Exploitation of JT-60SA (WPSA)

Planning for 2021 and beyond

PPM 2021

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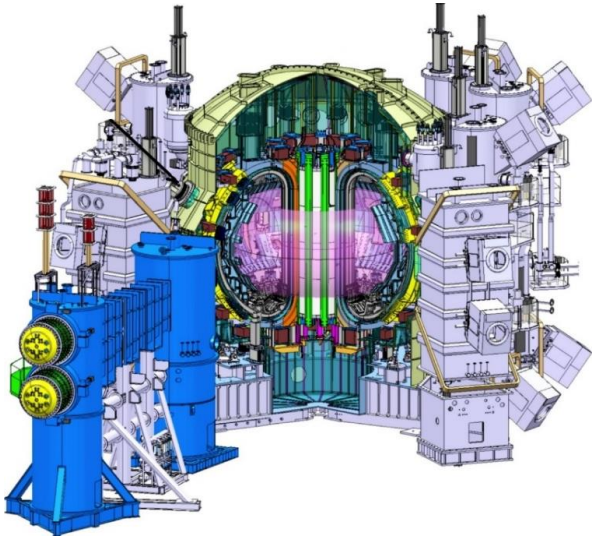
WPSA: Exploitation of JT-60SA – project objectives



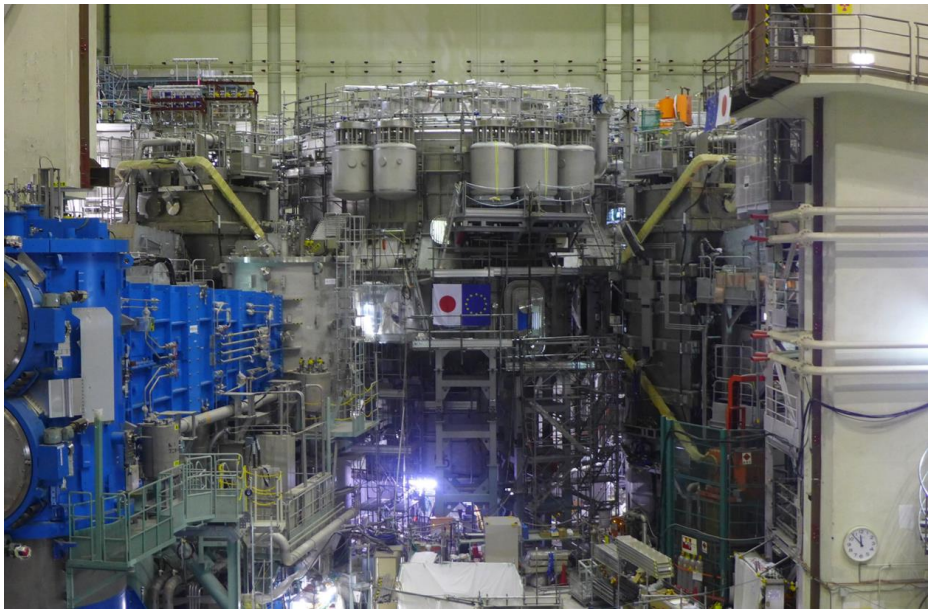
High current, large size, high triangularity shape
=> High confinement

Long pulse=>steady state

High electron heating, High energy Negative NBI
=>energetic particles, ITER and DEMO relevant scenario, plasma controllability

- support of the European exploitation of JT-60SA within the Broader Approach.
- The main objective is to support a high level EU participation in the JT-60SA scientific exploitation, fully integrated in the EU fusion programme.
  - preparing to play an active role in scientific exploitation and campaigns management
  - participation to the machine integrated commissioning and to plasma operations
  - preparing a full and efficient access to data and analysis tools, on site and remotely;
  - contributing to the machine enhancements plan with specific procurements
- Maintaining/developing control room experience in a large superconducting machine in view of EU participation in ITER operation
- Contribution to specific items of the ITER Research Plan
  - Start-up, Wall conditioning (w and w/o EC)
  - Disruption loads, mitigation, detection, triggering, avoidance…
  - H-mode, L-H transition, ELM control, plasma magnetic control, NBI shine-through
  - Topics in diagnostics R&D (high neutron flux resilience, very high temperature, in-situ calibration…)

JT-60SA status



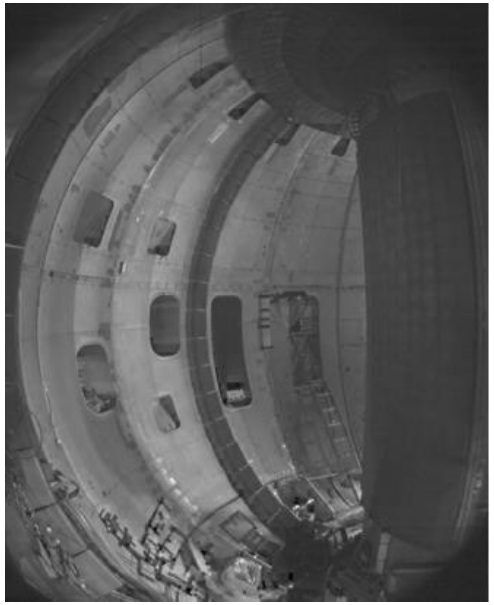
- Assembly completed in March 2020
- 14 September 2020 Vacuum vessel pump-down started
- 10 October 2020 Magnets cooling down
- Current temperature of the vacuum chamber and the magnets
- http://www.jt60sa.org/jt60sa_tmon/
- Superconducting status reached on 26.11.2020
- Vacuum vessel baking started on 02.12.2020
- Coils energization test started on 13rd January
- 02.03.2021 ECR plasma (toroidal field only) obtained
- 02.03.2021 Toroidal field coils energized with a current of 25.7kA - full design magnetic field of 2.25 T
- 09.03.2021 Operations temporary suspended for He leak, investigations on going. Some information in the F4E talk, fore sure delay in the programme

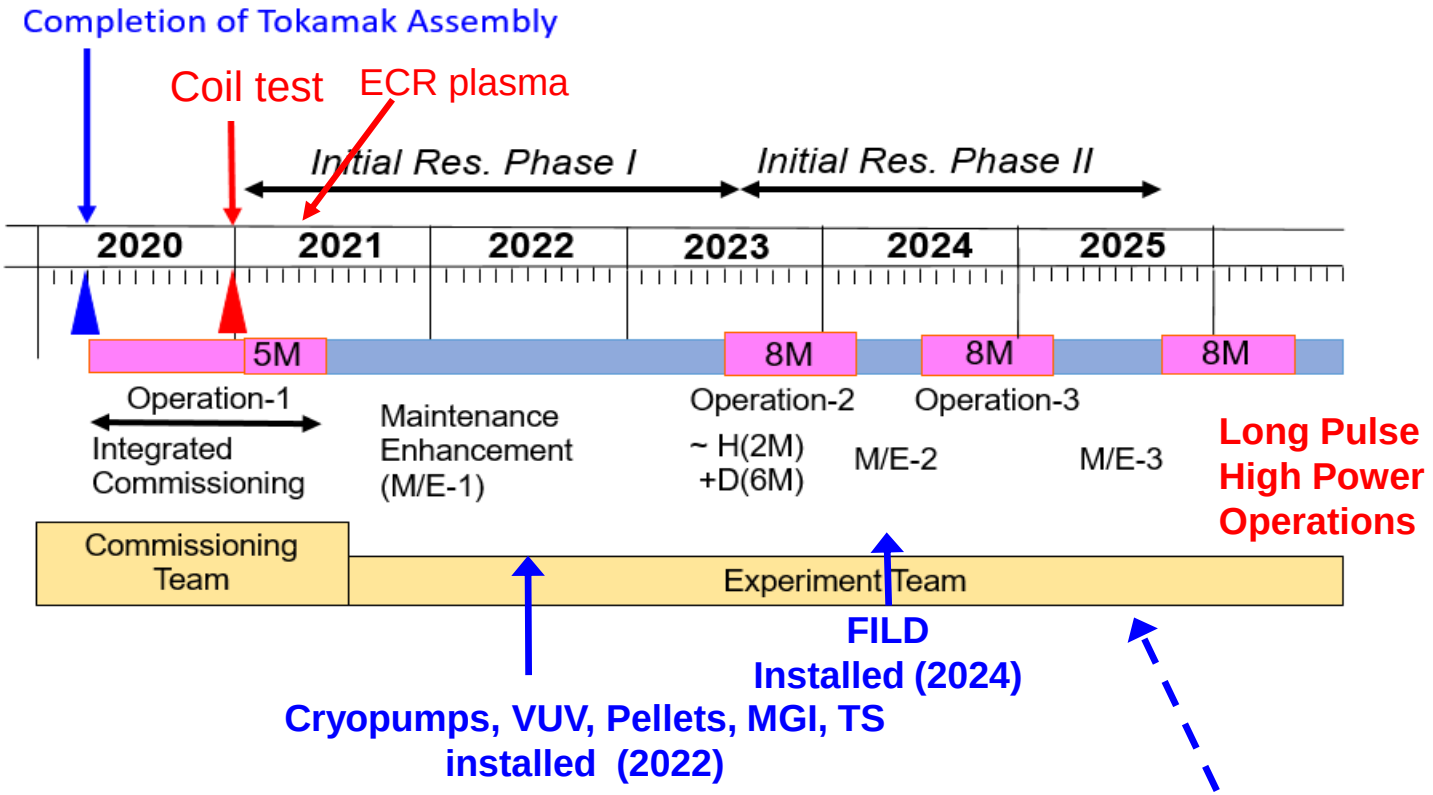
JT-60SA timeline

EDICAM
Delivered July 19,

Installed April 2020

First vessel image

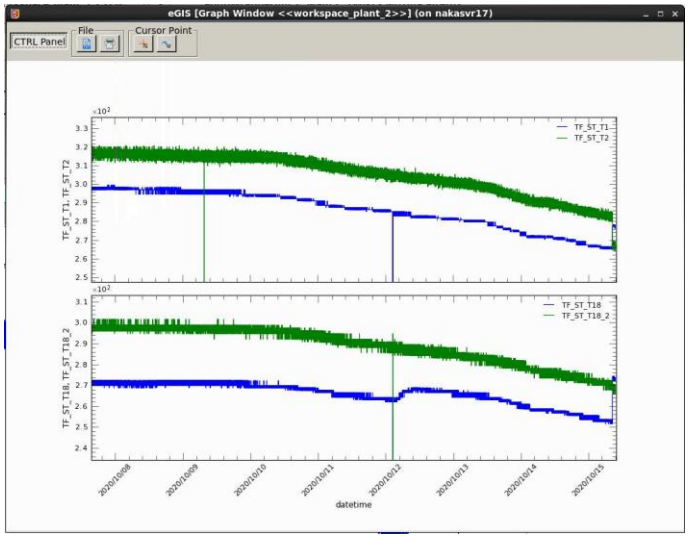




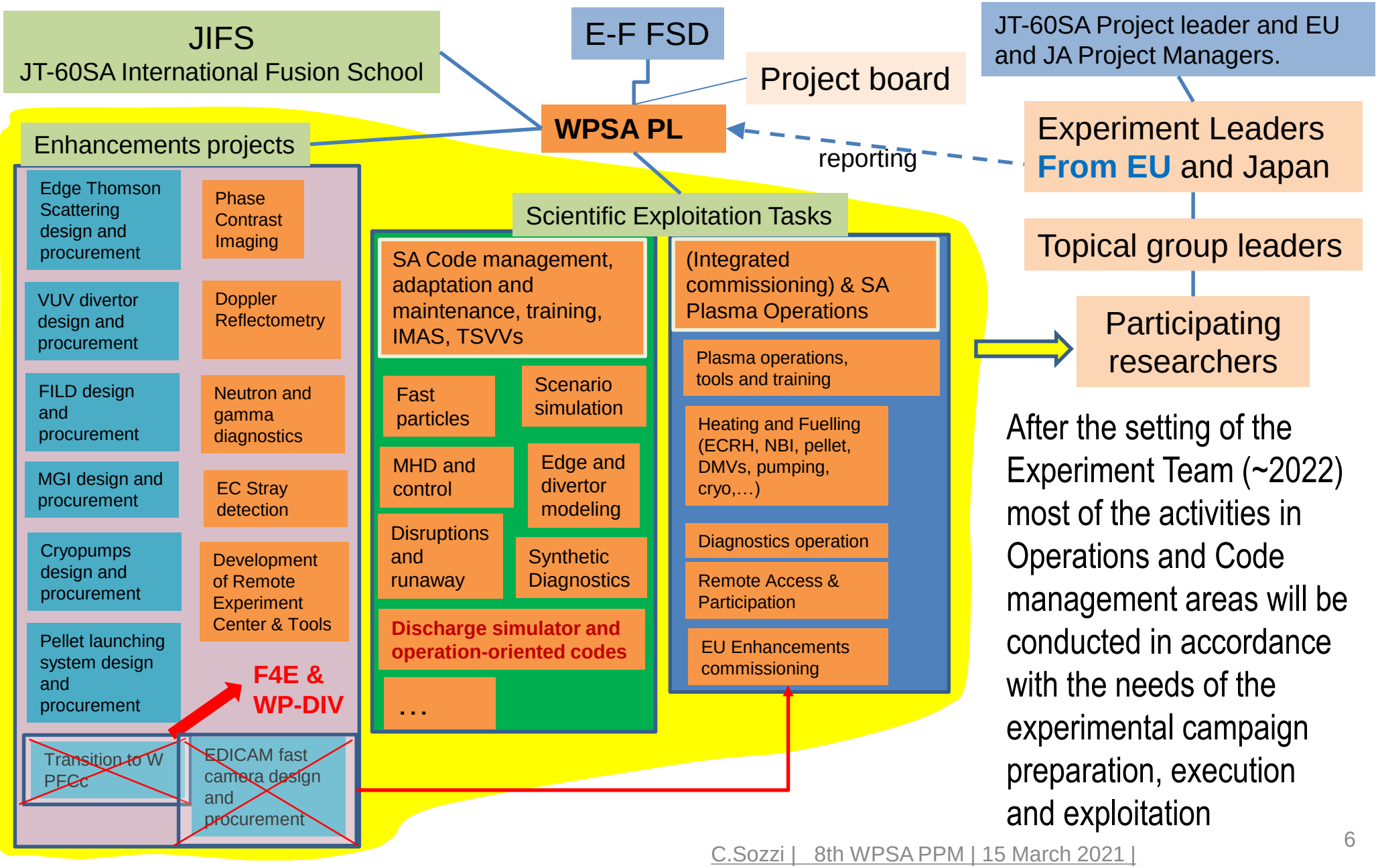
- Setting of the Experiment Team in 2021 for the preparation and exploitation of 2023-2024 experimental campaigns
- The Experiment Team will also assess the priorities for the implementation of new enhancements after the feasibility study

WPSA programme – *New phase in FP9*

- Participation to the machine commissioning and scientific campaigns
- Continuous presence on site of EU personnel during the experimental campaigns but also for periods during Machine Enhancement periods
- On-site team necessarily limited in number and then in range of know-how
- Key role of Remote Participation
  - Need of a steady, easy-to-run contact with the EU fusion community
  - => Development of a team participating through back-office work (from Europe) and available to spend periods on site
  - EU-Remote Experiment Centre(s) and remote participation/remote data access/remote computer access for work not directly related with plasma operations
- Strategic contact with the EU-based experimental program
- Develop an appealing program of education and training related to JT-60SA, from Master level to post-doc, with significant exchanges EU ⇔ Japan
  - Essential to attract promising young scientists and to promote strong partnership with Japanese colleagues in the coming years
  - **Initiative: JT-60SA International Fusion School (JIFS)**



WPSA –structure and organization in FP9



After the setting of the Experiment Team (~2022) most of the activities in Operations and Code management areas will be conducted in accordance with the needs of the experimental campaign preparation, execution and exploitation

Key priorities of JT-60SA in the EU programme

- Participation of EU scientists to the JT-60Sa scientific programme will be lead by the EU Strategic priorities in the JT-60SA research program as in https://idm.euro-fusion.org/?uid=2NPW2R&version=v1.1

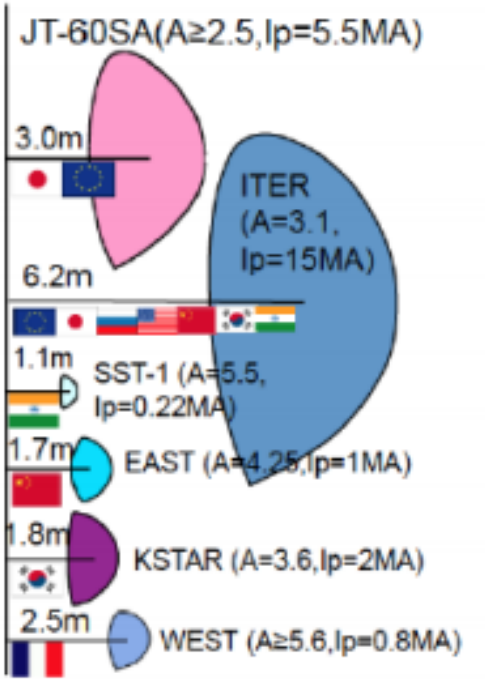
  - Development and investigation of high performance scenarios compatible with future W-PFCs.
  - Avoidance and mitigation of disruptions and runaways
  - Fast ion physics
  - Development and validation of high level real-time control strategies

- For technology, under the main responsibility of F4E and with the contribution of EUROfusion in terms of scientific motivation and support

  - Development of cost-effective W-PFC materials;
  - Development of a remote handling system to address specific needs for the device operation phase;
  - An enhancement program for the toroidal field, cryogenics, power supplies and heating systems;
  - Consolidation and verification of the engineering models to expedite the verification against structural integrity during the operation phase.

Key interfaces for WPSA

- ***F4E***
- *Within Fusion Science D.*
  - *Tokamak exploitation (WPTE)*
  - *Advanced computing (WPAC)*
  - *Preparation of ITER Operation (WPPrIO)*
  - *Plasma Wall Interaction and Exhaust (WPPWIE)*
- *Synergies with some Fusion Technology D. WPs for **DEMO R&D***
  - *Divertor (WPDIV)*
  - *Heating and Current Drive (WPHCD)*
  - *Diagnostics and Control (WPDC)*
- *Various Theory, Simulation, Verification, and Validation (TSVV) tasks*
  - *Establishment of "Thrusts", meant to provide a platform for discussion and interaction between TSVV leaders, PLs, and SB members. WPSA part of this organism.*
- *Various Enabling research (Theory and modelling, Technology)*



JT-60SA project organization

- The collaboration between the EU and Japan for JT-60SA became possible in the framework of the “Broader Approach Agreement” (2007) to complement the ITER Project toward a commercial fusion power plant.
- The JT-60SA project is conducted by the Integrated Project Team (IPT) as a single, collaborative organisation of the staff of the key international stakeholders under the coordination of the JT-60SA Project & JA Home Team Leader and of the EU Home Team Leader
- The EU and JA Home Teams conduct the technical design and procurement activities in JT-60SA. For Japan this is carried out by QST. For Europe it is carried out by F4E, with the support of the European Programme EUROfusion, with the bulk of the procurement actually handled by voluntary contributing governments through designated institutions

JT-60SA Integrated team at the Research Coordination Meeting at Naka on 24-26 June 2019

- Centre d’Etude de l’énergie Nucléaire **(SCK-CEN)**, Belgium
- Karlsruhe Institute of Technology **(KIT)**, Germany
- Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas **(CIEMAT)**, Spain
- Commissariat à l’Energie Atomique et aux Energies Alternatives (**CEA**), France
- Consorzio **RFX**, Italy
- Agenzia nazionale per le nuove tecnologie, l’energia e lo sviluppo economico sostenibile **(ENEA)**, Italy

The JT-60SA Experiment Team

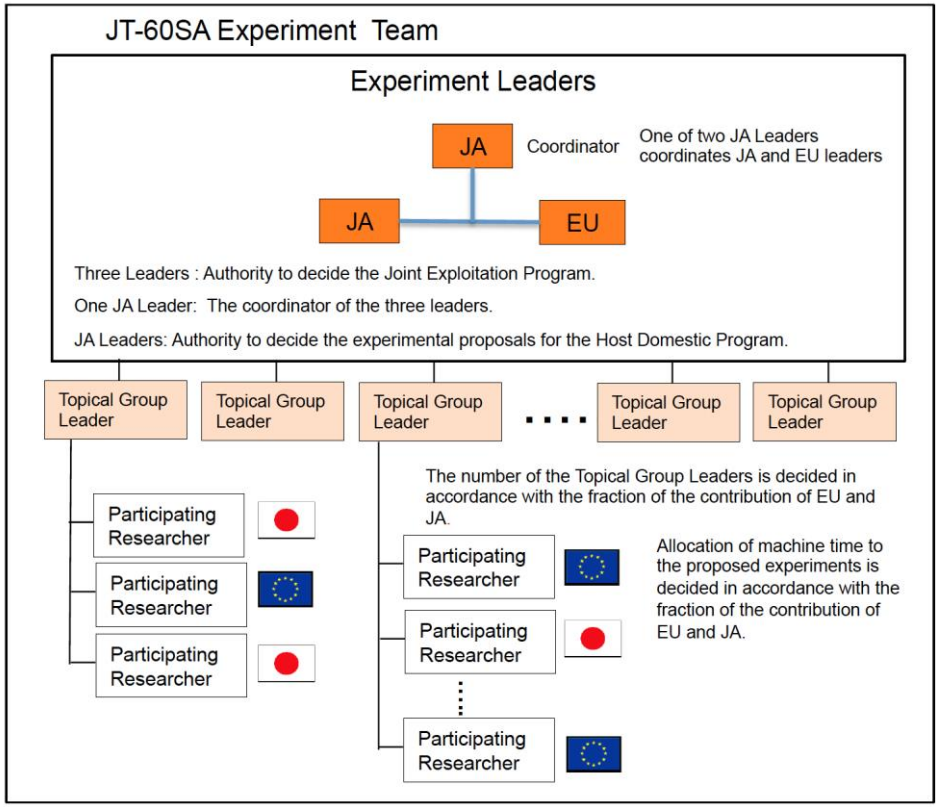
- The JT-60SA Experiment Team is the unified Experiment Implementation Structure for the JT-60SA experiment

- Experiment Team Leaders (2 from Japan, 1 from Europe)
  - jointly select the Topical Group Leaders and organize the work of the Experiment Team;
  - jointly develop and implement the Annual Experiment Programme by calling and selecting experimental proposals
  - jointly coordinate the experimental campaigns in all its phases (preparation, analysis, publication)
  - jointly analyse, document and prioritise proposals for machine enhancements

- Topical Group Leaders (shared JA,EU)
  - coordinate the scientific discussion of experiment proposals and the execution of the experiments assigned to the Topical Group

- Participating Researchers
  - Experiment proponents or experiment contributors **selected within and outside WPSA**

JT-60SA Project leader and EU and JA Project Managers.



The call for the ETL has been issued-deadline 15th Jan. 2021
Calls for TGLs and Participating Researcher will follow in 2021

Key EU modelling items for physics and operations (FP8)

- Breakdown model BKD0 combined with CREATE equilibrium for EC-assisted breakdown GRAY (ECRF beam tracing and power deposition)) (developed in the Operations area)
- Discharge simulator (free boundary equilibrium code FEEQS, closed loop dynamic simulator CREATE-NL, with appropriate set of controllers, METIS fast transport simulator) (developed in the Operations area)
- JINTRAC scenario modelling with pellet ablation module HPI2
- Edge and detachment control (EDGE2D-EIRENE, SOLPS-ITER, SOLEDGE2D-EIRENE)
- Energetic Particle driven instabilities and EP transport (LIGKA workflow, MISHKA/CASTOR-K)
- First-principle ELM simulations, ELM control by RMP or pellet (JOREK)
- High-β MHD, RWM stability (MARS-K, CarMa)
- GRAY (ECW beam tracing and power deposition) for ECRF system performance evaluation (developed in the Enhancements area)
- NTM and ECCD control via Generalized Rutherford Equation

Code management and modeling

Role Title	*Required Competencies*

Suite of codes manager	• Knowledge of numerical simulation tools in tokamaks
	• Knowledge of the simulation infrastructure and platforms
	• coordination skills
	• Activity goals will include:
	  • to coordinate selection, validation, adaptation and benchmark of simulation tools for application to JT-60SA in order to prepare, perform and analyze the future experimental campaigns
	  • Prepare and coordinate training activities for the application of the simulation tools

Simulation expert, data analysis tools developer	• Scenario development and analysis • Disruption and runaway, physics, consequences and mitigation • Synthetic diagnostics development, including image processing for scientific cameras, particularly but not exclusively for EU-led diagnostics EDICAM, Edge TS, Divertor VUV, FILD • Fast particles • MHD and Control • Edge and divertor modeling • Operation-oriented tools : (equilibrium, control, discharge fast simulator etc.) • Energy, Matter and Impurity Transport

- Adaptation/preparation of analysis tools (predictive, interpretative) to support
  - Experiment preparation
  - Experiment analysis
  - Interpretation of diagnostics data
  - New enhancements
- Strict relation with the Experiment Team before and during the campaigns

Code Management and Simulation

Activity	2021	2022	2023	2024	2025
Plasma operation oriented tools	Simulate JT-60SA discharge with the plasma discharge simulator coupling METIS-CREATE codes with controllers.				
Plasma operation oriented tools	Validate ECWC simulation tools on the first data from commissioning.				
Plasma operation oriented tools	Breakdown simulators, combining free-boundary equilibrium, evolution equations for energy, particles and current and EC beam tracing: application to the optimisation of breakdown with ECRH.				
Plasma operation oriented tools	Integrated Data Analysis and Validation (IDAV) : requirement capture and specifications				
MHD and control	MHD stability workflow: demonstrateapplication on nominal and reduced power scenarios.				
Scenario development and analysis	Validation of IM simulators on the nominal scenarios and identification of viable high-radiation long discharge scenarios for the initial phase				
Scenario development and analysis	Gyrokinetic study of EM anomalous transport in a representative JT-60SA plasma discharge				
Edge and divertor modeling	Investigate conditions for divertor detachment for the initial phase scenarios, includig impurity seeding impact				
Fast Particles	Investigate the stability of high-energy ions for the initial phase scenarios				
Disruption and runaway, physics, consequences and mitigation	Disruption mitigation studies on the initial phase scenarios				
Disruption and runaway, physics, consequences and mitigation	Develop disruption database during commissioning activity				
Disruption and runaway, physics, consequences and mitigation	RE stability studies on the initial phase scenarios				
Synthetic diagnostics development	Develop tools for visible imaging analysis. Provision and test of tomography for emissivity reconstruction of visible imaging for EDICAM exploitation.				
Synthetic diagnostics development	Synthetic diagnostics development for EDICAM, Edge TS, Divertor VUV, bolometry.				
Tools for MHD analysis		MHD analysis and modelling in support of scenario development. Mode identification			

+

Non linear MHD simulations for disruption physics and control of runaway, ELMs, disruption Mitigation (JOREK)

+

Edge turbulence

New Enhancements

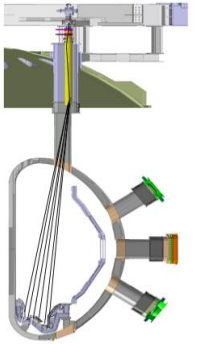
Role Title	*Required Competencies*
Enhancements coordinator	• Experience in Specification, Design, Procurement, Assembly, Integration and Commissioning of Tokamak sub-systems, auxiliary and diagnostics
Diagnostics and tokamak subsystems engineering and design expert	Experience in development, design and implementation of tokamak diagnostics systems, in particular • Phase Contrast Imaging* • Doppler Reflectometry* • Electron Cyclotron Stray Detection system feasibility study • Neutron and Gamma diagnostics (scoping study). • Technical support to review the design of the JT-60SA remote access architecture with the objective of enabling reliable Remote Participation and Remote Data Access • New Enhancements proposals *decision about implementation being evaluated

- Other projects in preparation (funding scheme for implementation not yet defined)
  - Phase Contrast Imaging diagnostics – advanced conceptual design (started in FP8)
  - Doppler Reflectometry diagnostics – feasibility study (started in FP8)
  - Neutron and Gamma diagnostics – scoping study to be launched (FP9)
  - EC Stray radiation detectors – scoping study to be launched (FP9)
  - Remote Experiment Centre(s) & tools - to be launched (FP9)
  - …open for feasibility of new proposals in connection with the experimental programme

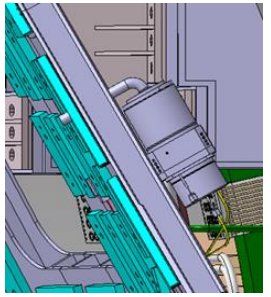
Enhancements (implementation started in FP8 => extended to 2022 with the same rules)

- From 2016 some of the enhancements feasibility studies entered the implementation phase
  - EDICAM fast survey camera (pilot project) – INSTALLED, IN COMMISSIONING
  - Divertor cryo-pumping system – PROCUREMENT
  - Pellet injector - DESIGN/PROCUREMENT
  - MGI (massive gas injection)- PROCUREMENT
  - Edge Thomson Scattering (TS) -DESIGN/PROCUREMENT
  - VUV spectrometry) - DESIGN/PROCUREMENT
  - FILD (fast ion loss detection) - DESIGN
- EUROfusion Scientific drive, Proposals, Design, personnel, led by the team in WPSA
- Key support from F4E for sharing in financing, procurement process, engineering support

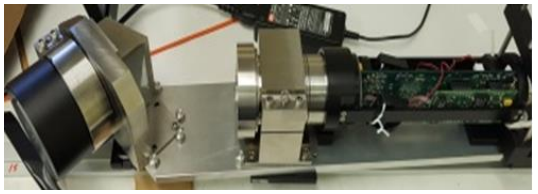
VUV Divertor Spectrometer



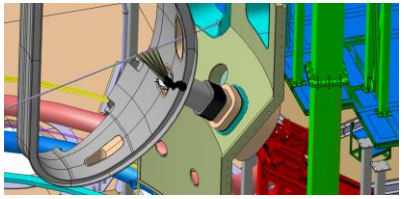
MGI



EDICAM wide-angle camera

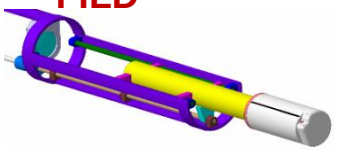


Edge Thomson Scattering

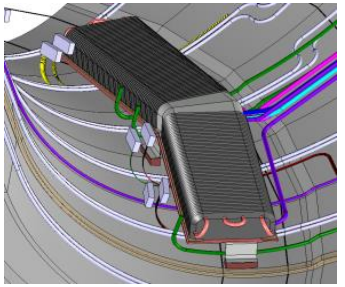


Pellet Launching System

FILD



Divertor Cryopumps



New Enhancements

New enhancements projects	2021	2022	2023	2024	2025
Phase Contrast Imaging	Finalization of Conceptual Design Review and Discussion for Implementation	Implementation			Commissioning
Doppler Reflectometry	Finalization of Conceptual Design Review	Discussion for Implementation	Implementation		
EC Stray	Conceptual Design Review	Finalization of Conceptual Design Review and Discussion for Implementation	Implementation		Commissioning
Neutron and Gamma	Scoping study	Preliminary Conceptual design	Discussion for Implementation	Detailed design and implementation	
Beam Emission Spectroscopy	Update of performed Feasibility Study and Discussion for Implementation	Detailed design and implementation			Commissioning
Reflectometry upgrade	Scoping study	Conceptual design and Discussion for Implementation	Implementation		Commissioning
Infrared Imaging	Scoping study	Conceptual design and Discussion for Implementation	Implementation		
Remote Access and Remote Participation	Review of the design of the remote access architecture	Implementation of basic functionalities / Design of upgrade	Operation		

Operations

Role Title	*Required Competencies*

Plasma Operations Activities Coordinator	• In depth knowledge of plasma operations
	• coordination skills
	• Activity goals will include:
	  • Coordination and training of control room experts
	  • Coordination of Remote Access and Participation
	  • Coordination of EU-led Enhancements commissioning

Plasma operation expert	Operational experience and skill for data production and validation where applicable on one or more of the following: • Plasma operation • Plasma controllers • Plasma Heating (NBI, NNBI, ECRH), • Fueling control, particularly pellet and massive gas injection • Diagnostics, particularly camera systems, Thomson scattering, VUV spectrometer, FILD

- Focus on supporting
  - plasma operations
  - EU systems commissioning
  - EU systems daily operations
  - Exploitation of the scientific programme

Operations

Activity	2021	2022	2023	2024	2025
Cryo and Magnets	Review coil energisation in the integrated commissioning, analyse lessons learned and support EEG on magnets.	Review coil energisation in the integrated commissioning, analyse lessons learned and support EEG on magnets.			
EDICAM operation	Review operational experience from the integrated commissioning	update where needed	diagnostics operation	diagnostics operation	diagnostics operation
Plasma Operations	Review the operational experience of the integrated commissioning in 2021	Train and contribute to plasma operation preparations	Train and contribute to plasma operations	Train and contribute to plasma operations	Train and contribute to plasma operations
Real-time Networks	Consider tools for JT-60SA based on integrated commissioning experience	Learn about the RT networks at JT-60SA. Develop / integrate suite of tools for JT-60SA	Develop RT networks and support operation	Develop RT networks and support operation	Develop RT networks and support operation
Wall conditioning	Review vacuum conditioning and the ECWC in 2021 from the operational aspect	Contribute to preparation of vacuum conditioning for the 2023 campaign	Monitor wall condition and contribute to operation of ECWC	Monitor wall condition and contribute to operation of ECWC	Monitor wall condition and contribute to operation of ECWC
Divertor Cryo operation		Installation and test	Commissioning and operation, training of resident staff	Commissioning and operation, training of resident staff	Commissioning and operation, training of resident staff
ECH		prepare for operation	Support operation	Support operation	Support operation
NBI			Support operation	Support operation	Support operation
Edge Thomson Sscattering		Installation	Installation / commissioning	diagnostics operation	diagnostics operation
VUV operation		Installation	Installation / commissioning	diagnostics operation	diagnostics operation
FILD operation				Installation / commissioning	diagnostics operation
Massive Gas Injection			Installation / commissioning	operation	operation
Pellet Launching System			Installation / commissioning	operation	operation

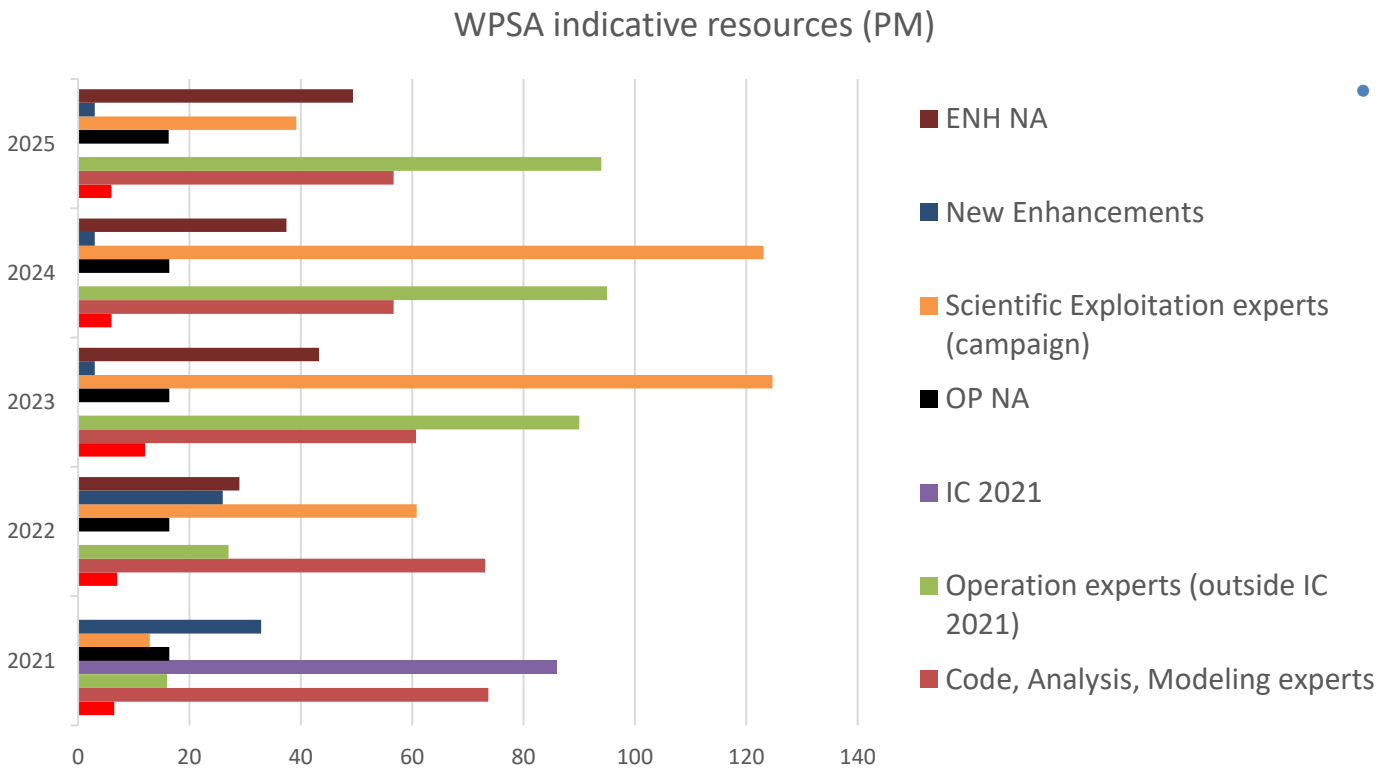
JIFS (Young researcher training)

JIFS School Organization	• Broad knowledge of the aspects of tokamak science, operation and technology • Organizational and communication skill in particular related to high profile training events

- New initiatives for students :
  - a Japan-EU summer school at Naka
  - 6 Japanese Universities involved (school + on-site Lab)
  - PhD students exchanges
- School objectives:
  - Completing the training of selected students by:
    - lectures on fusion physics, engineering, operation
    - group work using the JT-60SA facility, environment and data for practical examples and applications
  - Creating links between Japanese and EU students and young professionals, who could then:
    - participate in the JT-60SA operation, scientific exploitation and upgrades
    - be involved in the future Japanese and EU participation in the ITER programme

Resources

	2021	2022	2023	2024	2025
JIFS Organization	6.5	7	12	6	6
Code, Analysis, Modeling experts	73.7	73.1	60.7	56.7	56.7
Operation experts (outside IC 2021)	16	27	90	95	94
IC 2021	85.89				
OP Not Allocated	16.4	16.4	16.4	16.4	16.3
Scientific Exploitation experts (campaign)	12.9	60.8	124.7	123.1	39.2
New Enhancements experts	32.9	26	3	3	3
ENH Not allocated	0	29	43.3	37.4	49.4
TOT PM	244.29	239.3	350.1	337.6	264.6



- Significant amount of NA resources
  - for campaigns participation
  - to support of enhancements selected for implementation

Thank you for your attention