FSD Science Coordination Meeting – preparation AWP 2024 for WP TE

15/06/2023

Marco Wischmeier, E. Joffrin, M. Baruzzo, A. Kappatou,
D. Keeling, A. Hakola, B. Labit, E. Tsitrone, N. Vianello

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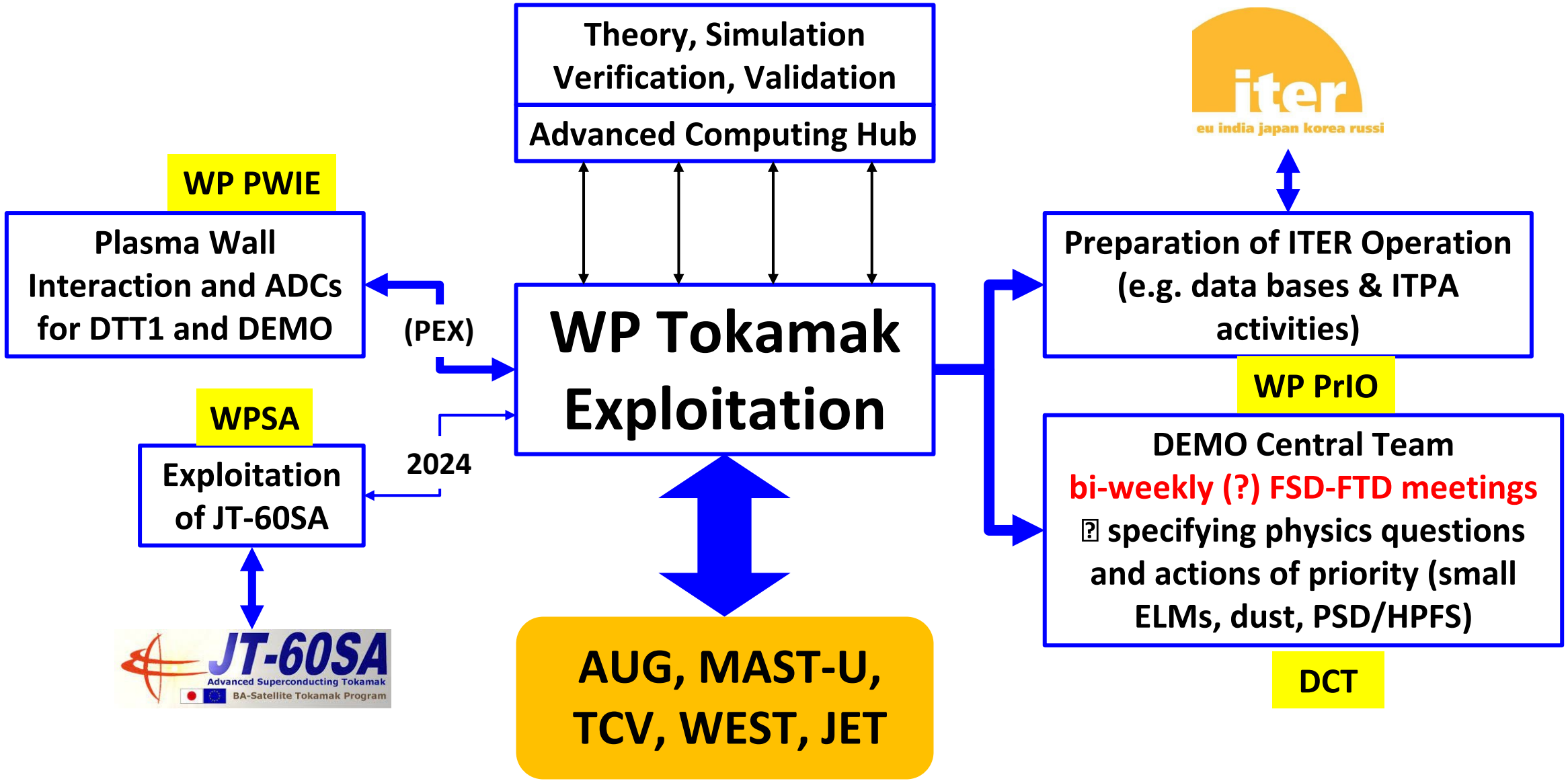
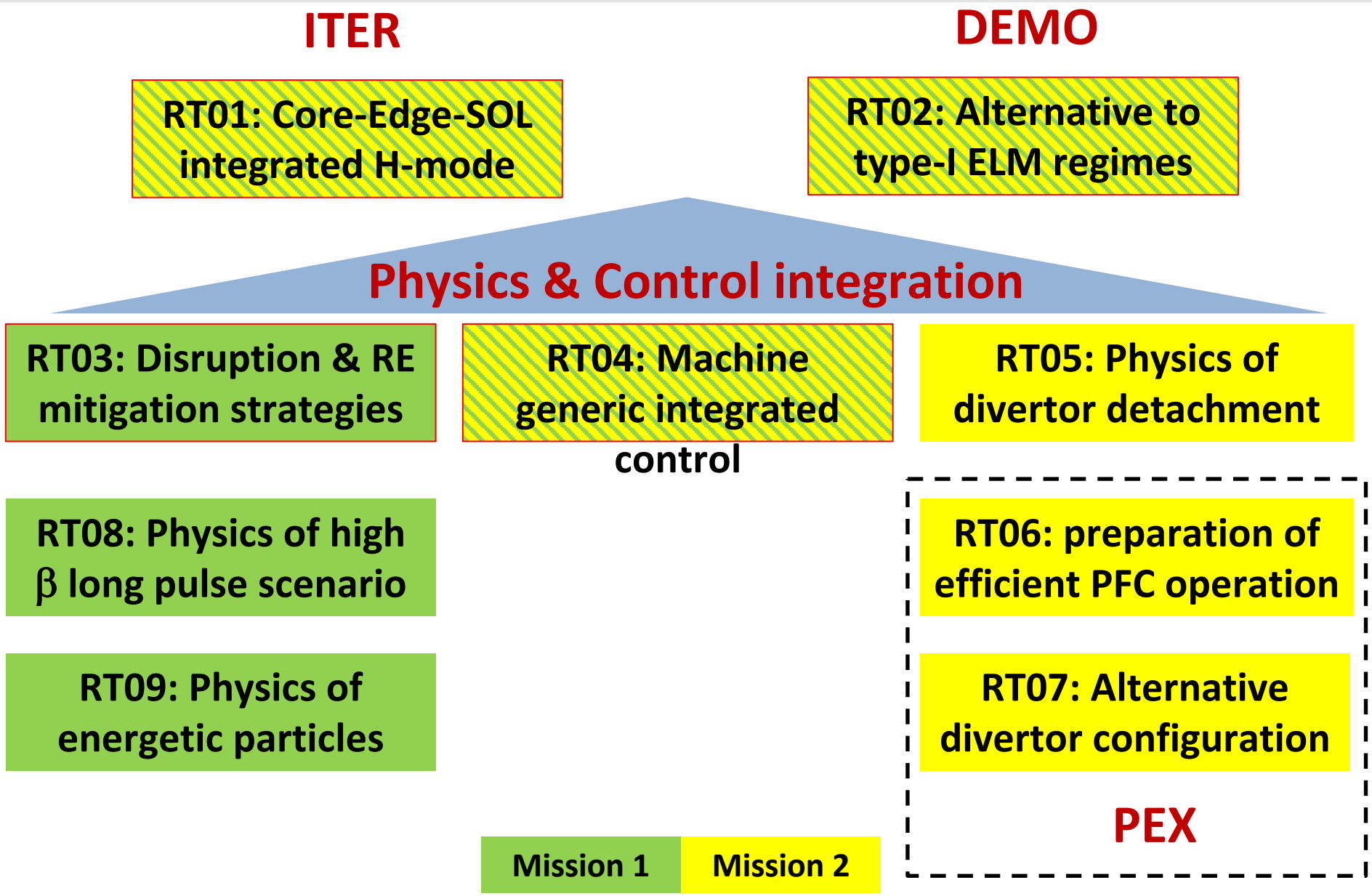
WP TE in FSD with overarching priorities: ITER & DEMO & PEX



WP TE is currently structured into 9 Research Topics + DTE2 A&M



Present status of RTs, Research Topic Coordinators, TFLs and other relations foreseen until end 2023

RT22-01	L. Frassinetti	C. Giroud	S. Wiesen	D. King	**AK**/NV/MW	IOS/PEP/DSOL	JET,TCV, MAST-U, WEST	
RT22-02	M. Faitsch	M. Dunne	O. Sauter	E. Viezzer	**BL**/*AK/MW*	PEP	JET, TCV, MAST-U, WEST	DCT
RT22-03	O. Ficker	U. Sheikh	C. Reux	S. Jachmich (M. Lehnen)	**AH**/MB/EJ	MDC	JET, TCV, WEST	
RT22-04	~~F. Felici~~	B. Sieglin	L. Piron		**MB**/BL/EJ	IOS	JET, TCV, MAST-U, WEST	PrIO
RT22-05	H. Reimerdes	M. Bernert	D. Brida	N. Fedorczak	**NV**/ET/MW	DSOL	JET, TCV, MAST-U, WEST	
RT22-06	Y. Corre	A. Winddowson	K. Krieger		**ET**/AH/EJ	DSOL	JET, WEST	PWIE
RT22-07	C. Theiler	K. Verhaegh			**NV**/AH/MW		TCV, MAST-U	PWIE
RT22-08	A. Burckhart	C. Piron	R. Dumont		**DK**/MB/EJ	IOS	JET, TCV, MAST-U, WEST	DCT
RT22-09	J. Galdon	S. Mazzi	Y. Kazakov		**DK**/AK/MW	FP	JET, TCV, MAST-U, WEST	

Replacement for M. Vallar

Call for replacement

Definition of Subjective Scientific Readiness Levels (Sep. 2021) – used *to reflect on status and identify progress in time*

Level	
Emerging	Little or no understanding yet on WP TE devices
Exploratory	Physical process is assessed on WP TE devices, transposing to ITER or DEMO is uncertain
Judgemental	Controlling physical processes has been assessed on WP TE devices, but extrapolation to ITER/DEMO requires scalable parameters and further investigation
Mature – needs underpinning	Good understanding of controlling physical processes on WP TE devices, but major uncertainty in view of transposing ITER/DEMO
Mature – needs support	A good understanding has been achieved on WP TE devices, further research exploring ITER or DEMO relevant parameters
Established	Understanding is well developed and can be applied to ITER or DEMO

- not been used so far for resource prioritization & quantification (as agreed in 09/2021)
- can be applied for device prioritization and device availability analysis for progress
- Change of SSRL currently this is evaluated as part of the drafting of the level 3 reports on a yearly basis jointly between RTCs and TFLs

List of Research Topics and scientific deliverables that changed SSRL as of March 2023

Level	Emerging	Exploratory	Judgemental	Mature-needs underpinning	Mature-needs support	Established

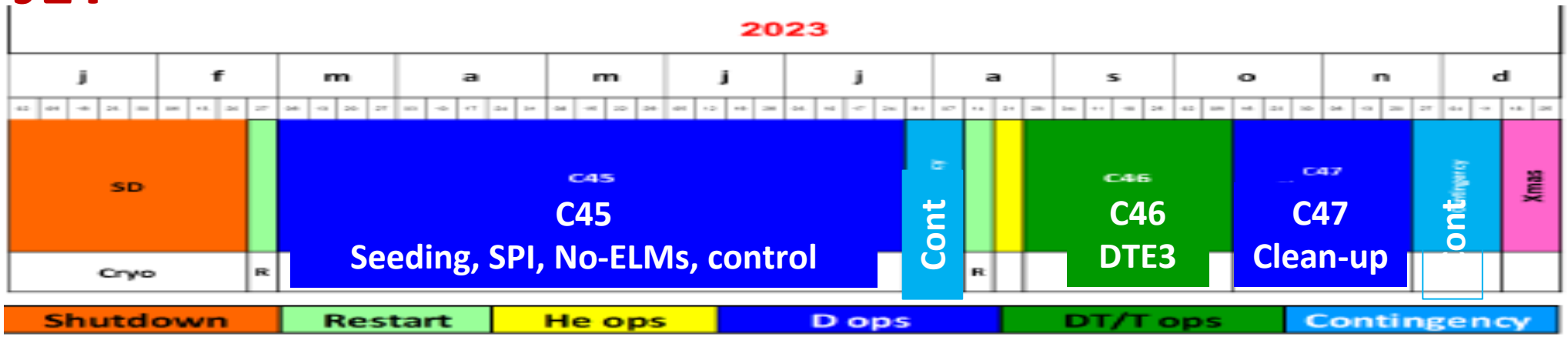
RT	Deliverable	Description
RT22-03	D1	Optimize disruption mitigations by single and multiple shattered pellet injection (SPI) at high plasma current and energy content in an all-metal environment to validate the ITER disruption mitigation strategy
	D3	Characterize/optimize the RE impact mitigation schemes and flushing effect with different deuterium injections techniques
	D4	Determine the physics mechanisms generating run-away electrons in the current quench and in the plasma start-up phase
	D5	Interpretative modelling of disruption mitigation dynamics (TSVV-8, TSVV-9) and prediction for ITER
RT22-04	D4	Develop robust strategies to optimize error field corrections supported by modelling
	D5	Optimize plasma start-up and current ramp-up schemes supported by modelling in ITER like scenarios
RT22-05	D5	Quantify the degree of ELM heat load mitigation achievable by impurity seeding, investigating the dependences on relevant machine parameters
	D6	Assess the evolution of detachment under slow transients (L-H transitions, sawtooth, loss of impurity seeding)
RT22-06	D3	Quantify material erosion sources from metallic walls under ITER relevant plasma conditions (including high power and impurity seeding plasmas) and determine material migration pathways
RT22-07	D1	Determine detachment onset, radiated power fractions, and core compatibility in H-mode for the alternative divertor configurations (ADCs) and characterize ELM activity in view of pedestal, heat flux and control in ADCs
RT22-09	D7	Identify AE control actuators and preliminary assess for ITER

TSVV: Code usage inside WP TE

Code Name	Code Contact Person	TSVV1	TSVV2	TSVV3	TSVV4	TSVV5	TSVV6	TSVV7	TSVV8	TSVV9	TSVV10	TSVV11
BIT1/BIT3	David Tskhakaya	RT22-01, RT22-02, RT22-06		RT22-01, RT22-02, RT22-06								
DREAM	Mathias Hoppe									RT22-03		
EBC												
EIRENE						RT22-05, RT22-07						
ERO2.0	Juri Romazanov							RT22-06				
EUTERPE												
FELTOR		RT22-01, RT22-05		RT22-01, RT22-05								
GBS	Paolo Ricci	RT22-07, RT22-05	RT22-07, RT22-05	RT22-07, RT22-05								
GENE	Tobias Görler	RT22-01, RT22-02	RT22-01, RT22-02									
GENE-X												
GO 1D										RT22-03		
GRILLIX												
GYSELA	Virginie Grandgirard	RT22-01										
GyselaX												
HAGIS												
HFPSeu	Francis Casson											
HMGC												
IMEP												RT22-01
JINTRAC	F. Casson, C. Bourdelle											RT22-02, RT22-01
JOREK	Matthias Hölzl								RT22-03, RT22_02	RT22-03, RT22-02		
LIGKA	Philipp Lauber										RT22-09	
LUKE										RT22-03		
MEMOS-U	Svetlana Ratynskaia							RT22-06				
MIGRAINE												
ORB5												
PICLS												
SDTrim												
SOFT												
SOLEDGE	Hugo Bufferand	RT22-01, RT22-05, RT22-06, RT22-07	RT22-01, RT22-05, RT22-06, RT22-07	RT22-01, RT22-05, RT22-06, RT22-07								
SPICE (2D/3D)								RT22-06				
XTOR												
ASTRA												RT22-02
TGLF												RT22-02
TRANSP												RT22-02

- About 40% of the codes addressed in TSVVs are not used in WPTE.
- Some of the used codes still do not have a contact person or the contact person is not known to WP TE
- Some validation and/or interpretative modelling activity in internal campaign (e.g. AUG & QCE)
- How to proceed from here?

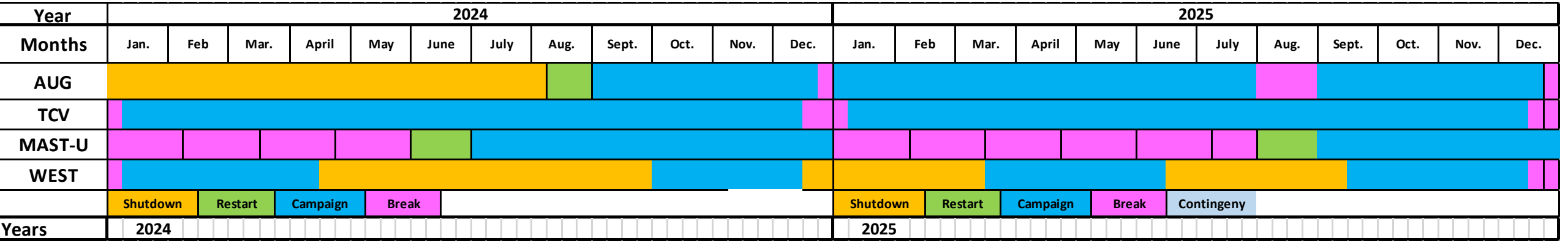
End of JET



Contingency	DTE3	C47	C48
2 weeks	**7 weeks**	**6 weeks**	**3 weeks**
TFLs will propose a timeline for the following cases: • For significant machine loss time and DTE3 milestones have not been achieved • More experiment within the RTs if machine loss time is within the built-in contingency and milestones are met	list of DT-targets established with their pirority and good pulses RTCs working now on the gas and neutron requirements • 5th July: Outline of campaign at JPEC with number of pulses, tritium and DT neutron budget per target • 17th of July: last review of the DTE3 content • 19th of July: Timeline approval	**TCU group**: Operator in charge of day-to-day management of the activities, with a restricted group of people (TCU group). This should not be exclusively PWI oriented, but have some expertise on other fields as well. ❑ Participation of WPTE to the C47 campaign ❑ Participation of WPTE to the operation (SLs, DCs) ❑ WP-TE to nominate 1-2 TFLs to be part of the TCU group : DK and AH We are also asking to have a couple of RTCs.	Still to be defined: TFLs will gather the ideas in the course of C46.

JET data analysis and modelling to be included at adequate level in the 2024-2025 programme, including data validation

Expected availability of devices in 2024 / 2025



TCV: semi-continuous operation; installation of tight baffled long legged divertor in/for 2nd half of 2025, present domestic campaign continues until end of 2024; new call for 25/26 expected in fall of 2024

AUG: Call for proposals for 24-25 in May ‘24 with Ringberg in June ‘24; Should not expect to be able to operate ADCs routinely or in feed-back control in 2024 – scenario development and RTC commissioning required and AUG expects this to be shared with TE…; AUG operation from Sep ‘25 until July ‘26;

WEST: continuous operation in Dec 23-Jan-March 2024, then usual 2 campaigns/year. ECRH expected by end 2024

PMU: Need to confirm fraction / overall machine time on devices for 2024 and later for 2025

Organizational strategy for 2024 & 2025 1/2

Propose to keep present C3 Research Topics and the associated scientific objectives

- DEMO priorities unchanged
- ITER re-baselining: *do not expect major changes in principle physics addressed* inside mission 1 and mission 2 – possibly shift of allocated machine time resources – might have an impact only in 2025 but depends on which needs are how urgent for ITER
- Calls will cover JET data validation (could be together with call for participation), analysis and interpretation of C44-C48 campaigns as well as analysis of C3 data on TCV, MAST-U & WEST and preparation, execution and analysis of experiments in 2024 (2025) in ASDEX Upgrade, MAST-U, TCV and WEST
- creating 2 new *very specific RTs for DTE2 continuation inside DTE3 and C47* (clean up and more)

- Defined priorities per device following guidance by SSRL table and which machine can contribute most to provide progress including the (present) ITER & DEMO priorities and the PEX exploitation (AUG new upper divertor, TCV baffles, MAST-U Super X and WEST ITER like components)
- While the DTE3 targets have been defined to achieve scientific objectives of RTs and milestones defined for JET C45 ➔ would like to designate *2 or 3 of the DTFLs as DTE3 "commissioners" that guarantee a special focus of the DTE3 exploitation across RTs*

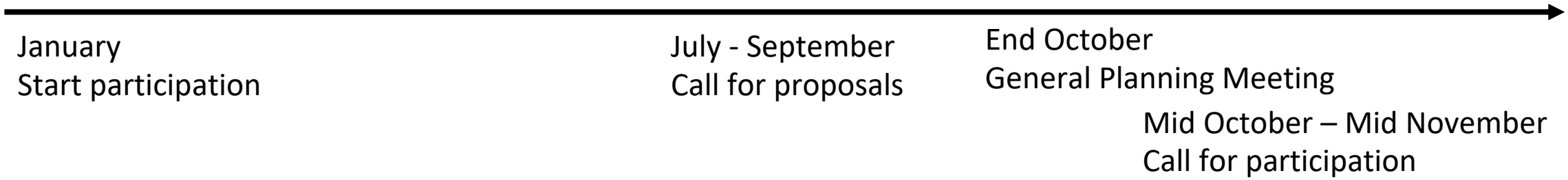
Timeline for 2024 & 2025

Propose to have annual calls for proposals and participation in view of machine schedules and programmatic uncertainties – allows corrections for 2025

- Call for proposals for calendar year 2024: end July to end September 2023
- Call for proposals for calendar year 2025: end July to end September 2024

- "Virgin" Call for RTCs simultaneous with call for proposals:
  - unclear if to be appointed for one year or 2 years
  - Without JET operating the RTCs for some RTs might be less coherent in organizing cross device activities
- Call for participation for 2024 Mid October to Mid November 2023
- WP TE programme meeting in week of October 30th (after IAEA and ITPA weeks)
- Selection starts last week Nov would leave 4 weeks till December break
- Start participation January (WEST & TCV) – maybe with some delay in start of TE contribution but unclear

Timeline proposed for 2024 and 2025



As example: Anticipated contribution of devices to advancing the SSRL of the scientific objectives for the Research Topics 22-01 & 22-02 relevance to ITER/DEMO/PEX

Research Topic	Scientific objectives	Status (March 2023)	JET analysis 2024	JET DTE3 relevant	ASDEX-U 2024	ASDEX-U 2025	TCV 2024	TCV 2025	MAST-U 2024	MAST-U 2025	WEST 2024	WEST 2025	ITER priority (talk EJ FSD)	DEMO priority (talk EJ FSD)	PEX relevance
RT22-01: Core-Edge-SOL integrated H-mode scenario compatible with exhaust constraints in support of ITER	**D1:** Develop stationary high-power H-mode scenario at low core and pedestal collisionalities compatible with detached divertor	Judgemental					can contribute but likely lower impact	can contribute but likely lower impact	can contribute but likely lower impact	can contribute but likely lower impact	even with H-mode - XPR/CRD in 05/07	even with H-mode - XPR/CRD in 05/07	2		
	D2: Provide physics-based cross-field transport coefficients to TSVVs (1, 3, 4 and 11) for turbulence modelling	Exploratory													
	D3: Determine the impact of different impurity mixes for partially detached divertors in high power operations in view of ITER radiative scenarios	Judgemental*					low impact as no metal wall	low impact as no metal wall	low impact as no metal wall	low impact as no metal wall	low impact even with H-mode	low impact as no metal wall	2		
	D4: Assess pedestal performances with large SOL opacity	Judgemental											3		
	D5: Determine pedestal stability and transport characteristics at large plasma current (>3MA)	Exploratory											2		
	D6: Quantify impurity screening for high temperature pedestals	Exploratory											2		
	D7: Assess the compatibility and stability with X-point radiator regimes with confinement	Judgemental												1	
RT22-02: Physics understanding of alternatives to Type-I ELM regime	**D1:** Quantify turbulent and MHD driven transport in the vicinity of the separatrix and implications for predictions for ITER and DEMO	Exploratory												1	
	D2: Quantify first wall load in no-ELM scenarios and provide model for SOL transport extrapolation	Judgemental									(a)	(a)			
	D3: Extend the parameters space of no-ELM scenarios to large Psep/R and/or pedestal top collisionallities relevant for ITER and DEMO	Exploratory			QCE and EDA are quite mature on AUG. More time on QH-mode? Will I-mode be revisited with upper divertor?		QH-mode might be search for with the new NB (more energy)		In principle QCE and QH are of interest on this device		(a)	(a)		1	
	D4: Determine the key physics mechanisms regulating edge transport in order to access no-ELM regimes	Exploratory									(a)	(a)		1	
	D5: Determine access window and physics understanding for RMP ELM suppression and its compatibility with ITER FPO scenarios	Judgemental											2	1	
	D6: Quantify the overall performance of negative triangularity plasmas in view of DEMO	Exploratory													

Table for all RTs exists

Device relevance color coding:	
	essential for progressing SSRL
	beneficial for expanding and confirming understanding
	no major input for progress expected

Further evolution of SSRLs in time…

Are there SSRLs where we might expect not to make any major progress with the available devices?

- In 2024/2025: With *low SSRLs most devices likely able to contribute* to solidify the knowledge by providing more data or different combinations of data and to even increase the SSRL (e.g. RT22-01 & RT22-02)
- In 2026/27: if a majority of the SSRLs change increase ➔ further progress in SSRL for several scientific objectives becomes possibly too challenging (e.g. RT22-04)
- *Which are the maximum SSRLs all devices together can reach by end of 2027?* – Analysis has not been done → to be considered in view of the facility review?
- How does outcome of TSVVs impact the SSRLs & how to quantify the uncertainty of predictions for ITER / DEMO
- Lack of devices for progress to increase the SSRLs towards ITER/DEMO? Are there gaps in the physics understanding?
- What will the impact of DTT and JT-60SA or any of the facility review upgrades be in this context?

Long term impact of termination of JET, delay of JT-60SA and accessibility to remaining 4 devices (1/2 scientific)

Some for the present objectives are likely to be impacted. Some elements:

- ❑ Objectives related to the pedestal behaviour at high plasma current and high opacity in the baseline scenario
- ❑ Objectives related to the real time control (kinetic control or disruption control) will have less relevance for transfering the knowledge to larger device.
- ❑ Objectives related to integration of scenarios with control elements and power and particle exhaust (low pedestal ν and high SOL collisionaility)

Long term impact of termination of JET, delay of JT-60SA and accessibility to remaining 4 devices (2/2 further consequences)

Some for the present objectives are likely to be impacted. Some elements:

- ❑ LIBS and long term sample analysis may require specific actions during JET decommissioning (starting in in 2024). To be discussed with PWIE
- ❑ Training of new operators on large devices or tritium plant for contributing to ITER may be affected by the loss of the facility present at JET. How does this affect our actions for the preparation to ITER (see EFPW)?
- ❑ Validation of the JET data must continue at least until the end of 2025. This will involve UKAEA resources and EUROfusion (WPTE) resources.
- ❑ Exploitation of existing data from tokamak devices – a lot of manual work to develop and validate databases → possible role or effort by AI possible?

Expected status of Grant deliverables (1/2) in 2023-2025

TE.D.01	Successful establishment of Type I ELMy H-mode scenario with dominant electron heating for the first safe operation of ITER.	Dec. 2021	
TE.D.02	The effect of total flux expansion and snowflake configurations in environments with intrinsic impurities on power dissipation quantified.	Dec. 2021	
TE.D.03	High fluence operation on actively cooled divertor at WEST assessed, and documented.	Dec. 2022	Dec 2023
TE.D.04	Achievement of ELM control during the transient phases (I_p ramp-up and down, entering and exiting H-mode etc.) integrating ITER operational constraints.	Dec. 2022	
TE.D.05	The role of turbulent and MHD driven transport in the vicinity of the separatrix for the stability of the pedestal quantified and the implications for predictions for ITER and DEMO reported.	Dec. 2022	Dec 2023
TE.D.06	Achievement of state-observer based control of radiative detachment using multiple diagnostics.	Dec. 2023	Likely with JET experiments
TE.D.07	The disruption and run-away electron mitigation efficiency by single and multiple shattered pellet injectors on different sized devices to validate the ITER Strategy assessed and documented.	Dec. 2023	JET 2023; RT22-03 several deliverables adressing SPI utilization
TE.D.08	Balance between gross and net erosion of W under different operational conditions in full-metallic toroidal devices (comment in PMU file: Quantify material erosion sources from metallic walls under ITER relevant plasma conditions (including high power and impurity seeding plasmas) and determine material migration pathways)	Dec. 2023	Might move to 2024 or even 2025 – should be completed by 2023 – better definition of the target FSD

Delayed compared to originally foreseen due date

Expected status of Grant deliverables (2/2) in 2023-2025

TE.D.10	The role of electron and ion heat channels and plasma rotation on the access to H-mode for hydrogen, helium and mixed plasmas in view of the ITER non-active phase quantified.	Dec. 2023	Data exists, analysis is lacking,- Phd from McDermott (Benedikt), role of rotation, JET limited CXRS data – we are not fully aware if on time or not; simulations using TRANSP/ASTRA to determine if Qi scales with F. Ryter scaling simulations ongoing; A&M of DTE2 feeds into this GD
TE.D.12	The physics basis for the decision for an alternative divertor configuration for DEMO.	Dec. 2024	Dec 2025 in view of AUG delay? Link to the FTD Gate review currently scheduled for end of 2024 might be moved to 2025 might still inform DTT?
TE.D.13	Recommendation on the seeding impurity mix in view of a future reactor.	Dec. 2024	JET data from 2023 – experiments at high current – potentially achievable if we get some interpretative modelling
TE.D.14	The radiation asymmetry during disruption mitigation, and SPI disruption dynamics using improved power balance, radiation diagnostic capabilities and fast cameras characterized, and documented.	Dec. 2024	Dec 2025 in view of AUG delay? – need to find out if the MP coils on AUG can be used for investigating the asymmetry - tbc

TE.D.11 and TE.D.15 undergoing cancellation

Expected additional resources

- JET: C44/C45/DTE3/C47/C48 analysis & interpretation: 24 ppy for 2024-2025 (based on DTE2 A&M analysis that had been allocated) – assessment underway of currently available budget
- JDC: JET data validation and associated resources currently being investigated by UKAEA/FSD-PMU/TFLs (probably likely larger than 2 ppy, t.b. assessed based on J. Bernardo's presentation in JDC meeting from 09/06/23)

Further items for discussion in view of relation of WPTE with other WPs and topics in FSD (I)

- WPSA:
  - Long term integration of scientific exploitation of JT-60SA with WPTE – coordination of priorities in view of mutual gaps and JT-60SA Research Plan → FP10? Will the output of JT-60SA merge into the SSRLs?
- WP PrIO:
  - progress on various databases – pedestal database in the process of deployment
  - Water activation – currently being installed on JET
  - Break down - common scientific meeting coordinated by RT04 RTCs with actions
- WP PWIE:
  - ADCs: Interaction between PWIE and RT22-07 on needs and requirements could be improved, what is the possible impact on the role of ADCs in the gate review for 2024? (left over from FSD meeting in June 2022)
  - Sample removal from JET and LIBS (budget sufficient?)

Further items for discussion in view of relation of WPTE with other WPs and topics in FSD (II)

- WP 7X:
  - Progress on 3D equilibria progress;
  - Exhaust: no common activities but should foster the scientific exchange to serve as a resonator/feedback as only other device for W7-X is LHD;
- TSVVs:
  - thrusts established – fairly loose connection to work programme/exploitation of TE
  - TE generally lacks sufficient funds for interpretative modelling – allocated resources often symbolic as an incentive hoping that participants and Rus cover the rest
  - Facilitators provide platform for exchange but connection to WPs remains unclear (unchanged since 2022)
- DTT:
  - No explicit role at this stage
- Facility Review:
  - No explicit input or feedback requested at this stage – *what is expected from the TE TFLs and over which time scale and in which period of time?*
- EU Roadmap revision
  - No explicit input or feedback requested at this stage
- ITER:
  - Required EUROfusion input for ITER re-baselining?

Publication plan for 2024 and beyond…

- T.b.d.

Back up

C2: List of Research Topics and scientific deliverables that changed SSRL as of March 2023

Level	Emerging	Exploratory	Judgemental	Mature-needs underpinning	Mature-needs support	Established

RT	Deliverable	Description
RT01	D1	Assess the core transport properties of IBL scenarios with dominant electron heating (low nu*, low rotation) and He seeding.
	D2	Improve the understanding of MHD stability and impurity accumulation during the transient phases of the H-mode
RT02	D4	Improve predictive capabilities of pedestal performance with coupled SOL/pedestal integrated modelling
	D5	Estimate the impact of radiative impurities on the H-mode access
RT05	D1	Determine the conditions including density increase by pellets for the damping physics mechanisms generating run-away electrons after the thermal quench.
	D2	Determine the physics dependencies including heating, shape, and density for generating run-away electrons in the plasma start-up phase
	D3	Develop and exploit measurement tools including (e.g., energy spectrum, density) for characterizing run-away electron beams.
RT06	D1	Establish RMP ELM suppression on MAST-U and compare to AUG.
	D3	Determine access window to RMP ELM suppression and its compatibility with low torque, dominant electron heating, and radiative divertor for ITER FPO and DEMO
	D4	Quantify the influence of 3D magnetic perturbations (2021) and transport of impurities (2022) on kinetic modelling of RMP ELM suppression for extrapolations towards ITER and DEMO.
	D5	Determine effectiveness of ECRH / ECCD-driven ELM mitigation for DEMO
RT07	D1	Investigate power exhaust and detachment with simulations and in experiments in AUG and TCV
	D2	Advanced MHD equilibrium and stability analysis of TCV and AUG plasmas.
	D3	Develop similar scenarios in TCV and AUG to support iDTT design
	D4	Provide answers on the plasma core confinement properties (density limit, plasma current limit, ...) to the EUROfusionAd-hoc Group ("Proof of principle Phase")
RT09	D3	Assess the compatibility of both regimes with various radiative conditions (ITER/DEMO conditions)
RT10	D1	Determine fast-ion characteristics, plasma performance, and transport in ICRF-heated scenarios in multiple machines in preparation for ITER PFPO and FPO operations.
	D2	Provide essential diagnostics information for the characterization of confined and lost fast ions in plasmas relevant for ITER PFPO and FPO
	D3	Quantify Ti heating and core turbulence stabilization by ICRF-generated fast ions in view of ITER and DEMO
	D4	Integrate the available heating, fast-ion and transport modelling tools for interpretation of experimental results in view of ITER and DEMO.
RT11	D1	Assessment of fast-ion transport and losses induced by MHD perturbations such as ELMs, NTMs, Sawtooth, Alfvén Eigenmodes and other relevant continuum fast-ion driven fluctuations.
RT12	D3	Identify, define and test the required control schemes for robust operation
	D4	Compatibility of long pulse (> several resistive time) with the boundary interface with high-performance core.
RT13	D1	Determine existence diagram and improve under-standing for X-point radiation on all WP TE devices in comparable scenarios in H-mode.
	D2	Identify the stability of X-point radiator using available analytical models and numerical methods in conjunction with experimental data.
	D3	Demonstrate reliable (multi-sensor) detachment control schemes in multiple devices
	D4	Demonstrate exhaust-compatible ramp-up/-down into detachment (including L-H transition) for at least one device
RT14	D5	Measure divertor heat loads and assess power/energy balance in attached & detached divertor operation.
RT15	D3	Quantify particle and heat load in the near and far SOL under different confinement regime (including no-ELM regimes) and divertor recycling state.
	D5	Determine filament dynamics dependence on separatrix and divertor condition (ne,sep, collisionality, shearing, αt, recycling state) and how it impacts the near and far SOL transport