Preparation of ITER Operation, WPPrIO Project Board#2 2021-08-11

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WPPrIO: High level objectives

- **Contribute to lay the foundation of a coordinated significant EUROfusion participation in the ITER team benefiting from the strength of the EUROfusion programme in operation, technology and simulation**

- **Integrate Physics and Engineering Optimization in line with the Roadmap priorities**

- **Implement some of the recommendations[*] on "EUROfusion role in ITER operation and scientific exploitation"**

*) EUROFUSION GA (20) 32 - 4.7 - ITER White Paper Report WG1 Issue 1 10-Dec-2020 (Decision).docx and EUROFUSION GA (20) 32 - 4.7 - ITER White Paper Report WG2 Issue 3 7-Dec-2020 (Decision).docx

Recommendations* on "EUROfusion role in ITER op. & scientific exploitation", link with DEMO and PrIO contributions

WPrIO contribution

Pending resources

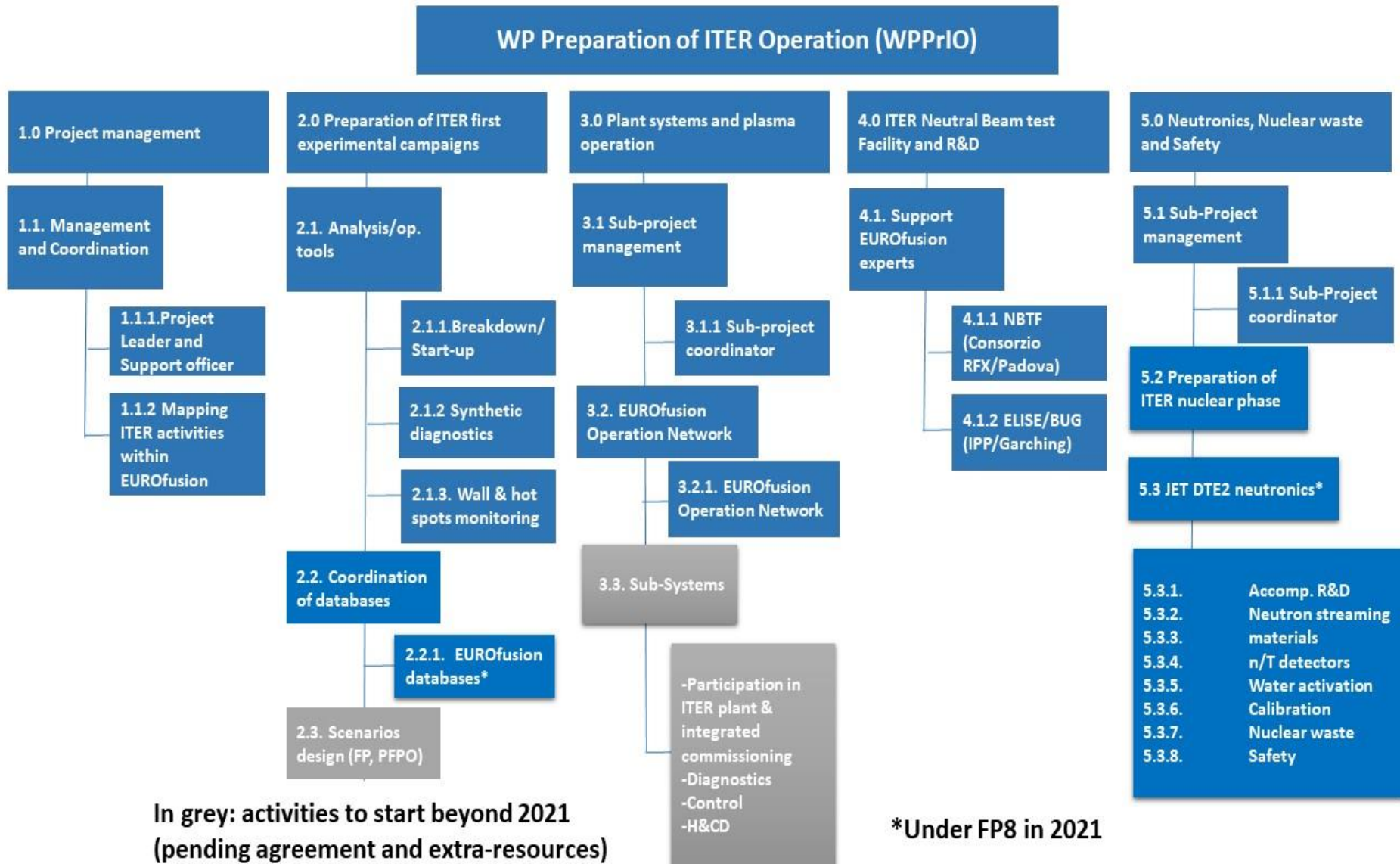| Sub-systems	Required involvement for EU implication in ITER operation	Impact level on the EU DEMO design
TF & PF Magnets and Cryo-plant	*** in commissioning phase (* during full operation)	++ (for DEMO design)
Divertor & PFCs	***	++
Tritium Plant	***	+++
Breeding Blanket System	***	+++
H&CD: Neutral Beam	*** (NBTF)	+++
Diagnostics	***	+++
Control and Analysis/operational/simulation tools	***	++ (+++ for some control aspects)
H&CD: Electron Cyclotron	**	++
H&CD: Ion Cyclotron	** (present operation in present facilities)	+
Neutronics, Waste and Radiological Protection	**	+++
Vacuum Vessel	*	+
Remote Handling Equipment	*	+
Vacuum Pumping & fueling	*	+
Building and Electrical Power Supply & Distribution System	*	+++ (for DEMO design)

(+++): Unique, (++) High, (+) Significant

(***) Strong: Organized team with defined commitments, (**) Organized team, (*) Expertise for follow-up

4 High level scientific objectives

WP Preparation of ITER Operation (WPPrIO)

1.0 Project management

1.1. Management and Coordination

- 1.1.1.Project Leader and Support officer
- 1.1.2 Mapping ITER activities within EUROfusion

2.0 Preparation of ITER first experimental campaigns

2.1. Analysis/op. tools

- 2.1.1.Breakdown/ Start-up
- 2.1.2 Synthetic diagnostics
- 2.1.3. Wall & hot spots monitoring

2.2. Coordination of databases

- 2.2.1. EUROfusion databases*

2.3. Scenarios design (FP, PFPO)

3.0 Plant systems and plasma operation

3.1 Sub-project management

- 3.1.1 Sub-project coordinator

3.2. EUROfusion Operation Network

- 3.2.1. EUROfusion Operation Network

3.3. Sub-Systems

- -Participation in ITER plant & integrated commissioning
- -Diagnostics
- -Control
- -H&CD

4.0 ITER Neutral Beam test Facility and R&D

4.1. Support EUROfusion experts

- 4.1.1 NBTF (Consorzio RFX/Padova)
- 4.1.2 ELISE/BUG (IPP/Garching)

5.0 Neutronics, Nuclear waste and Safety

5.1 Sub-Project management

- 5.1.1 Sub-Project coordinator

5.2 Preparation of ITER nuclear phase

5.3 JET DTE2 neutronics*

5.3.1.	Accomp. R&D
5.3.2.	Neutron streaming
5.3.3.	materials
5.3.4.	n/T detectors
5.3.5.	Water activation
5.3.6.	Calibration
5.3.7.	Nuclear waste
5.3.8.	Safety

In grey: activities to start beyond 2021 (pending agreement and extra-resources)

*Under FP8 in 2021

2021 Milestones/Deliverables and 2022 Activities

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2021 Milestones and Grant Deliverables

no.	Milestones	Due Date
PRIO.M.01	All existing components of the European Plasma Simulator (Python workflow) hosted on the EUROfusion Git (TSVV11 responsibility)	Dec. 2021
PRIO.M.02	First release of a user friendly interface for the European Plasma Simulator (Python workflow) (WPAC and TSVV11responsibility)	Dec. 2021
PRIO.M.08	Assessment of the EUROfusion human resources requirements and their implementation for the efficient EUROfusion participation in the NBTF completed	Jun. 2021
PRIO.M.09	Commission the new CW power supply on ELISE facility completed	Jun. 2021
PRIO.M.10	Installation and commissioning of CW diagnostic calorimeter on ELISE facility completed	Dec. 2021
PRIO.M.13	Prioritisation programme for 2022-2025 of activities in support of neutronics and safety for ITER	Dec. 2021

no.	Deliverables	Due Date
PRIO.D.11	Report on EUROfusion participation in ITER NBTF, ELISE and BUG activities	Dec. 2021

2022 Milestones and Grant Agreement Deliverables

	Milestones Table
PRIO.M.03	Establishment of the EUROfusion Operation Network (June 2022)
PRIO.M.04	Coupling of existing breakdown/burn-through models to the European Plasma Simulator (together with TSVV11) (Dec. 2022)
PRIO.M.14	Preliminary analyses of measurements and simulations of JET nuclear quantities (neutron flux, dose rate, neutron induced activation, radiation damage) in DT (Dec. 2022)
PRIO.M.15	n/T validated data with detectors for the breeder blankets at JET during DT (Dec. 2022)
PRIO.M.16	Completion of collection of Occupational Radiation Exposure and waste data (Dec. 2022)
PRIO.M.17	Completion of calibration verification at JET in DT operations (Dec. 2022)

	Deliverables Table
PRIO.D.01	European Plasma Simulator (Python workflow) released to the EUROfusion community including all available IMAS modules and a user friendly interface (Responsibility TSVV11) (Dec. 2022)
PRIO.D.02	Report on the procedure for an automated and systematic validation of predictive integrated modelling including uncertainty quantification (Responsibility TSVV11) (Dec. 2022)
PRIO.D.12	Report on EUROfusion participation in ITER NBTF, ELISE and BUG activities (Dec. 2022)
PRIO.D.13	Report on long pulse operation 1000s extraction of H- on ELISE facility (Dec. 2022)
PRIO.D.22	Report on testing of n/T detectors in JET DT for breeder blanket (Dec. 2022)
PRIO.D.23	Report on Occupational Radiation Exposure and waste data collected at JET in DT operation (Dec. 2022)
PRIO.D.24	Report on calibration verification at JET in DT operation (Dec. 2022)

Indicative resources for 2022 *w/o UKAEA and EPFL (ref IMS on 27/09/2021)*

WBS ID	Topic	Effort [PM]*	E&GS [k€]**	Missions [k€]	Total resources [k€]	Consortium Contribution [k€]	Related D/M No. (GA / Project)	Involved Beneficiary(ies)/ Affiliated Entities
PrIO		0.00	0	13	16	11		Not allocated
PrIO-1	Project management and coordination	12.40	0	0	119	83		CEA
PrIO-2	Preparation of ITER first experimental campaigns	29.50	0	0	250	125	PRIO.M.04	CEA, ENEA, JSI, LPP-ERM-KMS, VR
PrIO-3	Plasma and sub-systems operation	8.65	0	0	68	34	PRIO.M.03	not allocated
PrIO-4	ITER Neutral Beam test Facility and R&D for the ITER Neutral Beam	180.00	203	0	2,089	1,266	PRIO.D.12 PRIO.D.13	CIEMAT, ENEA, IPPLM, IST, MPG, not allocated
PrIO-5	Neutronics, Nuclear waste and Safety in support to ITER	160.00	66	0	1,072	494	PRIO.D.22 PRIO.D.23 PRIO.D.24	CEA, CIEMAT, ENEA, IPPLM, JSI, KIT, NCSRD, not allocated
Grand Total		390.55	269	13	3,612	2,013		

Indicative resources for 2022 *for UKAEA and EPFL (ref IMS on 27/09/2021)*

WBS ID	Topic	Total resources [k€]	Involved Beneficiary(ies) / Affiliated Entities
PrIO-2	Preparation of ITER first experimental campaigns	38	EPFL
PrIO-4	ITER Neutral Beam test Facility and R&D for the ITER Neutral Beam	304	EPFL
PrIO-2	Preparation of ITER first experimental campaigns	35	UKAEA
PrIO-3	Plasma and sub-systems operation	15	UKAEA
PrIO-4	ITER Neutral Beam test Facility and R&D for the ITER Neutral Beam	93	UKAEA
PrIO-5	Neutronics, Nuclear waste and Safety in support to ITER	253	UKAEA
Grand Total		739	

SP-1: Project management and coordination

- **Manage WPPrIO and Coordinate SP-2 and SP-4 activities**

- **PL Member of E-TASC Scientific Board and Thrust 5 facilitator on whole device modelling (TSVV2, 11 and 14)**

- **Continue the mapping of the EUROfusion scientific activities for ITER with the support of the contact person**

  - New contact persons from ENEA, CIEMAT, UKAEA

- **Ensure the links with IO and ITPA for the relevant activities**

  - Contact person for all ITPA TG

  - Dedicated PrIO WikI page WPPrIO-ITPA: EUROfusion Interface with ITPA Topical Groups - EUROfusion MediaWiki (euro-fusion.org)

  - Improve the scientific coordination between ITPA and EUROfusion

  - WPrIO funds (transfer resources from PMU) and validates missions of the EU experts and keeps track of scientific mission reports - for approval -

- **Develop breakdown/burn-through simulation tools and apply to ITER operation**

  - Complete the development of plasma volume evolution model (circuit equation) in DYON

  - Model the localized electron avalanche process for the ECH pre-ionization phase with a Particle-In-Cell code.

  - Automatize the scenario optimization workflow in DYON, validate it against experiments and first application to ITER

  - Adaptation of the simulation workflow CREATE-BD/BKD0/GRAY to IMAS with ACH support

  - Scan the breakdown operational window for ITER

  - Benchmark CREATE-BD/BKD0/GRAY workflow to DYON

  WPTE: Validation on all EUROFusion facilities

SP-2: Preparation of ITER first experimental campaigns [2/3]

- **Develop IR temperature synthetic diagnostic for offline analysis and ITER real-time application**

  - Benchmark ray-tracing codes Raysect (open-source) and ANSYS-SPEOS
  - Improve ray tracing code for IR images modelling inside SMITER & incorporate inverse method to retrieve the surface temperature after reflections filtering
  - Investigate the detailed numerical models of Bidirectional Reflectance for implementation in IR synthetic diagnostics
  - Compare the photonic models against dedicated experiments: benchmark IR reflections models against controlled laboratory experiments reproducing tokamak environment
  - Include transient events (Disruption or ELM) in the IR synthetic diagnostics

- **Develop wall thermal events and hot spot monitoring system for ITER**

  - Demonstration of a data pipeline for processing thermal events in a thermographic movie operating off-line. Key actions: detection, data enrichment and classification.

SP-2: Preparation of ITER first experimental campaigns [3/3]

- **Develop synthetic diagnostic for the Fibre Optics Current Sensor**

  – Transfer to IMAS the algorithm for a FOCS synthetic diagnostics

- **Develop, expand and validate EUROfusion Multi-Machines databases**

  – Include new data from EUROfusion facilities

  – Extend the pedestal database to JET TT and DT campaigns

  – Initiate inclusion of 1D profiles for the confinement and pedestal databases to analyze the 2-D peeling-stability limits at the pedestal

  – Progress with disruption data validation for hundreds to thousands of disruptions data in AUG-TCV-JET

SP-3: Plant systems and plasma operation

- **Coordinate the EUROfusion Operation Network (EON)**

- **Set-up new EON competency-based subnetworks and organise workshops on high-priority operational topics for EUROfusion and ITER**

  - Complete NBI seminar series (initiated in 2021)
  - Set-up a pilot project on Session Leader training
  - Define new topics e.g. vacuum conditioning, ECRH, …

- **Create a knowledge database for Operations and contribute to knowledge management activities within EUROfusion**

- **Set-up coordination meetings with the European members of the ITER Operations Network (ION)**

Contribute to ITER FILD diagnostic design

- **Following IO review :**
  - select reciprocating scintillator detector vs dedicated IR based solution
- **Design activity will be initiated by IO in 2022**
  - Q2/2022: design team forming
  - 10/2022: CDR
- **Proposal: EUROfusion takes responsibility of the development of the ITER FILD simulation programme**
  - Simulation of fast ion flux to ITER FILD detector
  - Synthetic ITER FILD signal & scintillator images including collimator geometry, optical transfer system and camera sensor
- **While IO leads the engineering design**
- **Shift by one year the 2021-2023 pre-allocated EUROfusion resources and develop synergy with SA**

- **20 ppy in 2022: 6 ppy at MPG and 14 ppy at Padova including 2 EPFL and 1 UKAEA** [coop. Agreement IO-RFX EUROfusion LGA-2020-A-50]

- **18 ppy/y in 2022-2025**

- **Participate in the exploitation of ELISE and BATMAN Upgrade for the demonstration of stable long pulse operation**

  - Routine operation of the new CW power supply on ELISE:
    - up to 1000s in H on ELISE and BATMAN, initial test in D
  - Symmetrisation and reduction of co-extracted electrons for stable long pulse
  - Test the CW diagnostic calorimeter on ELISE
  - Assess new Caesium management approaches on BATMAN
  - Study the beam optics:
    - dependencies on various source parameters, characterisation of the beam as well single beamlets with an extended set of diagnostics

SP-4: Neutral Beam Test Facility and R&D for ITER Neutral Beam [2/2]

- **Participate in the installation, commissioning and operation of the ITER Neutral Beam Test Facility (ENEA-RFX, Padova):**

  - SPIDER (source) in shut-down in 2022.
    - ○ Participate in the shutdown intervention: upgrade of the pumping system, replacement of the RF oscillators with solid state amplifiers, maintenance and improvement of the Beam Source

  - MITICA (injector):
    - ○ Investigate and analyse the root causes of the failures due to Breakdowns that occurred during the 1MV power integrated tests;
    - ○ repair and improve the MITICA power supply system; complete the integrated power tests of MITICA's power supplies

  - Simulate SPIDER plasma and beam operations
  - simulate initial MITICA beam operations

SP-5: Neutronics, Nuclear Waste and Safety

- **Assumption:**

  - **JET operation ends in 2021**

  - **2022 and 2023 resources allocated to complete TT and DT analysis**

  - **2022 Second part of TT not initially foreseen**

- **Organise the hand-over of the activities from JET3 (2021 under FP8) to WPPrIO-SP-5**

- **Complete the analyses of the measurements and simulations of JET nuclear quantities (neutron flux, dose rate, neutron induced activation, radiation damage, tritium production in TBM) for JET TT and DTE2**

- **Conduct preliminary collection of Occupational Radiation Exposure and waste data following the completion of JET for TT and DTE2 campaign**

- **Implement activities in support of ITER neutronics and safety as defined in 2021 by a working group of experts**

SP-5: Neutronics, Nuclear Waste and Safety

- **Working Group to define the 2022-2025 activities in support to ITER with active participation of IO and F4E**

  - R. Villari (ENEA) Chair, Y. Peneliau (CEA), L. Packer (CCFE), R. Jaurez (CIEMAT), M. Angelone (ENEA), J. Mietelski (IPPLM) , L. Snoj (JSI), D. Leichtle (KIT) , Th. Vasilopoulou (NCSRD) , A. Hjalmarsson (VR), M. Loughlin (IO), M. Fabbri (F4E)

- **great interest and active participation from IO and F4E**

- **4 Workshops on 4 topics: High participation and interest**

  - Neutronics code simulations and development
  - Neutron activation and damage in materials
  - Nuclear measurements and instrumentation
  - Nuclear safety and waste

- **High interest from EU labs and oversubscription by a factor 5 vs SP-5 resources : 35 proposals from EU beneficiaries– > requested 705 PM+ hardware/facility 450 k€!!!**

Activities in support to ITER –Preliminary-

- **Activated Corrosion Products code development and experiment for code validation towards ITER extrapolation**
  - ENEA, CCFE, CEA, CIEMAT-UNED
- **Fluid activation tools development and experiment for extrapolation to ITER relevant conditions**
  - ENEA, CCFE, IPPLM-IPPLM, CEA, CIEMAT-UNED, JSI, VR, NCSRD, KIT
- **Radiation source development and simulation of the radiation field in ITER**
  - CIEMAT-UNED, JSI, VR
- **Techniques for low radiation dose level measurement in D-D and D-T plasmas for ITER**
  - ENEA, CEA, IPPLM-IFJ
- **Dose rate calculation for real time application in Virtual Reality**
  - CEA, CCFE
      Work in progress but around 160PM in 2022-2025

WP Milestones

WP Milestone Title	Due Date
At least one breakdown/burn-through model ready to be coupled to the integrated modelling code within TSVV11	10/2022
SPEOS (IR synthetic diagnostic) interface ready to use input data from JOREK to simulate transient heat fluxes (disruption or ELMs)	07/2022
At least one database ready for scientific exploitation deployed on the EUROfusion Gateway	12/2022
Machine generic session leaders training detailed plan	09/2022
Demonstrated routine operation of the new CW power supply on ELISE	07/2022
Analysis of implications of JET DTE2 nuclear performances for PrIO Subproject 5.3	02/2022

Interfaces/Synergies

- **Scenario modelling with TSVV11, FDT-CDT**

- **Breakdown simulator activity in synergy with TSVV, WPSA and WPTE**

- **Development of synthetic diagnostics (WPSA, WPTE, WPAC/TSVVs...)**

- **Development of reduced model (WPAC/TSVV)**

- **Real time protection of the plasma facing components (WPTE, WPW7X)**

- **Multi-machines databases (WPTE, ITPA)**

  - JT-60SA disruption database could be connected to the EUROfusion database

- **Operation PrIO-3 Wall conditioning sub-topics (WPPWIE, WPTE, WPW7X)**

- **Interface with ITPA and significant involvement of IO**

- **Low level of interaction with F4E except the active and fruitful participation on the neutronics aspects**

Opportunity for Training & Development

- **Post Docs and PhD students**

  - IR synthetic diagnostics and Real Time Wall protection (IA techniques)
  - Simulation of the plasma formation

- **Training new generation of engineers/physicists at NBTF and/or BUG-ELISE facilities**

- **EUROfusion Operation Network:**

  - Seminars, workshops, trainings opportunities for EUROfusion students and open to IO & JT-60SA staff
  - Development of machine generic courses for SL is opportunity for training and exchange

- **EUROfusion Engineers – Two topics under development -**

  - Development of Infra-Red monitoring system using artificial intelligence techniques in view of ITER application (WP7X)
  - Engineering support on the wall conditioning and ITER GDC design (proposal in 2021 to be re-submitted)

Project Change Requests (PCRs)

For approval by the PB

- **SP-1**
  - New contact persons for ITER specific activities: UKAEA (F Militello), ENEA (P Batistoni), CIEMAT (C Hidalgo)

- **SP-2**
  - Departure of T Wauters/ERM-KMS: Task to be canceled (4PM)
  - Spare resources to be used to cover extra activity on IR synthetic diagnostics by JSI (improving ray tracing code for IR images inside SMITER)

- **SP-3**
  - New EON members: ENEA (L Boncagni, M Lafrati), CEA (A Gallo), CIEMAT (E Ascasibar), MPG (AUG: M Teschke)
  - FILD design activity - shifted by one year (2022-2024)
  - New focus on FILD synthetic diagnostic/analysis tool development

- **SP-4**
  - Resources to cover 2 staffs without secondment hired at NBTF from Nov. 2021 to Dec. 2022 in replacement of 2 staffs who have left
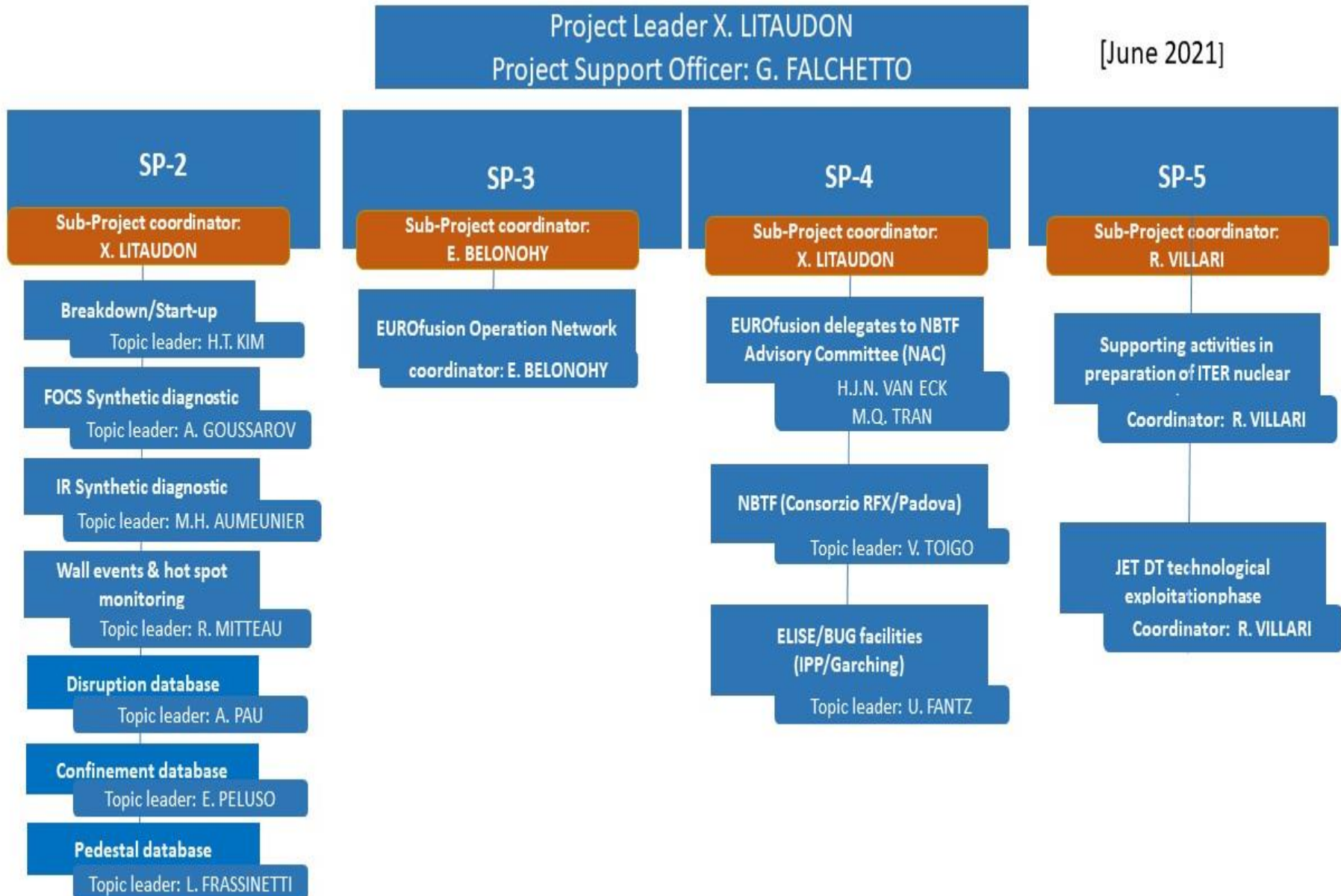 - 4PM in 2021 + 24PM in 2022 taken from the 2021 secondment missions at Unit Cost

Back-up

High-level resource assignment matrix

Interfaces to other WPs

- **WPTE**

  - Specific ITER experiments and validation of the ITER tools
  - Plasma breakdown experiments
  - Validation of synthetic diagnostics development
  - Real time protection of the plasma facing components
  - Multi-machines databases

- **WPPWIE:**

  - ITER first wall issues
  - Wall conditioning topics

- **WPSA**

  - Specific ITER experiments and plasma simulator development
  - Plasma breakdown experiments

- **WPAC/E-TASC**

  - HPC/Gateway
  - IMAS support
  - EUROfusion databases
  - TSVV11 and thrust on whole device modelling

- **WPW7X**

  - Real time protection of PFC

- **WPPRD**

  - Neutral Beam system.

- **+ link with the ITPA groups**

SP-5 Neutronics for ITER Topics selected [1/2]

- **Activated Corrosion Products code development and experiments for code validation towards ITER extrapolation:**

  - Development of methodology for the assessment of the dose contribution due to ACP in ITER relevant conditions.

  - Design, carry-out and analyse dedicated experiments at the Frascati Neutron Generator (FNG) to validate OSCAR-Fusion code and the approach used for ITER estimates of the radiation dose and dose rate due to ACP.

- **Fluid activation tools development and experiment for extrapolation to ITER relevant conditions:**

  - Enhancement of simulation tools and assessment of nuclear loads due to fluid activation in ITER relevant conditions.

  - Water activation and 6 MeV gamma shielding shielding experiments at JSI TRIGA reactor to validate ITER predictions.

SP-5 Neutronics for ITER Topics selected [2/2]

- **Radiation source development and simulation of the radiation field in ITER:**

  - Development of neutron and decay gamma ray sources for Monte Carlo calculations of the radiation field in early ITER phase.
  - Development of the methodology to model photon-neutrons induced from Be interaction for the simulation of the radiation field and estimate the relevant nuclear response in different ITER operation phases. Techniques for low radiation dose level measurement in D-D and D-T plasmas for ITER:

- **Techniques for low radiation dose level measurement in D-D and D-T plasmas for ITER:**

  - Development of on-line and off-line systems for the measurements of low dose rate level in D-D and D-T plasmas relevant for ITER phases of operation.

- **Dose rate calculation for real time application in Virtual Reality**

  - Development of a simplified dose rate calculation methodology consistent with the « real time » constraint in Virtual Reality and possible coupling to a Virtual Reality tool in order to assess dose rate and cumulated dose during the maintenance operation.

Use of facilities for 2022

Research activity	Facility Name	days	Beneficiary
Calibration of Thermoluminescent detectors (TLDs) for JET DTE2 neutron streaming experiment	FNG	4	ENEA/ENEA-FSN
Calibration of Thermoluminescent detectors (TLDs) for JET DTE2 neutron streaming experiment	INMRI Thermal neutron and gamma facilities	4	ENEA/ENEA-FSN
Preparation, calibration and reading of TLDs for neutron streaming experiment, measurements and analyses of irradiated materials following JET TT and DTE2	Lab of radioactivity and radiochemical	90	IPPLM/IFJ-PAN
Measurements and neutron analyses following JET TT and DTE2	Lab of gamma spectroscopy	15	IPPLM/IPPLM

Facilities not funded within PrIO but essential:

- **NBTF , ELISE and BATMAN Upgrade**
- **MARCONI Fusion HPC and Gateway**