EUROfusion Physics Project Board #09

Overview of Status 2026 and Outlook

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Fusion Science Department – objectives and status 2026

Objective	Status 2026
Physics gaps for ITER, priority on the ITER re-baselining	Joint activities with IO launched (kick-off Jun 2026, meeting at ITER Jul 2026)
FoaK physics programme – DEMO parameters as proxy (e.g. no/small-ELM regimes such as QCE, with XPR exhaust)	STAC recommendations from EFPW 2026 (exhaust): replies on their impact on the FSD WPs (Sep 2026)
High-level EUROfusion priorities for the devices with EU involvement	JT-60SA: C phase updated, W phase agreed; BEST: proposal reviewed by STAC
Scientific readiness (SSRL)	WP TE: per scientific objective (since 2021); WP PWIE: none yet; WP STEL: gap analysis published (Apr 2026)
Interpretative modelling and uncertainty quantification	Constrained by the 2026–27 resources
Use of resources	Priority-1 items accepted by the GA; transfers 2026 → 2027 with spending case; DTT review resources released

ITER – EUROfusion: activities on gaps in the ITER physics basis

- Physics-gap topics agreed with IO; specifications prepared by FSD with WP TE, WP PWIE, WP TM
- Kick-off 2 Jun 2026; meeting at ITER 6 Jul 2026: work plan, who does what
- Deliverables D1–D4 fixed; next meetings with IO: 2nd half of Jan 2027, summer 2027, Dec 2027 – progress, deliverables, amendments
- Topics: W sources and transport; fuel retention with boronised W; ICH-assisted start-up; disruption loads, SPI, runaways; ECH 2nd harmonic; plasma models and analysis workflows
- JT-60SA-related ITER gaps: via the Broader Approach–ITER arrangement
- Still being clarified with IO (feedback Oct 2026; details forwarded to the WP leaders):
  - IO staff and postdoc support per topic – 4 IO postdoc topics, ≥ 50 % of their time beyond Dec 2027
  - analysis workflows (equilibrium, core profiles, impurities): IMAS adaptation and focus
  - simulator validation (DINA, HFPS, SOLPS, JOREK) on AUG, WEST, TCV and JET data

A. Loarte (IO), meeting at ITER, 6 Jul 2026:

– ≈ 20 IO bilateral contracts / agreements with individual labs (e.g. FZJ, DIFFER, IPP, KUL)

– EUROfusion regarded as an important pillar of support

– bilateral and EUROfusion activities complementary

JT-60SA – status of the EUROfusion exploitation 2026

- Physics and operation:
  - W transition: physics basis; focus on required ECRF power (central vs off-axis deposition)
  - OP2 (2027): WP TE call for participation launched on 2 Nov 2026
- Resources:
  - JT-60SA exploitation 2026–27 among the PMU priority-1 items accepted by the GA (Oct 2026)
  - F4E SNE scheme: 9 experts in Naka in 2027 (WP TE 6, WP SA 3); 507 k€ EC approved by the GA
- EC and F4E:
  - ENER, RTD, F4E: EUROfusion the only organisation to ensure JT-60SA exploitation for EU scientific priorities
  - SNE scheme temporary – FP10 funding and deployment mechanisms for Japan needed
  - WP 2026–27 evaluation response: JT-60SA essential for the scientific readiness towards ITER

Integration into the EUROfusion programme remains challenging: Broader Approach legal framework with 2 Parties (Euratom, Japan) – no direct EUROfusion say in the JT-60SA organisation, interaction only through F4E

JT-60SA EUROfusion scientific priorities – C and W phase

C phase – updated high-priority items	W phase – high priorities (ITER satellite, towards FoaK)
1. Development and investigation of high-performance scenarios compatible with future W-PFCs	1. High-performance, long-pulse, core-edge-compatible scenarios with W-PFCs, including no-ELM regimes, in view of fusion reactors
2. Avoidance and mitigation of disruptions and runaways	2. Disruption-free and safe operation
3. Physics of fast ions and their impact on plasma confinement	3. Power and particle exhaust, including wall conditioning, W source and fuel retention control
4. Development and validation of high-level real-time control strategies	4. Energetic-particle physics in reactor-relevant fast-ion regimes

- FSD initiative, discussed across the FSD WPs (TE, SA, PWIE, TM); STAC feedback included; W phase accepted by STAC
- Communicated to F4E (C phase, May 2026) and the JT-60SA project (W phase); both presented at the 56th GA

BEST – proposed EUROfusion high-level scientific priorities

FSD proposal (31 Jul 2026), prepared with the WP leaders and WP TE TFLs; reviewed by STAC – minor comments

1. D-T alpha-particle and fast-ion physics at thermonuclear Q ≥ 1, towards burning-plasma conditions at Q ≈ 5
2. Reactor-integrated long-pulse D-T scenarios at low torque, incl. no-ELM regimes
3. Power and particle exhaust and PWI in an integrated full-W, D-T, long-pulse environment
4. Disruption avoidance, mitigation and real-time control in D-T at up to 7 MA

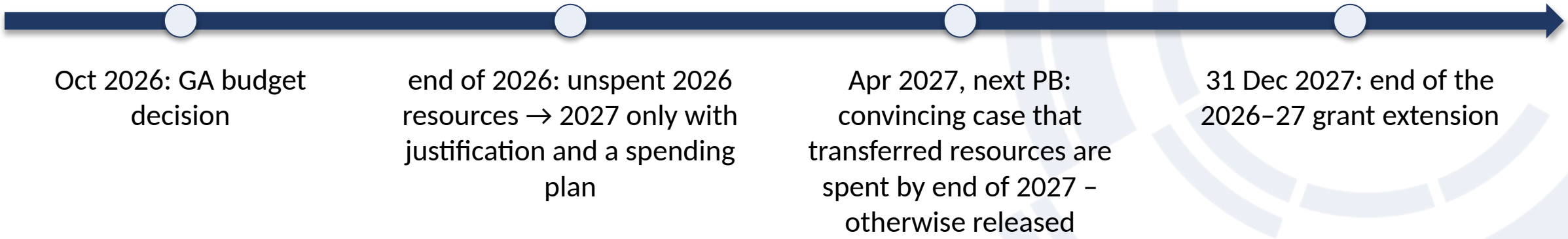
- Same four areas as the JT-60SA W phase, extended into the D-T / alpha-heated domain ahead of ITER D-T (2039)
- Highly desirable, not essential: JT-60SA remains the backbone; rights-based engagement (publication rights, full data access)
- Level of engagement (S0 monitoring → S3 embedded team) open; EC drafting an agreement with BEST

Presently blocked: publication procedure still to be approved by the private company BEST; publishing the science behind the research plan already agreed with ASIPP colleagues; ASIPP informed that the delay puts the collaboration at risk



Resources 2026–27 – transparency on use and transfers

- GA (Oct 2026): PMU priority-1 items accepted – JT-60SA exploitation funded; other items at the beneficiaries' risk if the EUROfusion budget falls short
- PLs and TFLs asked to justify transfers 2026 → 2027 and to flag resources unlikely to be spent – followed up in the biweekly FSD meeting with all WP leaders
- DTT: resources for the DTT Research Plan review (6 person-months, reserved 2024) released – start of operation delayed towards end of FP10



Aim: transparency on what can be delivered by end of 2027

Outlook – planned: readiness per high-level gap, as in WP STEL

- WP TE: SSRL per scientific objective since 2021 (6 levels) – origin of the approach, tied to the objective wording; WP PWIE: no SSRL yet
- Planned FSD activity towards FP10, ready in the first half of 2027: readiness per high-level gap, 9-level scale of the WP STEL gap analysis – FSD proposal as a starting point for discussion with WP TE and WP PWIE
- Research topics map onto gaps – which RT feeds which gap defined at work-plan level, e.g. for FP10

Research topics / objectives	High-level gap (stable across work plans)	Use
WP TE research topic (RT) – scientific objectives WP TE research topic (RT) – scientific objectives WP PWIE project – objectives	priority: high / medium / low SSRL: level 1–9 (WP STEL scale) investigation needs: a, b, c … means: theory, simulation, experiments, new devices, diagnostics, codes fed by: RTs / projects – mapping defined per work plan (e.g. FP10)	readiness towards ITER and FoaK comparable across WP TE, WP PWIE and WP STEL level changes traceable to evidence, independent of objective wording

phrasing may change with each work plan

Illustrative structure – FSD proposal as a starting point for discussion with the WPs

Items to be addressed in the first half of 2027

JT-60SA

- Integration into the EUROfusion programme – particularly important in view of FP10
- Broader Approach: legal framework with 2 Parties (Euratom, Japan) – EUROfusion interacts only through F4E
- JT-60SA science within the gap-based research topics – one agreed interface with the JT-60SA project

BEST

Level of engagement towards FP10

Scientific readiness

Gap-based structure for WP TE and WP PWIE towards FP10 – FSD proposal as a starting point for discussion with the WPs

Resources

Transfers to 2027 with a convincing spending case by the PB in April 2027

Backup slides

Backup: SSRL scale – WP STEL gap analysis (9 levels) vs WP TE (6 levels)

SSRL	WP STEL gap analysis (Apr 2026)	WP TE (since 2021)
1	Hypothesis / Emerging	Emerging
2	Conceptual understanding / Exploratory	Exploratory
3	Definition of requirements / Judgemental	Judgemental
4	Confidence gained but needs underpinning	Mature – needs underpinning
5	Partial validation / Mature needs support	Mature – needs support
6	Consolidated physics basis / Established	Established
7	Demonstration at reactor-like conditions	–
8	Established physics basis	–
9	Resolved gap / design impact	–

Levels 1–6 map one to one onto the WP TE levels; 7–9 need ITER and FoaK evidence

Backup: JT-60SA W phase – priorities and scientific objectives

High-level priority	Associated scientific objective
1. **High-performance, long-pulse, core-edge-compatible scenarios with W-PFCs, including no-ELM regimes, in view of fusion reactors**	Demonstrate and sustain high integrated performance (high H-factor, high βN, high f_BS), including no-ELM regimes, over current-diffusion and wall-saturation timescales (~100 s) at reactor-relevant ρ*, ν*; exploit the long-pulse capability to test W-PFCs under high-flux conditions, providing the basis to extrapolate to ITER Q≥5 steady-state and to define DEMO plasma parameters
2. **Disruption-free and safe operation**	Establish the physics and control basis for routinely disruption-free operation and reliable runaway-electron avoidance at high βN and high radiated fraction, as an ITER satellite, providing the operational basis required for FoaK and DEMO
3. **Power and particle exhaust, including wall conditioning, W source and fuel-retention control**	Demonstrate detachment and radiative power dissipation and impurity-seeding control compatible with sustained high-performance plasmas; establish the wall-conditioning strategy for operation between boronizations, and the control of tungsten sources, migration and fuel retention in a metal environment,moreover, the metallic dust production and conversion rate can be studied in ITER-relevant magnetic configurations at high fluence
4. **Energetic-particle physics in reactor-relevant fast-ion regimes**	Exploiting the 500 keV N-NB capability retained in the metal-wall phase, establish energetic-particle confinement and the control of fast-ion-driven instabilities (AE/EPM, kinetic RWM stabilization) at reactor-relevant fast-ion β and ρ_fast, including first-wall loss loads, and validate the EP transport models used for DEMO

Backup: BEST in the mix of devices (proposal, 31 Jul 2026)

Reactor-relevant research theme	BEST	JET (data)	SA-C	SA-W	AUG	WEST	TCV	MAST-U	Relevance for ITER / FoaK
1a · D-T alpha heating (Q ≥ 1)	◆	◐	○	◐ *	◐ *	○	○	–	High – only BEST pre-ITER
1b · Alpha-particle & fast-ion physics / instabilities	◆	◐	●	●	◐	○ §	○	◐	High
2a · Long-pulse operation (> 100 s), D → D-T	◆	–	●	●	○	●	–	–	High
2b · No-ELM / small-ELM scenarios, D → D-T	◆	◐	◐	●	●	○	◐	◐	High
3 · Power / particle exhaust & PWI in D-T (full-W at scale)	◆	◐	○	●	◐	◐	○	○	High
4a · Disruption & runaway-electron avoidance / mitigation in D-T (7 MA)	◆	◐	◐	●	●	◐	◐	○	High
4b · Real-time control in D-T long-pulse plasmas	◆ †	○	◐	●	● ‡	● ¶	●	◐	High

Symbols (role per theme, not a ranking): row tags: 1–4 = the four proposed BEST high-level priorities (1a/1b, 2a/2b, 4a/4b = facets of priorities 1, 2 and 4) · R = EU-retained return · ● = leading platform within the EUROfusion programme · ◐ = contributing · ○ = limited / supporting · – = not addressed · ◆ = extends the parameter space beyond the EU-accessible fleet · JET (data) = archived D-T data & experience (DTE1–3; device retired 2023; QCE / XPR with Ne seeding demonstrated in D-T) · SA-C / SA-W = JT-60SA carbon / W phase · FoaK = first-of-a-kind plant · TSVV = EUROfusion Theory, Simulation, Validation & Verification programme

Priority 1 (rows 1a–1b): alpha heating (row 1a) exists in no operating EU device – emulated via dominant central e-heating at low torque (◐ *); on alpha-particle & fast-ion physics (row 1b) JT-60SA is the leading EU platform (●, both phases): strong alpha-physics programme (D-^{3}He / p-B alphas, nα/ne ~ 10^{-4}, GRS development) and 500 keV N-NBI fast ions at reactor-relevant βfast / ρfast; BEST expands and complements with ITER-level alpha concentrations (~1 %) and real alpha heating – next otherwise at ITER DT-1 (2039)

Priorities 2–4 (rows 3–7): complementary – physics basis and development led by JT-60SA and the EU fleet (●); BEST adds the D-T end of the parameter space (◆). TCV / MAST-U on exhaust (○): detachment / alternative-divertor physics, C walls – supporting, not full-W PWI. WEST: designed for long pulse (2a ●) but first H-mode only in 2026 (2b ○); MAST-U: no-ELM regimes (2b ◐) but short-pulse (2a –)

* alpha-heating emulation via central e-heating at low torque (done on AUG; foreseen for the JT-60SA W phase: +2–3 gyrotrons) † RT control: published EU methods only; development on JT-60SA + AUG/WEST/TCV/MAST-U ‡ AUG: demonstrated RT control – X-point-radiator / detachment feedback (Bernert et al., Nucl. Fusion 61 (2021) 024001), NTM stabilisation via RT-steered ECCD § WEST: ICRF fast ions – contribution grows once a fast-ion loss detector (FILD) becomes operational (in FP10) ¶ WEST: RT control of long-pulse operation – 1337 s world-record discharge (Feb 2025) under sustained RT feedback incl. IR-based wall protection