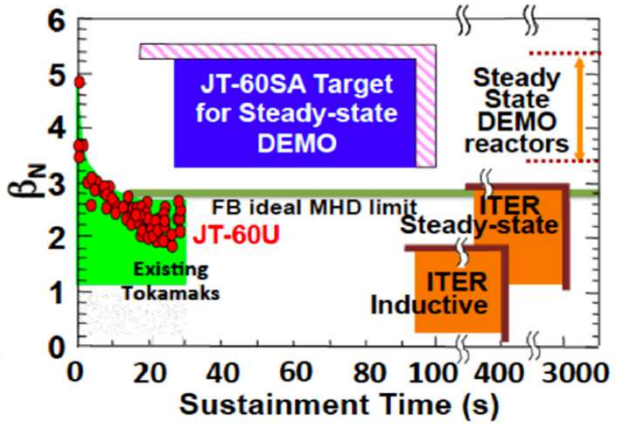
JT-60SA:

- Large superconducting: R_P~3.0 m, a_P~1.2 m
- High plasma current: I_P/B_T=5.5 MA/2.3 T
- High power and long pulse: 41 MW × 100 s
- Highly shaped: $S=q_{95}I_P/(a_PB_T)$ ~7, A~2.7, k_x ~1.9, d_x ~0.5

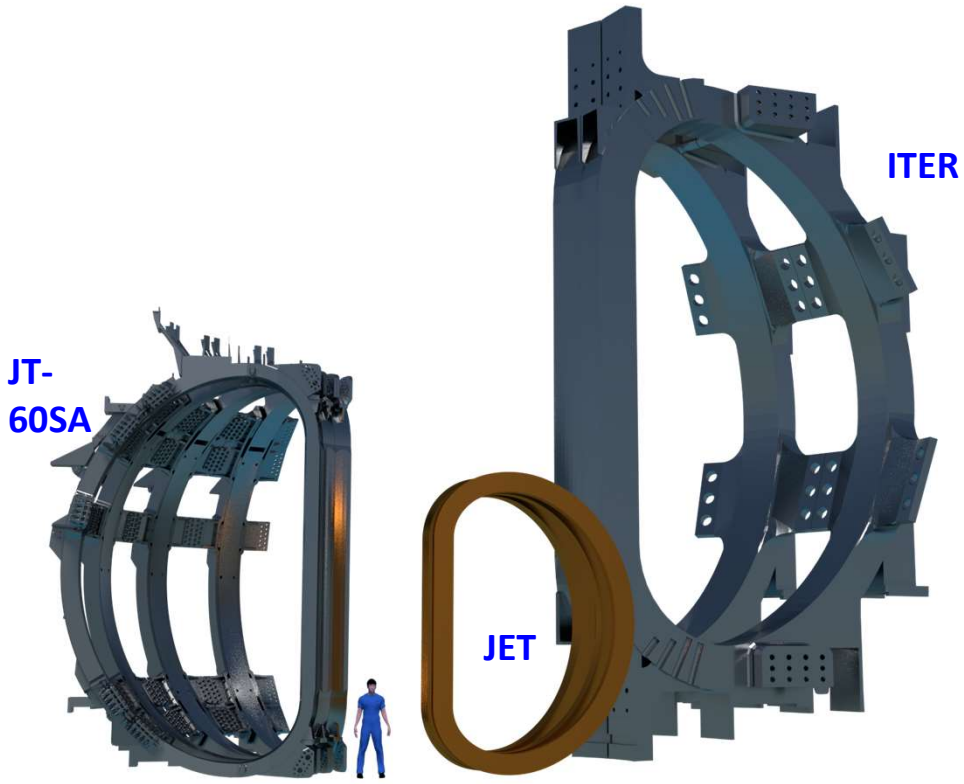


Mission:

- Contribute to the early realization of fusion energy by addressing key physics issues for ITER and DEMO
- Aim at fully non-inductive steady-state high β_N operations above the no-wall ideal MHD stability limits, for long time (~3-4t_R)



JT-60SA: big step beyond JET towards ITER

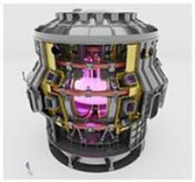


- JT-60SA is the **largest** tokamak before ITER
- JT-60SA represents an intermediate step between JET and ITER

JT-60SA: big step beyond JET towards DEMO

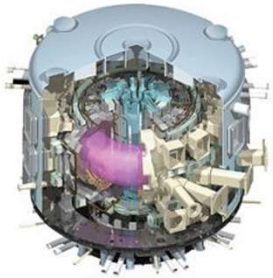
JET

80 m^3



JT-60SA

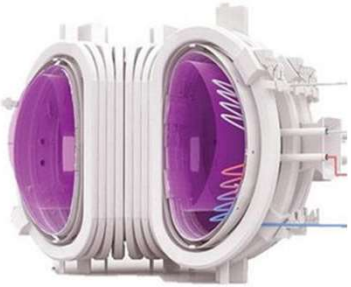
135 m^3



ITER

800 m^3

(one-third the size of an Olympic swimming pool)



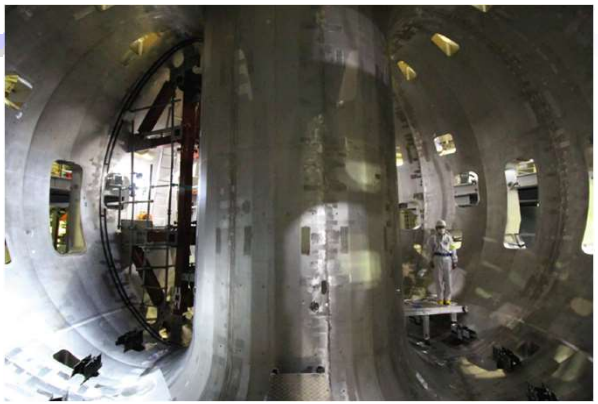
DEMO

~ 1000 – 3500 m^3

(half to one and a half times the size of an Olympic swimming pool)

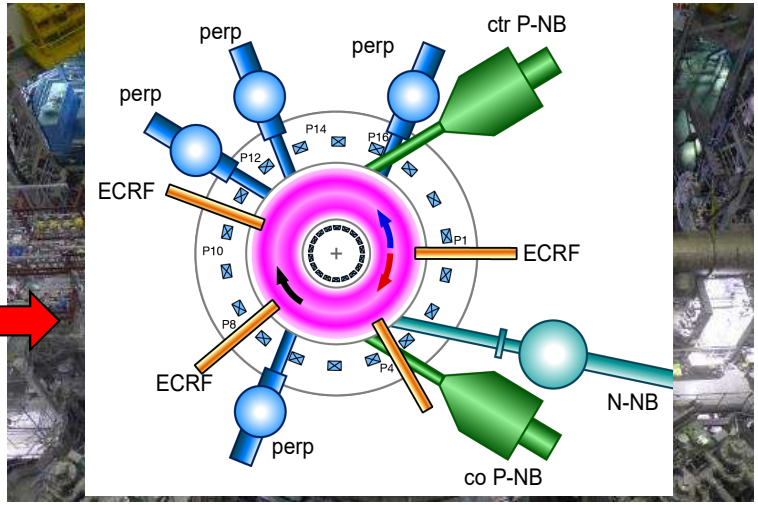
- JT-60SA is the **largest** tokamak before ITER
- JT-60SA represents an intermediate step between JET and ITER
- Unlike JET, JT-60SA can address long pulse sustained operation
- Continuous operation is necessary for DEMO

The JT-60SA tokamak

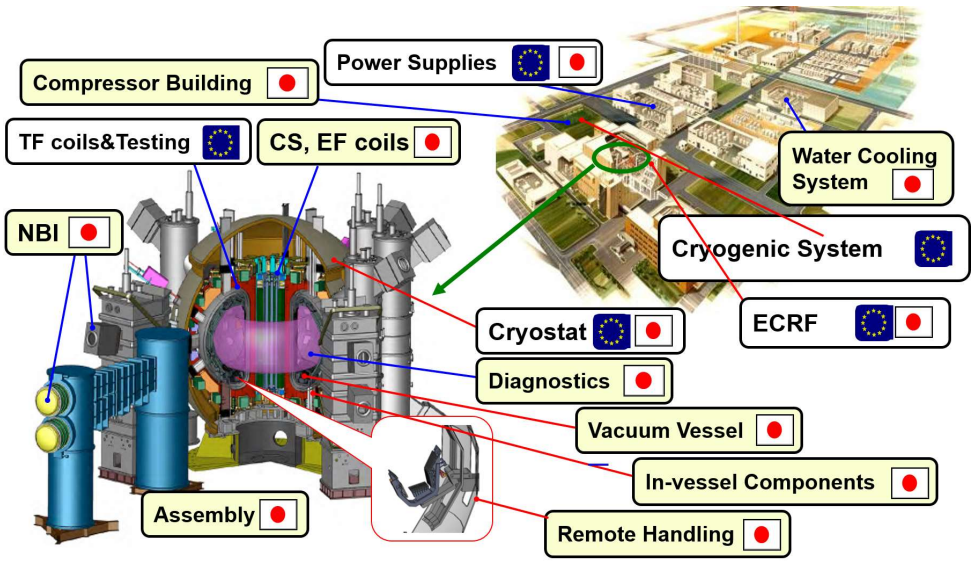


- Designed and built **jointly** by **Japan** and **EU** at the Naka site under the Broader Approach agreement
- Fully **superconducting**, high **current**, highly **shaped**
- **High input power flexibility**
- **Jointly exploited** by Japan and EU

B_t	**2.25 T**
I_p	**5.5 MA**
R / a (A = 2.5)	**2.96 / 1.18 m**
κ / δ	**1.93 / 0.5**
t (flat-top)	**100 s**
N-NBI (500 keV)	**10 MW**
P-NBI (85 keV)	**24 MW**
ECRH (82, 110, 138 GHz)	**7 MW**

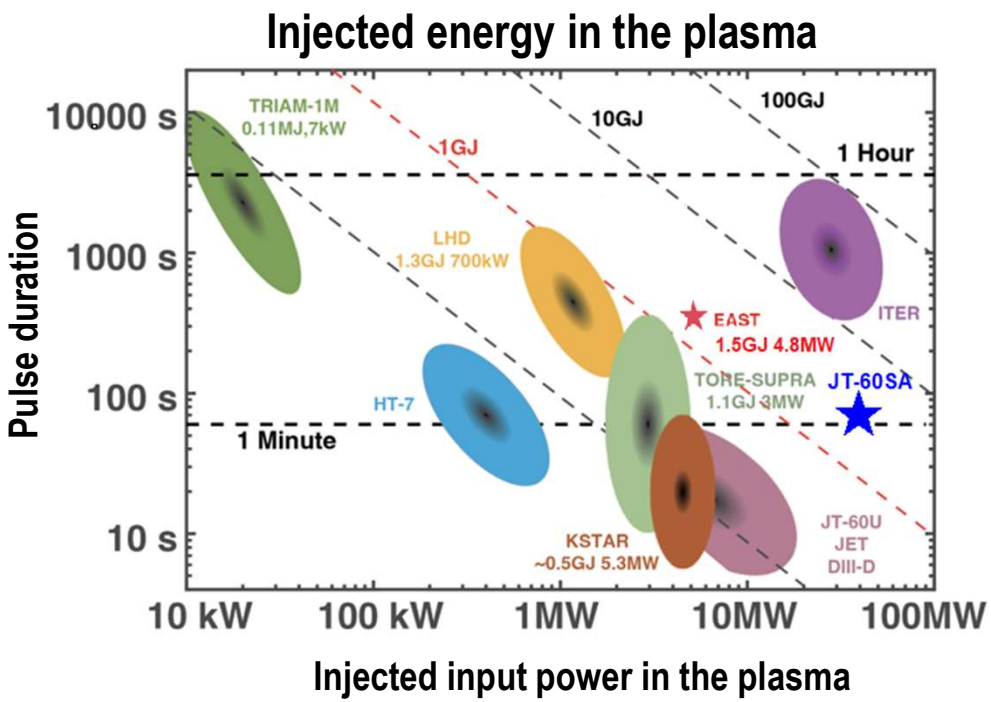


JT-60SA: A technological challenge



- JT-60SA operation requires cutting-edge technology:
  - Precise large machine assembly
  - Cryogenic systems
  - 500 keV N-NBI
  - Remote Handling

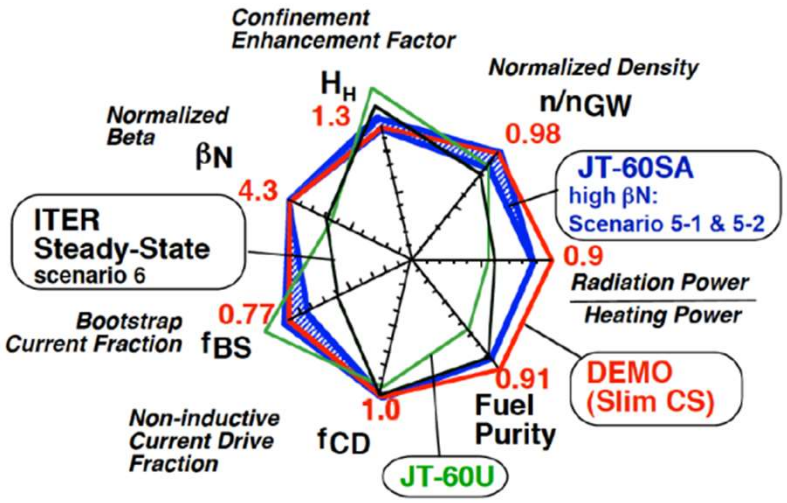
JT-60SA: A technological challenge



- JT-60SA operation requires cutting-edge technology:
  - Precise large machine assembly
  - Cryogenic systems
  - 500 keV N-NBI
  - Remote Handling
- Unexplored technological space:

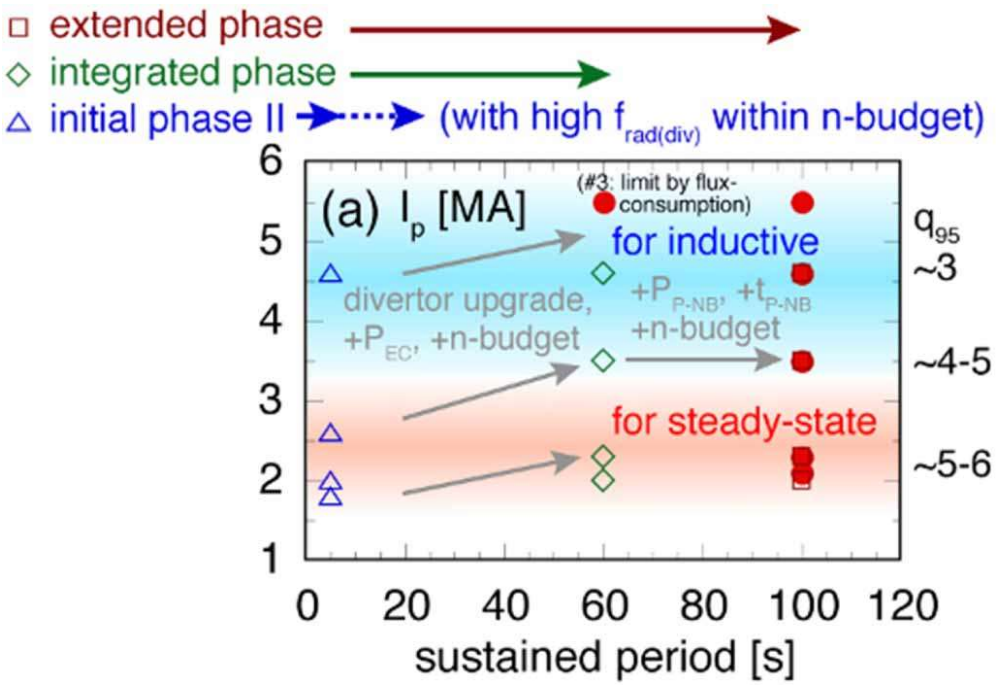
  Closing the gap with ITER

JT-60SA: A scientific challenge



- JT-60SA aims at DEMO and ITER normalized plasma parameters
  - High: beta, non-inductive current fraction, normalized density, confinement

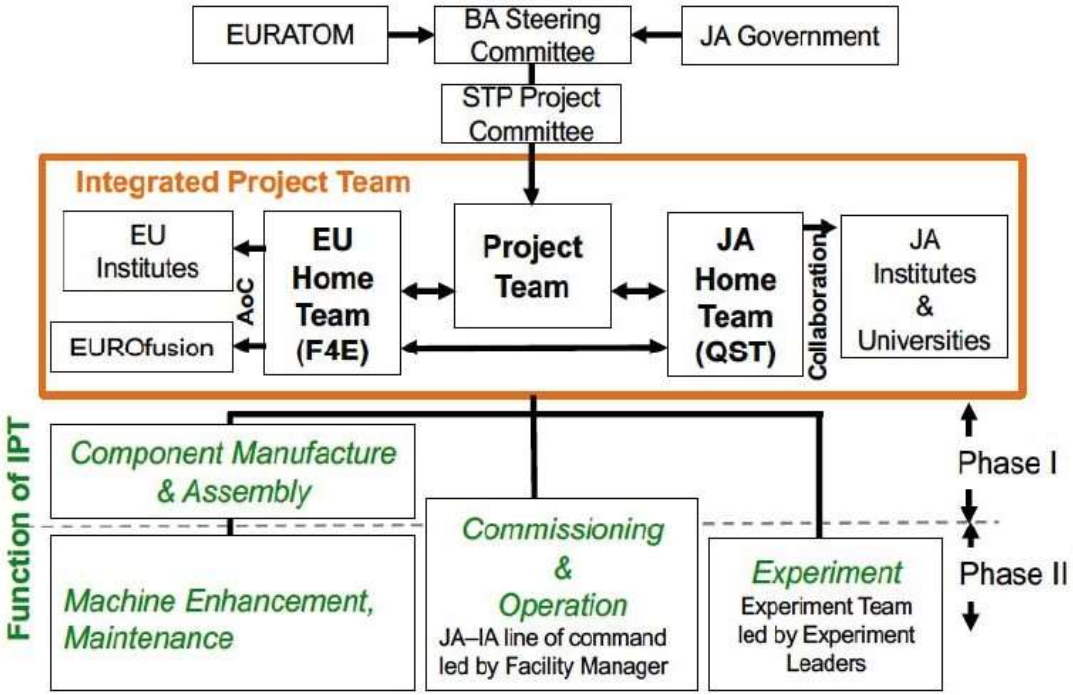
JT-60SA: A scientific challenge



- JT-60SA aims at DEMO and ITER normalized plasma parameters
  - High: beta, non-inductive current fraction, normalized density, confinement
- While working at high absolute plasma parameters:
  - Ip, Wdia, Wth, Neutron rate
- *Caviat: No Tritium operations*

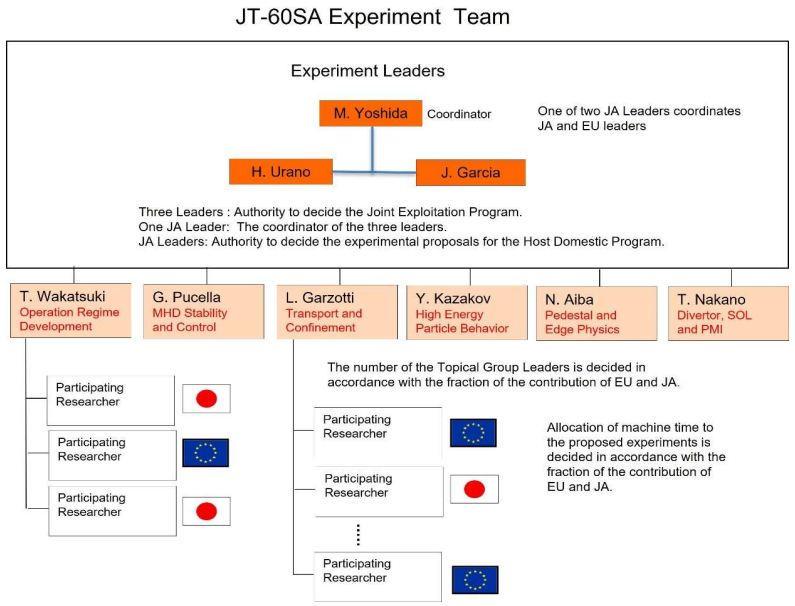
Contents

Global structure of the JT-60SA project



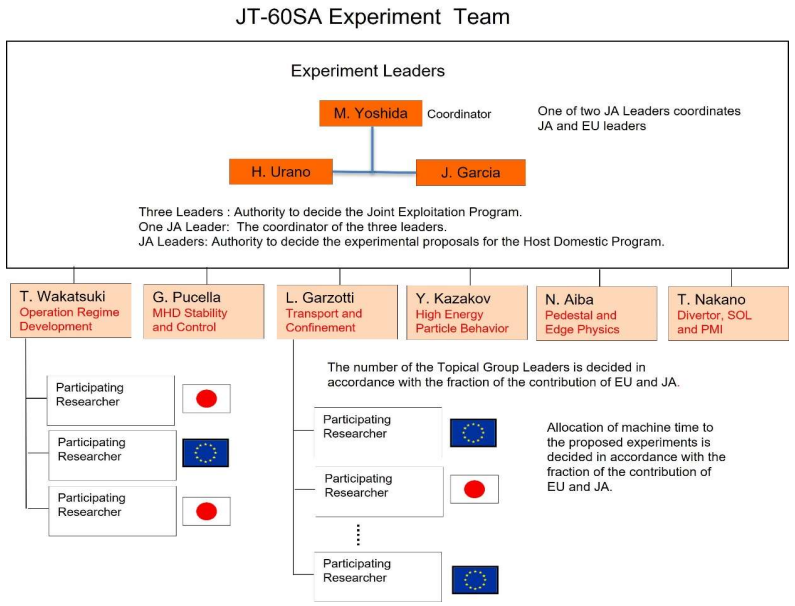
https://www.jt60sa.org/wp/

JT-60SA Experiment Team



- The JT-60SA Experiment Team is the unified Experiment Implementation Structure for the JT-60SA experiment
- Three Experiment Leaders
  - Maiko Yoshida
  - Hajime Urano
  - Jeronimo Garcia

JT-60SA Experiment Team: experiment leaders



- **Experiment Team Leaders are responsible for:**

- Jointly develop the Annual Experiment Programme
- Jointly assessing, prioritizing, and allocating machine time to experimental proposals
- Jointly coordinate and validate the publications related to the Experimental Team activity.
- Jointly contribute to the evaluation of the machine enhancement proposals

JT-60SA Experiment team structure

Experiment Leaders



Operation Regime Development
Takuma Wakatsuki
(QST, Japan)

MHD Stability and Control
Gianluca Pucella
(ENEA, Italy)

Transport and Confinement
Luca Garzotti
(UKAEA, UK)

High Energy Particle Behavior
Yevgen Kazakov
(LPP-ERM/KMS, B

Pedestal and Edge Physics
Nobuyuki Aiba
(QST, Japan)

Divertor, SOL and PMI
Tomohide Nakano
(QST, Japan)

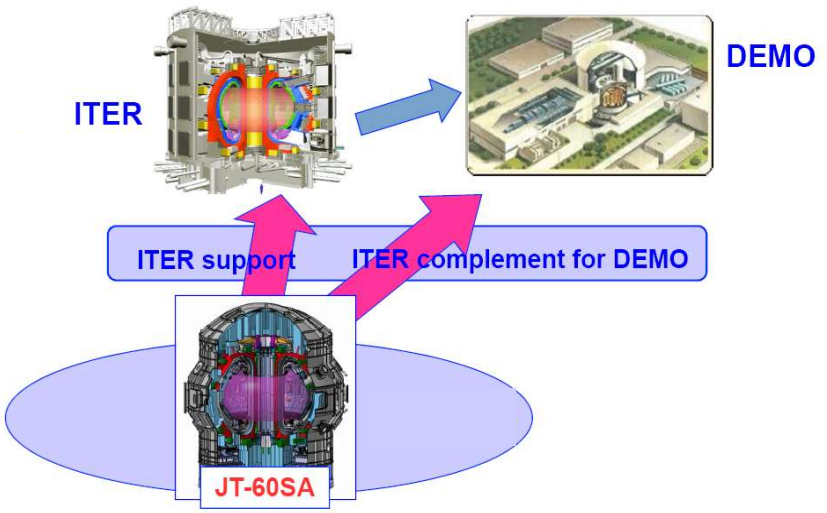
- **Topical group Leaders are responsible for**:
  - coordinate the scientific discussion of experiment proposals and the execution of the experiments assigned to the Topical Group
  - the Experiment Coordinator is assigned by the Topical Group Leader of the topic or by the Experiment Leaders when it is across multiple topics
  - the Topical Leader also summarizes the results and reports to the Experiment Leaders.

Contents

The JT-60SA project objectives

- Contribute to early realization of fusion energy by:
  - **supporting** the comissioning, start-up and exploitation of ITER
  - **complementing** ITER in resolving key issues for DEMO
  - **train** the next generation of fusion physicists and engineers

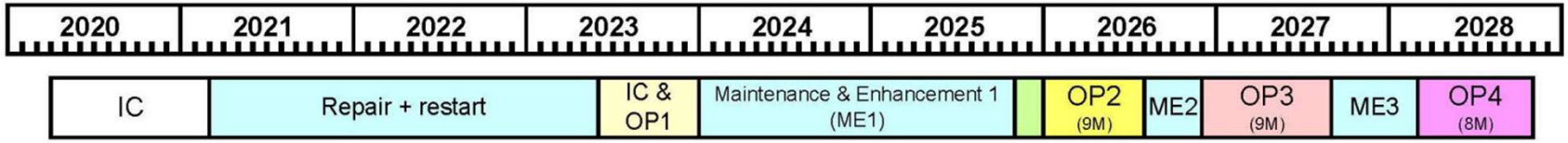
- The most important goal of JT-60SA is:
  - to **decide** the practically acceptable DEMO plasma design
  - including practical and reliable **plasma control** schemes



Experiment team: Beyond the research plan

- JT-60SA research plan is a key pillar to understand our scientific objectives https://www.jt60sa.org/pdfs/JT-60SA_Res_Plan.pdf
- Research plan is giving generic scientific objectives, mainly focus on key goals
- Need to clarify the scientific targets and operation for the initial campaigns, coherent with
  - Machine Enhancements (including diagnostics)
  - Scientific priorities
  - Analysis of OP1
  - Modelling

The JT-60SA initial phased operation plan



Research phase	Operation Campaign	Expected operation schedule		Divertor	P-NB 85keV	N-NB 500keV	ECRF	Max. usable aux. power
Initial research phase I	Op-1	2020-2021 (6M) 2023 (6M) First plasma 2023	H	C	0	0	1.5 MW	1.5MW
	Op-2	2025-2026 (9M)	D		16MW (with H) 23.5 MW (with D)	10MW	3.0 MW	19MW
Initial research phase II	Op-3	2026-2027 (9M)						26MW
	Op-4	2027-2028 (8M)			30 MW			33 MW

Timeline and main scientific topics

Initial research phase I
(Includes commisioning)

Initial research phase II

2023 — 2026 — 2027 — 2028

- **Commissioning with H plasmas for D plasma operation**
  - Commissioning NB injectors into plasma, including monitoring of shine-through vs energy (esp. N-NBI)
  - Step-by-step increase of plasma current up to 5.5 MA
  - Test of plasma control schemes: current, position, density, heating
  - Break down and plasma formation studies
- **ITER risk mitigation**
  - Studies of L-H transition comparison between H and D
  - Disruption studies including suppression of disruptions with MGI;
  - Runaway Generation and mitigation techniques
- **Scenario development**
  - Initial integrated scenarios development towards ITER standard H-mode

- Consolidate results from OP2
- **ITER risk mitigation**
  - Optimise ELM control and disruption mitigation with a focus on risk reduction for ITER
  - Advanced studies about the destabilization of Alfven modes by N-NBI and impact on fast ions confinement
- **Scenario development**
  - Further development of integrated scenarios including advanced real time control techniques
  - Initial steps towards radiative integrated scenarios
  - Initial steps towards high beta scenario development for ITER and DEMO and specific transport and turbulence studies in this regime

Call for participation

Better assessment of the experimental programme to be developed in OP2 and OP3→ the Experiment Leaders are launching a call for participation in the experiment team in the framework of the BA

Participants will work together to contribute to

- detailed analyses and modelling of IC-OP1 experimental data
- and/or to assess, by means of modelling or significant expert contributions, the main scientific topics proposed for OP2 and OP3.

List of data available and topics to be studied are included in the call

Call for participation

- Proponents should describe their intended contribution by providing their scientific expertise, corresponding to one of the Topical Groups, and a short workplan or intended activity
- The proponents should clearly indicate if they are intending to use experimental data from IC-OP1. In case modelling will be performed by the proponents for OP2 or OP3, a short description of the models and the input data to be used is necessary

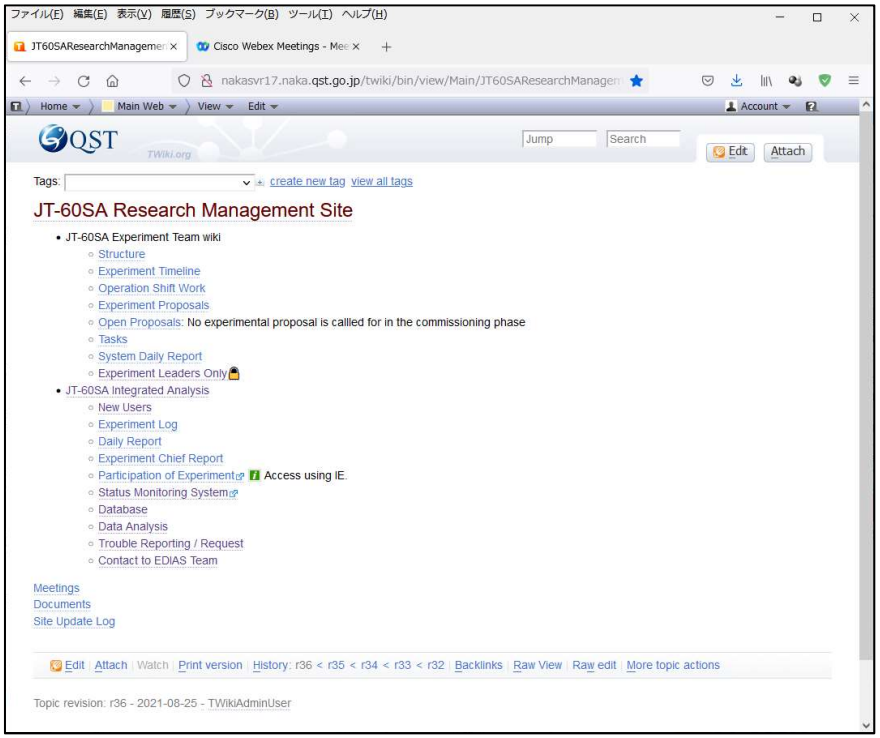
Call for participation

- Scientific proposals outside the scope of IC-OP1, OP2 and OP3 (e.g. scientific analyses in the framework of future machine enhancements or operation) will be considered and potentially selected by the Experiment Team in an individual basis
- Proposals involving data integrated validation or generic data access (e.g. using IMAS for testing purposes) which require a validating process with experimental data will also be considered. Proponents should clearly indicate the experimental data required for such validation. In this case, their expertise should be labelled as “Data access and validation”.

Call for participation

- BA Experiment team call to be distributed to EUROfusion
- EUROfusion call for interest will be launched
- Final participation in the experiment team and activity to be performed will be discussed and decided by the EL and TGL
- For any question related to this call, please contact the JT-60SA experiment leaders Maiko Yoshida (yoshida.maiko@qst.go.jp), Jeronimo Garcia (Jeronimo.GARCIA@cea.fr) and Hajime Urano (urano.hajime@qst.go.jp).

Tools for management onsite and offsite



- Environment of participation to experiment and data analysis is being developed for as equivalent access as possible between on-premise and remotely
  - HMI: control and monitor for whole JT-60SA operation
  - Data Analysis and DB Access Infrastructure
  - eDAS: basic analysis software
  - Data Access Library: further advanced analysis
  - Remote Access: RCA and RDA
  - JT-60SA RMS: information sharing among participants
  - JT-60SA Pinboard: effective publication management

Contents

Conclusions

- The experiment team structure was stablished in 2022.
- EL+TGL are already appointed
- Initial ideas for the first experimental campaigns and diagnostics have been discussed
- Towards first campaigns: Call for participation
- Important for getting used with JT-60SA capabilities, data, joint discussions, information sharing

Control Room Structure

Plasma Operation Chief: Execute plasma operation requested by **Exp proposers**. Optimize discharge conditions and shot plan in the day considering subsystem status.

Plasma Operator: Program discharge conditions in Human Machine Interface (HMI) according to Plasma Operation Chief.

Experiment proposers: Design the plasma and shot plan and analyze data, request the shot to Plasma Operation Chief / Plasma Operator.