FSD Planning Meeting (2025 Objectives)

# WPAC

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Many thanks to the E-TASC Scientific Board

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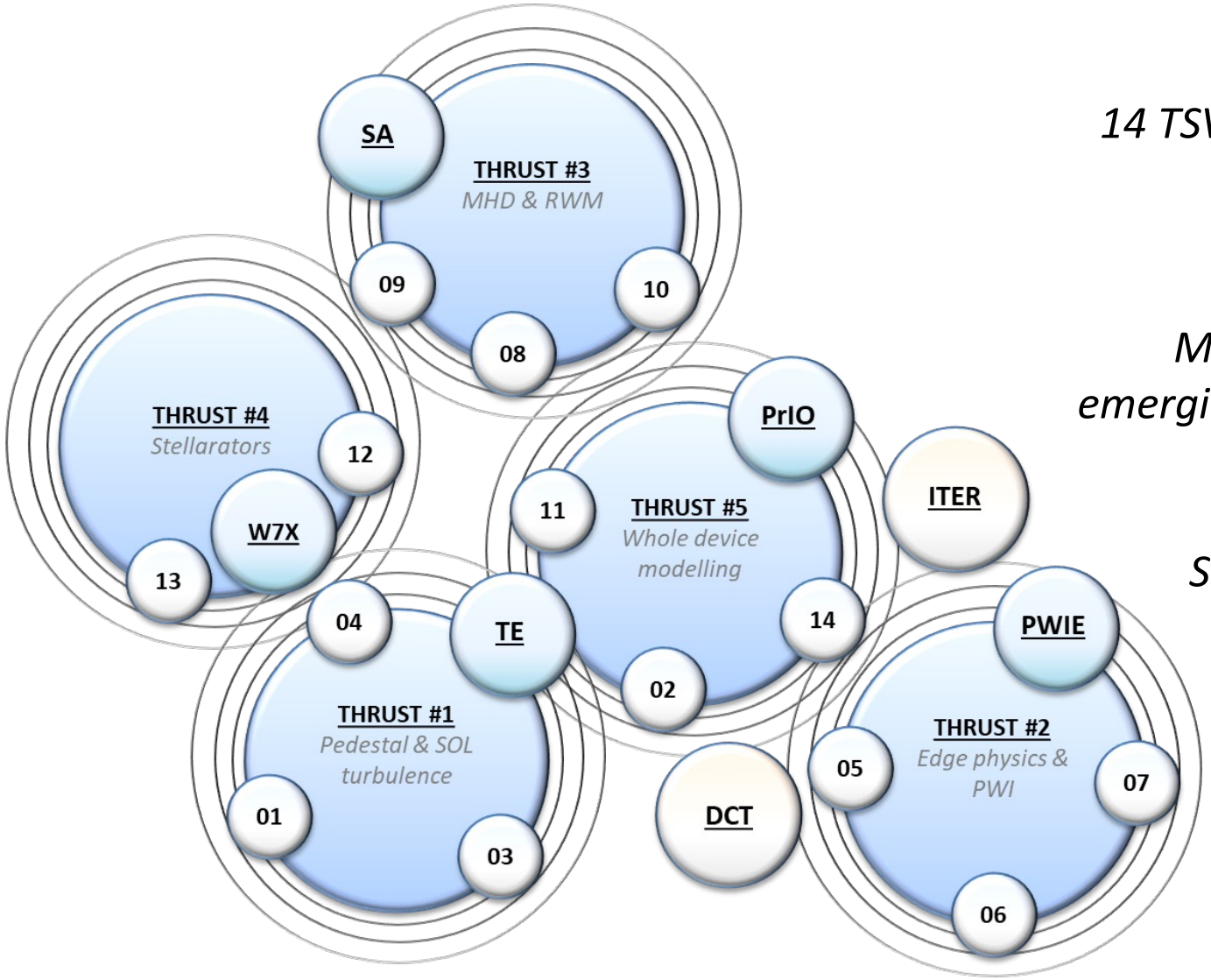
# The E-TASC ecosystem




*14 TSVV teams working together in close collaboration*

*Related TSVVs form 5 thematic Thrusts*

*Mutual interest between Thrusts on specific topics, emerging interactions between tokamak and stellarator efforts (turbulence, 3D effects, HPC, AI)*

*Several services provided (mostly through 5 ACHs) for the benefit of the entire E-TASC ecosystem*

*Interactions with the DEMO Central Team*

*Interactions with the ITER Organization*

# Main milestone in 2023: TSVV review

- Assess the TSVV projects' **performance** (in terms of both code development and physics applications), the efficiency of the **project management**, and the project's **broader impacts** on the EUROfusion program and the wider scientific community.

- The project **achievements** are considered, along with **possible deviations** from the original proposal. Specific **challenges and opportunities** are identified, and changes to project priorities, activities and objectives are proposed.

- Untapped **synergies** between various projects within E-TASC and EUROfusion should be exploited, and adjustments to the **overall project portfolio** can be proposed.

*Reference materials:*

- *Presentation of each TSVV project's achievement at https://indico.euro-fusion.org/event/2429/*
- *Input by the Thrust Facilitators at https://indico.euro-fusion.org/event/2611/*
- *Detailed results at https://idm.euro-fusion.org/default.aspx?uid=2P9MS8*

# Key conclusions

## Successful start of the 14 TSVV projects

The SB was very impressed by the major progress that was achieved during the first phase of the TSVVs, despite a delayed start in 2021, Covid-related communication restrictions during the first two years, and the need to overcome several losses of key personnel. This achievement reflects the teams' dedication and capability.

## World-class research, theory, and code development

The TSVVs address key open questions in fusion science, developing and using state-of-the-art simulation tools. This is reflected, among other things, in many papers in top-notch journal and invited talks at major international conferences. The basis for this success is a healthy mix of setting ambitious scientific goals and fostering a collaborative spirit, both of which are part of E-TASC's DNA.

## Fruitful interactions with all relevant WPs

The Thrust Facilitators confirmed this very positive impression in their reports. The establishment of Thrusts which are coordinated by WP leaders has proven to be a useful step towards strengthening the links between TSVVs and all relevant WPs, serving as a communication platform in both directions.

# General recommendations

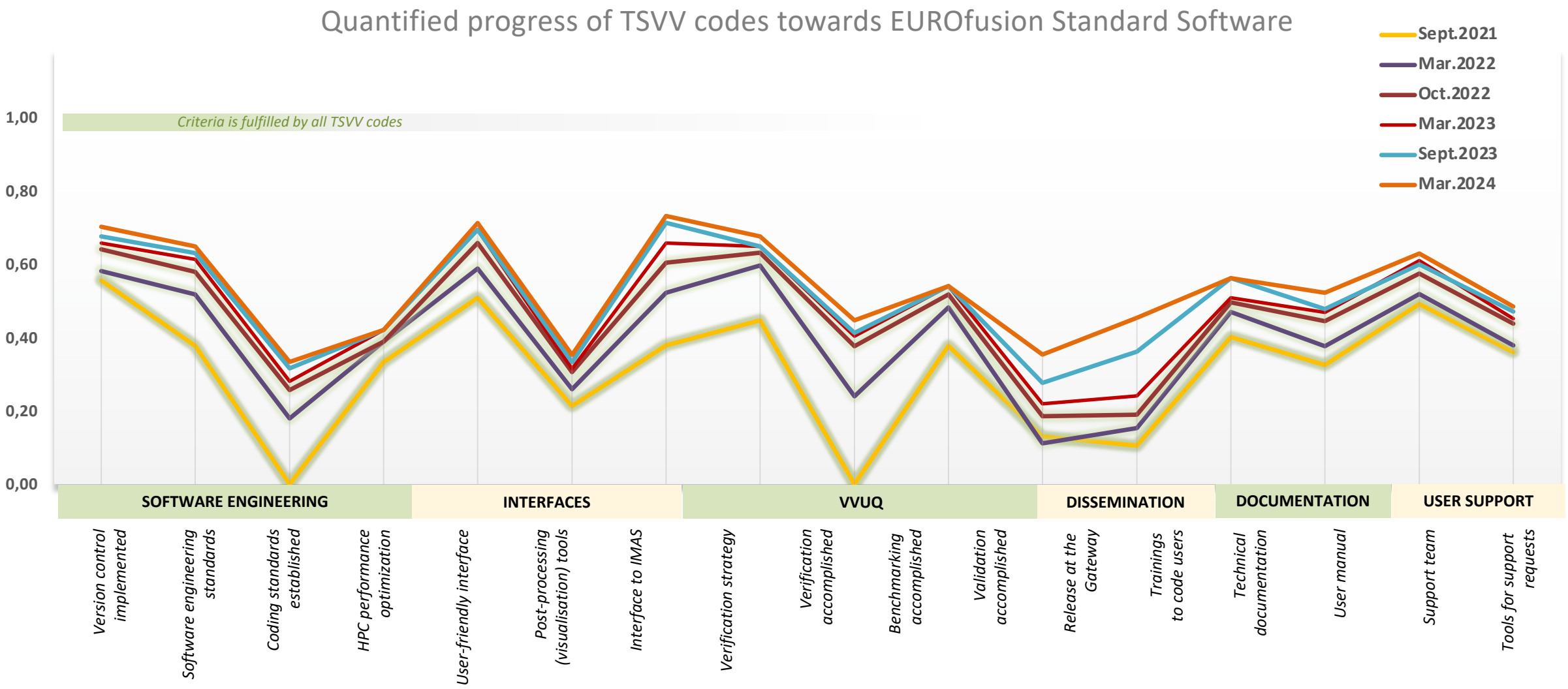
**Providing resources for strengthening collaborations within the E-TASC ecosystem**

- Allow each TSVV to have at least one in-person meeting per year in 2024 and 2025 (on top of Zoom meetings)
- Organize occasional in-person meetings of (suitable subsets of) all TSVV leaders, selected WP leaders, all ACH leaders, and the E-TASC SB members (with plenary meetings & breakout sessions, focused on open discussions), to help strengthen the team spirit within E-TASC
- This is considered an extremely important aspect regarding the exploitation of the full potential of E-TASC

**Increased focus on the development of EUROfusion Standard Software**

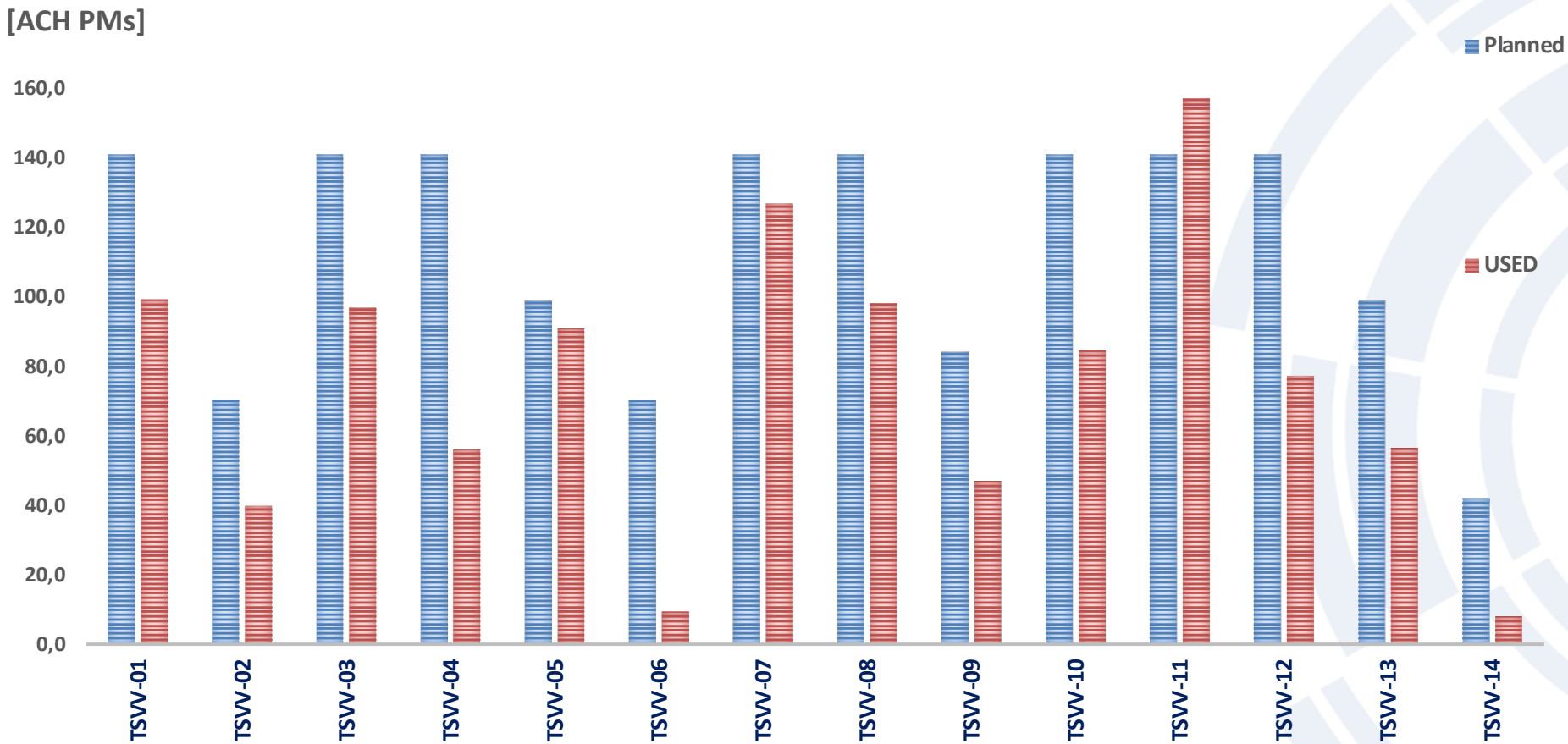
- More emphasis on cross-code fertilization, the completion of the IMASification, and the dissemination of the developed tools (incl. code documentation, code repositories, user training etc.)
- In this context, it is understood that code developers within the TSVVs and ACH team members must collaborate closely to achieve the desired results; each side must make concrete commitments

# Progress towards EUROfusion Standard Software




*The standard for the EUROfusion software is defined in: https://idm.euro-fusion.org/?uid=2Q72WQ*

# Use of Advanced Computing Hub resources by individual TSVVs




Total foreseen ACH support (per TSVV) in 2021-25

Projected use of ACH resources by the TSVVs in 2021-24

**Other activities** (about 300 PMs in 2021-2024) **are carried out by ACHs in addition to TSVV support** (small projects in other WPs and services on behalf of the entire scientific community)

# Other activities: HPC, DMP

## HPC systems

| | Conventional | GPU | | Conventional | GPU | TOTAL |
|---|---|---|---|---|---|---|
| | # nodes | # nodes | | HPL (Pflops) | HPL (Pflops) | HPL (Pflops) |
| | Marconi | Marconi 100 | | Marconi | Marconi 100 | |
| From Jan. 15, 2022 until July 23, 2023 | 2848 | 99 | | 5,96 | 2,19 | 8,14 |
| | Marconi | Leonardo | | Marconi | Leonardo | |
| From August 3, 2023 until mid-2024 | 2848 | 72 | | 5,96 | 5,00 | 10,96 |
| | Pitagora | Pitagora | | Pitagora | Pitagora | |
| From mid-2024 until mid-2030 | 1152 | 168 | | 12,90 | 28,22 | 41,12 |

Procurement process for PITAGORA currently in progress

Additional support to operation through ACHs (monitoring of machine performance and code effectiveness, HPC-MD)

**>2/3 of the compute power resides in GPUs**

# Implementation of the Data Management Plan (DMP)

| Scenario | Status |
|---|---|
| **Scenario A:** making metadata only available and searchable using IMAS data subsets for interoperable definitions of quantities [F,(I)]. | Going into production on the new GW mid ’24 **Available for testing now!** |
| **Scenario B:** adds to Scenario A by allowing a subset of the data to be accessed using common tools (UDA). Facilities are responsible for the access level and qualification of data through the data mappings [F,A,I,(R)]. | ~~Prototype!~~ Start implement! Original scope extended due to additional funding. **2024 focus!** |

# Deliverables & Milestones

| Sygma ID | "Title" in Sygma | Del/Mil | Title in CWP | Due Date | Date of completion | Status |
|---|---|---|---|---|---|---|
| D4.4 | AC.D.04 | Deliverable | Advanced Computing Hubs including JET data centre support to the EUROfusion simulation programme including IMAS exploitation and portfolio of EUROfusion standard software for ITER and DEMO | 31/12/2023 | 23/02/2024 | completed |
| D4.5 | AC.D.05 | Deliverable | Availability of HPC and Gateway in support of simulation programme as set by the Key Performance Indicators | 31/12/2023 | 02/02/2024 | completed |
| M25 | AC.M.05 | Milestone | Availability (defined by KPIs) of Gateway and HPC to EUROfusion users for production runs | 31/12/2023 | 31/12/2023 | completed |
| M26 | AC.M.06 | Milestone | Release core-edge IMAS workflow for fully integrated core SOL divertor modelling | 31/12/2023 | 16/10/2023 | completed |

# Highlights in 2024 (1/2)

## New AI/ML-Focused Projects

- Call for “Project proposals for innovative Artificial Intelligence and Machine Learning Methods used in support of EUROfusion programme objectives” (was closed on February 16, 2024)
- 33 proposals were received, with total requested budget of 2,7 M€ of CC
- 15 proposals were selected (by the E-TASC Scientific Board) and approved (by the GA)
- Beyond that: Support for eScience Center at DIFFER; AI/ML-related activities at the ACH in Helsinki

## Pulse Design Tool

- In the second half of 2023, a pilot project aimed to explore the needs and research opportunities was set up
- The original goals (e.g., running a single PDT on several machines) may be too demanding
- Focus should be on the development of a few reduced models for key physics aspects
- These could be included in a PDT as well as in a flight simulator (via IMAS interfaces)
- Call has been issued; deadline for submission of proposals is June 14, 2024

# Selected AI/ML projects (1/2)

| Short Reference No | Principal Investigator | Title |
|---|---|---|
| CEA-02 | David Zarzoso | *AI-augmented SOL modelling for capturing impact of filaments on transport and PWI in mean field codes simulations.* |
| CEA-03 | Feda Almuhisen | *Towards Tokamak operations Conversational AI Interface Using Multimodal Large Language Models* |
| CIEMAT-03 | Augusto Pereira | *Testing cutting-edge AI research to increase pattern recognition and image classification in nuclear fusion databases* |
| DIFFER-01 | Sven Wiesen | *Machine learning accelerated SOL simulations: SOLPS-NN* |
| EK-CER-01 | Gergo Pokol | *Fast inference methods of advanced diagnostics for real-time control* |
| ENEA-03 | Riccardo Rossi | *AI-assisted Causality Detection and Modelling of Plasma Instabilities for Tokamak Disruption Prediction and Control* |
| ENEA-04 | Michela Gelfusa | *Development of Physics Informed Neural Networks (PINNs) for Modelling and Prediction of Data in the Form of Time Series* |
| EPFL-01 | Alessandro Pau | *AI-assisted Plasma State Monitoring for Control and Disruption-free Operations in Tokamaks* |

# Selected AI/ML projects (2/2)

| | | |
|---|---|---|
| **IPPLM-05** | **Pawel Gasior** | *LIBS data-processing with Deep Neural Networks and Convolutional Neural Networks for chemical composition quantification in the wall of the next step-fusion reactors* |
| **IST-01** | **Jose Vicente** | *Deep Learning for Spectrogram Analysis of Reflectometry Data* |
| **LPP-ERM-KMS-01** | **Geert Verdoolaege** | *Identification and confinement scaling of hybrid scenarios across multiple devices* |
| **MPG-01** | **Marcin Jakubowski** | *Leveraging Generative AI Models for Thermal Load Control in High-Performance Steady-State Operation of Fusion Devices* |
| **MPG-02** | **Daniel Böckenhoff** | *Surrogate modelling of ray-tracing and radiation transport code for faster real-time plasma profile inference in a magnetic confinement device* |
| **VTT-02** | **Antti Snicker** | *Applying AI/ML for NBI ionization and slowing-down simulations using ASCOT/BBNBI* |
| **VTT-03** | **Aaro Järvinen** | *Machine learning accelerated pedestal MHD stability simulations* |

These projects will be grouped into Thrust 6.

# Call for the development of a Pulse Design Tool (PDT)

**Proposed Approach:**

Utilize existing integrated workflows from fusion labs as the foundation for the PDT. Initially, a few available workflows should be leveraged (without converging into a single tool) with a strong emphasis on developing and sharing ideas, models, and infrastructure tools between them. The PDT should target:

- **Interoperability:** Capable of simulating different tokamaks
- **Modularity:** Composed of interchangeable modules of varying physics parts and fidelity levels
- **Integration:** Modular inclusion of actuators and controls

The PDT prototypes should solve: Free Boundary Equilibrium (FBE), MHD, kinetic profiles, and the plasma edge region. This should eventually expand to include different heating schemes, exhaust physics for detached states, and impurity transport across the separatrix.

# Call for the development of a Pulse Design Tool (PDT)

**Coordination and Liaising:**

Technical/physics decisions and choices will necessitate coordination with the DEMO Central Team and ITER IO and liaising with developing machines like JT-60SA, Compass Upgrade, and DTT. Interfaces with these teams must be established. The direct monitoring of activity will fall under the E-TASC SB responsibility.

**Data Access and Validation:**

Continued validation of developed tools and modules requires easy access to data from WPTE machines. An additional action will enable the service of data from machines in IMAS format, and the tools developed must use IMAS for communication. Implementation of individual workflows should be in an openly available format, such as MUSCL3 or Python.

**Tasks to be covered with responses to the call:**

- Task 1: Demonstration of PDT prototype (porting at existing machines)
- Task 2: Development of Reduced Models and Workflow
- Task 3: Magnetic Equilibrium and Control for PDT

# Highlights in 2024 (2/2)

## ACH Review

- Given that the ACH structure is a key new element in FP9, it will be valuable to better understand and address the respective **challenges and opportunities**
- The goal is to further optimize the ACH structure to that its **benefit for the EUROfusion program is maximized**
- In the context of this review, the E-TASC SB will carry out **two surveys**: one for the code developers and one for the ACH teams
- The final review meeting is scheduled for **June 18-20, 2024**
- *The review process description and templates for questionaries are available @: https://idm.euro-fusion.org/default.aspx?uid=2RHUC2*

## E-TASC General Planning Meeting

- 11-15 Nov. 2024 (*https://indico.euro-fusion.org/event/3034/*)

# Open questions and action towards them

**Providing resources for strengthening collaborations and enabling trainings within the E-TASC ecosystem**

- Acceptance of the concrete travel budget proposal (following action: **FPB03-02** ) is a **subject to the current FSD PB**

**Increased focus on the development of EUROfusion Standard Software**

- More emphasis on cross-code fertilization, the completion of the IMASification, and the dissemination of the developed tools (incl. code documentation, code repositories, user training etc.)

**Enabling modern data-driven plasma science**

- The E-TASC SB fully supports the recent call for “Project proposals for innovative AI/ML methods used in support of EUROfusion programme objectives”
- Additional action items should include manned support for FAIR access to all EU tokamak databases in IMAS format and the acquisition of a long-term storage facility for simulation databases

**Software licensing**

- A clear recommendation on licenses (or license options) to be used should be provided on a EUROfusion-wide basis in a timely fashion; a subgroup of the E-TASC SB is working on a specific proposal

# Mission budget for 2024

For the year 2024:

• Each TSSV will be allocated a travel budget of up to about 6 k€.

• Moreover, there will be a restricted amount of travel assistance available for ACHs (about 2-3 k€ per ACH).

• Additionally, funds will be provided for participation in the E-TASC General Meeting taking place at Garching from November 11-15, 2024.

# Conclusions

E-TASC program plays a crucial role in **fostering theory and advanced simulation** research within EUROfusion. Up to now, most projects have focused on the (further) development and important applications of various codes, with remarkable results in many cases.

Moving forward, the emphasis will shift towards **cross-code fertilization, completing the IMASification, and disseminating** the developed tools. Consequently, TSVV projects must prioritize aspects such as code documentation, code repositories, and user training. It is crucial for code developers within the TSVVs and ACH team members to collaborate closely to achieve the desired outcomes.

There will be an increased focus on the development of **EUROfusion Standard Software**. The criteria for EUROfusion Standard Software will be regularly communicated to the TSVVs and ACHs, with continuous monitoring of progress along these lines.

Prototyping for **direct data access** has started (DMP scenario B): UDA/IMAS instances under testing on several sites, development of security layer in UDA being wrapped up (needed for user authentication/authorisation), JSON plugin being installed/tested for simplified data mappings, user requirements capture (input IDSs for different applications) has started (TSVV10, TSVV11,…), resources and plans for advancing the work in data mappings are being put in place.