Digital Solutions for Fusion Office (DSO)

2nd E-TASC General Meeting | Garching | Feb 9-13, 2026

Frank Jenko (DSO Head) & Denis Kalupin (DSO Coordination Officer)

Thanks to the E-TASC Scientific Board, Xavier Litaudon, and Gloria Falchetto

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Digital Solutions for Fusion Office (DSO) in 2026/27

Formula: E-TASC = DSO/WPAC + WPTM

The DSO will **drive and coordinate EUROfusion digital innovation activities**, including the provision and management of computational and data storage resources. It will **support the development of research and engineering software**, with a focus on integrating computational tools into a common environment. The DSO will **provide digital solutions** tailored to the specific needs of other WPs and departments.

Digital Twin Environment

Predictive capabilities, real-time control, coupled physics-engineering simulations, and analysis tools for next-generation facilities.

Advanced Computing Hubs

Support for code developers:

- High-Performance Computing;
- Modelling Frameworks and Standardized Workflows.

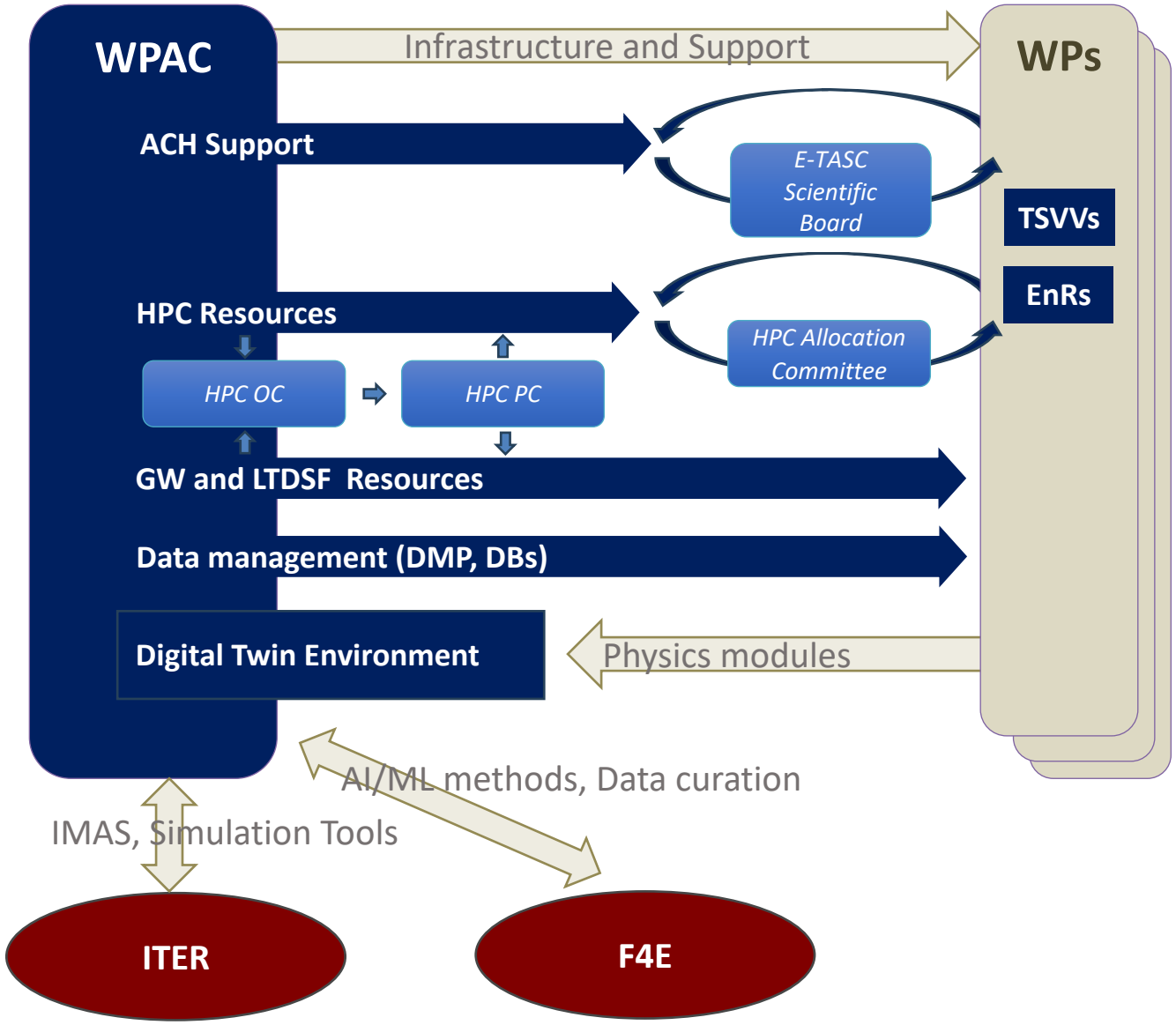
Data Management Plan

Unified access to experimental data using FAIR principles. Support further development and maintenance of existing multi-machine databases.

Computing & Data Storage Systems

Management & distribution of dedicated computing resources (PITAGORA HPC system, collaboration with Japan, new Gateway, Long-Term Data Storage Facility).

Processes and collaborations



Infrastructure and Support

Facilitate the development and deployment of advanced computational tools across all WPs.

Standardized Data Access (using FAIR principles)

Available for all MST devices as well as JET, ensuring transparency, reproducibility, and interoperability across systems.

Development of a Digital Twin Environment

Leverage the latest advancements from relevant TSVVs and WPs, integrating state-of-the-art computing and AI/ML to enhance predictive modeling capabilities.

Liaison to ITER and F4E

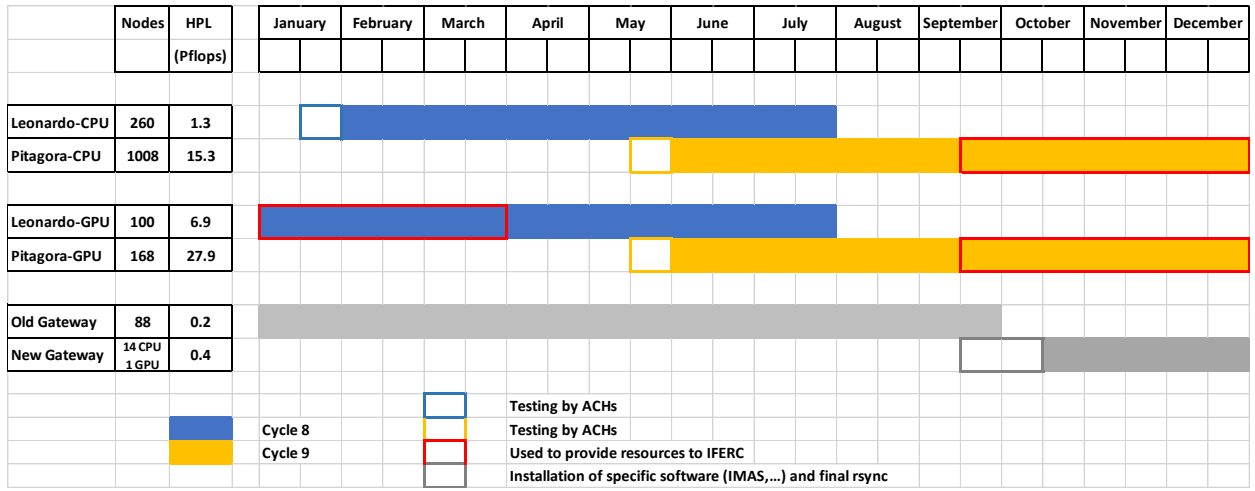
Ensure their effective engagement in the planning, implementation, and exploitation of software development activities.

Computational hardware

HPC PITAGORA (by CINECA)

- Computational resources for large-scale, time-consuming simulations
- CPU part.: 17 Pflops, GPU part.: 28.2 Pflops, storage: 16.2 PB (raw disk capacity) and 200 TB for home (backed-up)
- 10th cycle - **Mar.2026-Feb.2027**

	Nodes	HPL (Pflops)
Leonardo-CPU	260	1.3
Pitagora-CPU	1008	15.3
Leonardo-GPU	100	6.9
Pitagora-GPU	168	27.9
Old Gateway	88	0.2
New Gateway	14 CPU 1 GPU	0.4



EUROfusion Gateway (by CINECA)

- Central host for code development and releases, computing resources for codes not requiring HPC
- 14 CPU + 1 GPU, storage: 3.5 PB (raw disk capacity) and 100 TB for home (backed-up)

Long-Term Data Storage Facility (by PSNC)

- Long-term (~10 yrs) storage of simulation data
- Storage at PSNC (8 PB disks+8 PB tapes) + Fast (SSD) buffer at CINECA to provide fast connection to PITAGORA

What is a Digital Twin (DT) and a Digital Twin Environment (DTE)?

- The notion of a Digital Twin first emerged around 2002 in the context of Product Lifecycle Management. It was later adopted as a conceptual basis in aerospace engineering and many other discipines.

- Excellent source: “Foundational Research Gaps and Future Directions for Digital Twins“ (National Academies of Sciences, Engineering, and Medicine, 2024): http://nap.nationalacademies.org/26894

- **A Digital Twin (DT) is a set of virtual information constructs that mimics the structure, context, and behavior of a natural, engineered, or social system, is dynamically updated with data from its physical twin, has a predictive capability, and informs decisions that realize value.**
  - The key elements that comprise a DT include (1) a virtual representation of a physical counterpart, and (2) a bidirectional interaction between the virtual and the physical. This bidirectional interaction forms a feedback loop that comprises **dynamic data-driven model updating** (e.g., sensor fusion, inversion, data assimilation) and **optimal decision-making** (e.g., control, sensor steering).
  - A DT should be defined at a **level of fidelity and resolution that makes it fit for purpose**. Important considerations are the required level of fidelity for prediction of the quantities of interest, the available computational resources, and the acceptable cost. This may lead to the DT including high-fidelity, simplified, or surrogate models, as well as a mixture thereof.

- **A Digital Twin Environment (DTE) is an integrated, multi-domain physics application space for operating on DTs for a variety of purposes** (according to Michael Grieves & John Vickers: https://rdcu.be/d1wRu)

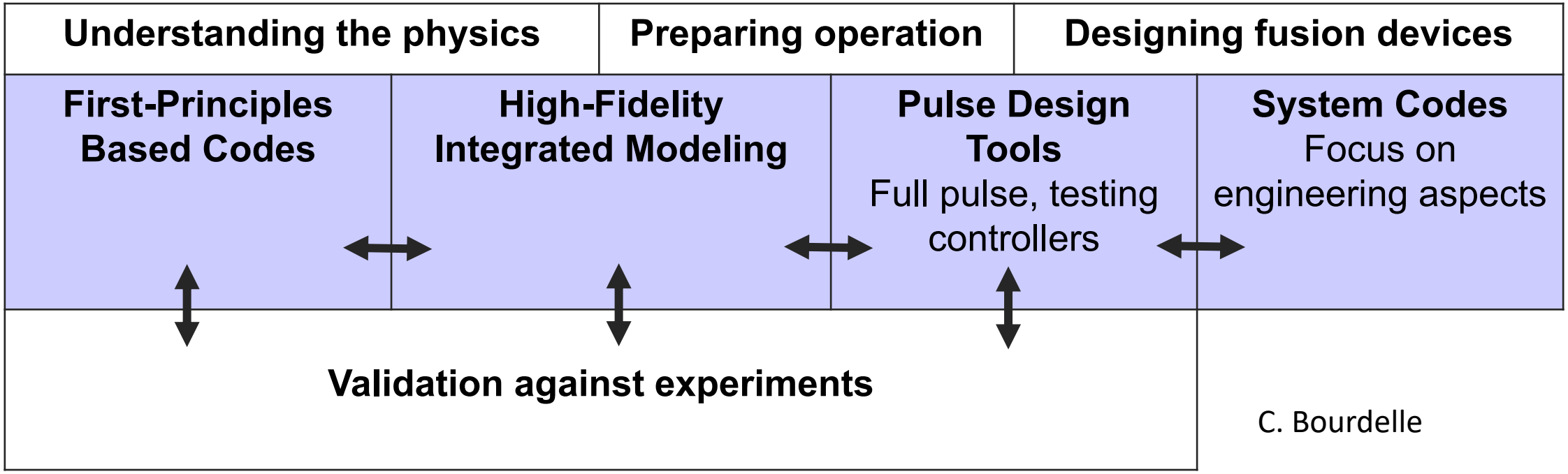
Digital Twins: Different fidelity levels and goals

HPC and AI allow researchers to simulate complex, multi-scale, multi-physics plasma dynamics with unprecedented realism and reliability.

The ultimate goal is to create digital twins of fusion systems, thereby saving cost and time.

To be effective, the fidelity level of a digital twin must match its intended purpose.

New research areas include multi-fidelity techniques and uncertainty quantification (UQ).



Digital Twin Environment (DTE) activities in 2026/27

Integration of various related activities into a unified **Digital Twin Environment** program

Ref.	Area Title	Objectives	Link to 2021-2025 programme
PDT	**Pulse Design Tool Extension**	Expand PDT for real-time, high-fidelity plasma forecasting and virtual control testing	TSVV-15
DDM	**Data-Driven Predictive Modelling**	Apply AI/ML for faster, validated simulations and real-time analysis/control	AI/ML – pilot projects
ENG	**Integrated Physics/Engineering Framework**	Develop coupled physics-engineering tools (e.g., breeding blanket, divertor models) and synthetic diagnostics	DTE PoC projects
VIS	**Advanced Visualisation Tools**	Create intuitive, interactive visualization for model validation and decision support	ACHs
+			
DMP	**Data Management Plan**	Develop coupled physics-engineering tools (e.g., breeding blanket, divertor models) and synthetic diagnostics	DMP
+			
Active collaboration and liaison with ITER on the IMAS development and F4E on utilization of AI/ML techniques			ACH-IPPLM

Selection of DTE projects (1/2)

Pulse Design Tool (PDT) Extension Towards Digital Twin Functionality

- Simulator-agnostic DTE integration – towards a consolidated framework with an ITER relevance
  - Sven Wiesen, DIFFER
- Development of generic coupling between transport and free-boundary eq. codes with breakdown modules for PDTs
  - Stefano Marchioni, IPP.CR

Data Driven Predictive Modeling for Real-Time Feedback

- A machine-agnostic DT framework towards fast simulation and real-time plasma prediction and control
  - Alessandro Pau, EPFL
- A novel ML-based DT architecture for real-time monitoring, integration, and control of the breeding blanket
  - Antonio Cammi, ENEA

Advanced Visualization

- Verification-oriented interactive visualisation and decision support for the DTE
  - Leon Kos, JSI

Selection of DTE projects (2/2)

Integrated Physics/Engineering Simulation Framework for Fusion Devices

- A highly scalable and flexible DT of FPPs and photorealistic renderer based on physically accurate models
  - Cristian Sommariva, EPFL
- DT platform for integrated design of tokamak components – case studies on EU-DEMO divertor and ITER divertor
  - Domenico Marzullo, ENEA
- Integrated DT framework for breeding blanket systems: Coupling plasma, fuel cycle, and thermal-hydraulics dynamics
  - Carlos Moreno, CIEMAT
- A comprehensive numerical platform for advanced thermal protection of tokamaks
  - Marie-Helene Aumeunier, CEA
- An integrated validation and benchmarking framework for the EUROfusion DTE
  - Anna Glasser, CEA
- Development of a DT framework for fusion
  - Andrew Davis, UKAEA

Selection of DATA projects

List of all selected DATA projects for 2026/27:

- **Implementation of the DMP and Data Area Coordinator**
  - Pär Strand, VR
- **Scalable Production and Collaborative Environment for EUROfusion Multi-Machine Databases**
  - Alessandro Pau, EPFL
- **EUROfusion's Multi-Machine Pedestal Databases (JET, MAST-U, TCV, AUG)**
  - Lorenzo Frassinetti, KTH/VR
- **Update and Maintenance of the International CICLOP Database on Long Pulse Operations**
  - Ernesto Lerche, LPP-ERM-KMS
- **Continued Support and Maintenance of the AMNS Database**
  - David Coster, MPG

Advanced Computing Hubs (ACHs) in 2026/27

Reduction of funds by ~30% compared to 2021-25 level

Call for ACHs in 2026-27
(issued: May 9, 2025; deadline: June 20, 2025)

Evaluation by the **E-TASC Scientific Board**:

- All proposals were evaluated positively
- **4 ACHs** recommended for 2026/27, aiming at broad competence coverage within available resources:
  - Cat1 (HPC): **CIEMAT**, **EPFL**, **MPG**
  - Cat2 (MFSW): **IPPLM**
- **VTT (AI/ML focus):** not funded as standalone activity due to budget constraints, but competences to be integrated under **ACH-MPG**

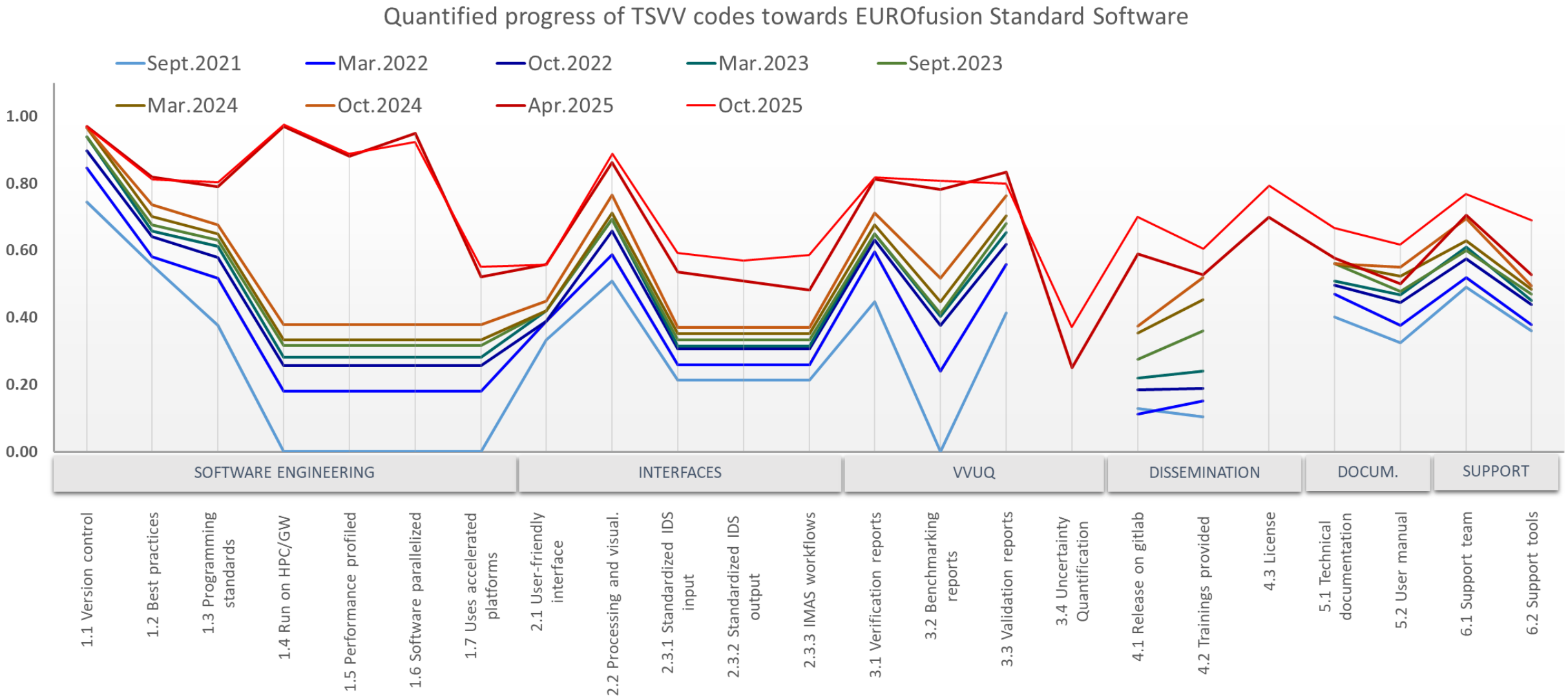
Category 1: High Performance Computing (HPC)	Category 2: Modeling Frameworks and Standardized Workflows (MFSW)
Tasks under the category include:	
• Enabling effective GPU usage of a selected set of codes on EUROfusion's HPC platforms with expanded GPU partitions • Selecting and implementing scalable algorithms • Assisting with code parallelization and performance optimization • Optimizing communication patterns and memory usage • Supporting code refactoring efforts • Providing targeted support and training for code developers • Promoting best practices in software engineering and efficient HPC resource utilization • Providing support for the development of AI/ML surrogates for physics models • Supporting large-scale model training and inference on EUROfusion infrastructure • Supporting the development and application of advanced visualization tools	• Supporting the development and maintenance of the Integrated Modelling and Analysis Suite (IMAS) framework to ensure extensibility, maintainability, and usability • Offering technical support to code developers in adapting their codes to the IMAS data model to enable integration and validation • Assisting with code integration and workflow optimization • Contributing to the development of a unified, scalable, and interoperable modelling ecosystem aligned with EUROfusion's long-term objectives • Advancing database infrastructure and evaluating/implementing software solutions for data storage, management, and analysis, as well as authenticated/authorized access control

Criteria for EUROfusion Standard Software (excerpt, from 2020)

EUROfusion standard software will be developed with a very rigorous, consistent quality assurance process that is common across the E-TASC initiative; it is designed to benefit a wide range of users across EUROfusion, well beyond the team of code developers, and will adhere to the following guidelines and criteria:

- Free availability (within EUROfusion) of an up-to-date release version of the source code used for production runs
- Good software engineering practices (version control, regression/unit testing, shared development rules etc.)
- High-quality code documentation via user manuals and reference publications (including, in particular, a detailed description of the underlying model)
- Excellent support of users, co-developers, and support staff within EUROfusion (via contact person, mailing list, issue tracker, and the like)
- Specific plans for code verification and validation (involving a third party), in particular within EUROfusion, including aspects of uncertainty quantification
- User-friendly, intuitive interfaces and visualisation/post-processing tools, including interfaces to the IMAS Data Dictionary (where applicable)
- Specific plans for code dissemination and user training within EUROfusion

Progress towards EUROfusion Standard Software



The quality assurance framework for EUROfusion Standard Software (endorsed by the E-TASC SB on March 12, 2025)
https://idm.euro-fusion.org/?uid=2Q72WQ&version=v2.2

WPAC/DSO in 2026/27: Engagement

Core team:

- **Frank Jenko (Head, DSO)**
- **Denis Kalupin (Coordination Officer, DSO)**

Supported by the new E-TASC Scientific Board:

(est. in Sept 2025 and co-chaired by XL and me):

- José Luis Velasco (CIEMAT)
- Fulvio Zonca (ENEA)
- David Tskhakaya (IPP.CR)
- Rui Coelho (IST)
- Colin Roach (UKAEA)
- Francesca Rapetti (CEA)
- Egbert Westerhof (DIFFER)
- Stephan Brunner (EPFL)
- Yannis Kominis (NCSRD)
- Aaro Jarvinen (VTT)

Community Participation:

- **14 Research Units**
- **55 person-years per year**

Collaborations:

- **WPTM & other WPs**
- **ITER & F4E**
- **USA & UK**
- **Fusion Startups**

WPAC/DSO in 2026/27: Goals and activities

Key goals

- Build a vibrant, collaborative **ecosystem that integrates physics, engineering, and digital technologies**
- Develop and employ **digital twins of fusion systems (helping to save cost and time)**
- Emphasize **development & dissemination of EUROfusion Standard Software (opportunity to build user bases)**
- Close **coordination with various departments and WPs**, particularly the newly established **WPTM**
- Collaborations with **colleagues in the UK and the U.S.** (see 1st E-TASC General Meeting in Nov 2024)

Recent and ongoing activities in preparation of 2026/27

- Selection of **ACHs** (down from 5 to 4 due to a ~30% budget reduction w.r.t. 2021-25 values)
- Selection of **TSVVs** (down from 15 to 11 due to a ~30% budget reduction w.r.t. 2021-25 values)
- Selection of **DTE projects** (replacing the 7 Proof of Concept projects, since April 2025)
- Selection of **DATA projects**
- Selection of **ACH projects** for 2026

Looking back – and ahead

- **Jan 14 & 28, 2026**: EUROfusion Science Meeting - TSVV Final Reports (2021-2025)
- **Feb 9-13, 2026**: 2nd E-TASC General Meeting (organized by DSO & WPTM)