Scientific goals of JT-60SA and timeline until W transition

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PSD Meeting on the transition to Tungsten PFCs in JT-60SA
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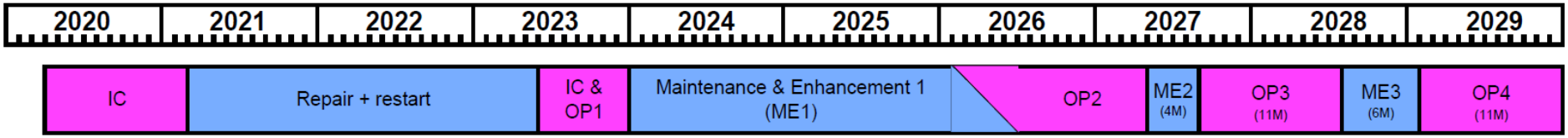
Operation Phases and Status of Key Components

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

Research phase	Focus of exploitation	Operation Campaign	Expected operation schedule	[1]	Annual neutron limit	RH	Divertor	Installed NB power	ECRF	Max. usable aux. power[2]
Initial research phase I	Integrated Commissioning	Op-1	2020-2021 (6M) 2023 (6M) First plasma 2023	H	-	R&D	Open upper inertially cooled carbon[3]	0	1.5 MW (2 Gyro.)	1.5MW
	Initial stable and reliable operation • H operation for commissioning towards D operation. • Stable operation at high current heated plasma	Op-2	2026-2027				Lower pumped carbon with intershot cooling [4] (limits high power heating duration) C-ICD	PNB 8 units, plus NNB Total 16MW (with H) 23.5 MW (with D)	3 MW (4 gyro)	19MW
Initial research phase II	**ITER and DEMO regime access** (high power and high Ip with short pulses) • Access to ITER-relevant high confinement H-mode at high Ip • High beta access • ITER risk mitigation (ELM, disruption)	Op-3	2027-2028 (11M)	D	3.2e19					26.5MW
		Op-4	2029 (11M)					PNB 12 units, plus NNB Total 30 MW		33 MW
		No. of campaigns to be confirmed	TBD							
Integrated research phase I	**High beta and metal wall compatibility**	TBD	TBD		4.0e20		W-ACD Actively cooled lower pumped tungsten		7MW (9 gyro.)	37MW
Integrated research phase II	**High beta long pulse** **Burning plasma relevant** • ITER standard and hybrid stationary (~2-3τ_R) • High beta steady-state (~2-3τ_R), DEMO contribution	TBD	TBD		1.0e21	Use				
Extended research phase		TBD	TBD		1.5e21			34MW[5]		41MW

High Level Project Schedule



[BASC-34, December 2024]

- Transition from ME1 to OP2 in 2026
- Each operating period is extended as long as possible (11M)
- Operating period includes cool-down, pump-down, wall-conditioning, comissioning etc
- Beyond 2029, Project aims to prioritize the development of integrated scenarios with W div/wall. No longer intended C-ACD
- OP4 may be the last opportunity to perform experiments in C-wall (TBC)

C-ACD: actively cooled carbon divertor

Scientific strategy for JT-60SA initial phases

- Scientific priorities for OP2-OP4 have been discussed and decided in the ET during 2023-2024
- Several events have impacted such a development:
  - Decision to skip the C actively cooled divertor and move towards W- ACD
  - ITER rebaseline and new IRP
  - Scientific results and plans from other tokamaks and projects

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- The development of scientific priorities has been carried at different levels:
  - General priorities for the C phase → Priorities per campaign (OP2-OP4) → L1 experimental programme for OP2

Main Subjects during C-ICD phase

Classification of priority level: (i) essential, (ii) important, (iii) desirable.

I. Should be done in early phase for robust general operation in JT-60SA and/or key physics identification with the machine uniqueness. Those will need dedicated shots. *"Minimum request before going to W-wall"*

II. Can reduce risks in W-wall experiments including required actuator assessment. Those should be done to a certain level through the items (i). Some dedicated shots will be required for documentation.

III. Will be beneficial by taking advantage of the C-wall, wider operational regimes, and obtain physics understanding however, these topics could be potentially investigated by (i)/(ii) analyzing discharges developed for other experiments

Priority (i): Essential

Operation Regime Development

- Break down and plasma formation studies in conditions of low loop voltage,
- Safe increase of toroidal current up to 5.5MA in L-mode,
- Test of fundamental plasma control schemes: plasma current, position, density, heating as those done in the typical tokamaks, like JT-60U, JET.
- Initial development of the access to ITER-relevant H-mode scenario ($H_{98}(y,2)$~1, β_N~1.8), high beta ($H_{98}(y,2)$~1-1.2, β_N~3-3.5), and low collisionality.

MHD Stability and Control

- Error field measurement, characterization and impact on locked mode
- Disruption studies at high current in L-mode to obtain an operation guideline
- Runaway electrons generation and control studies.

Priority (i): Essential

Transport and Confinement

- Initial characterization of H-mode confinement,
- Characterization of H-mode confinement in type-I ELMs plasmas,
- Testing of core and pedestal W screening with TESPEL/partial W tile/Xenon gas.

High Energy Particle Behavior

- Shine-through studies in H and D, especially with N-NBI,
- Initial studies of fishbone and Alfvén modes destabilization by N-NBI,
- Neutron emission studies and reproducibility with codes,
- Characterization of fast ions losses at high N-NBI power.

Priority (i): Essential

Pedestal and Edge Physics

- L-H power threshold characterization in H and D,
- Pedestal and ELMs generation studies in different plasma conditions,
- Characterization of the access to type-I ELMs.

Divertor, Scrape Off Layer and Plasma-Material Interaction

- Wall conditioning,
- Characterization of heat flux to divertor in the ITER-relevant H-mode scenarios developed and neutral compression by the V-shaped corner,
- SOL width scaling at high Ip.

Headlines in Op2

[Major goals in Project Plan]

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

- **Key commissioning in H for scientific experiments**
  - 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 in L-mode
  - Test of plasma control schemes: current, position, density, heating

- **ITER risk mitigation**
  - Studies of L-H transition
  - Disruption and mitigation technique studies
  - Runaway generation and mitigation technique studies

- **Scenario development**
  - Initial integrated scenarios development towards high confinement H-mode operation

Headlines in Op3

[Major goals in Project Plan]

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

- **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 Alfvén modes by N-NBI and impact on fast ions confinement and turbulence

- **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, hybrid and ITB, for ITER and DEMO and specific transport and turbulence studies in this regime

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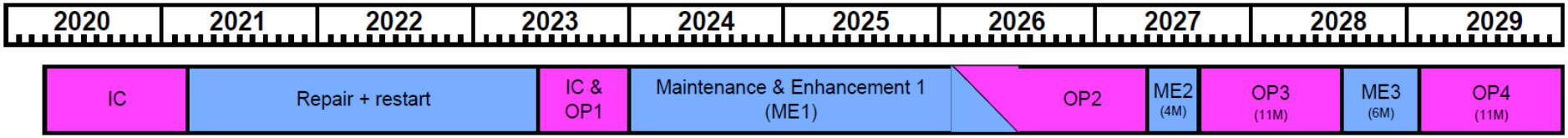

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