Physics Project Board #09

Digital Solutions for Fusion Office (DSO)

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EUROfusion PMU

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Digital Solutions for Fusion Office (DSO)

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.

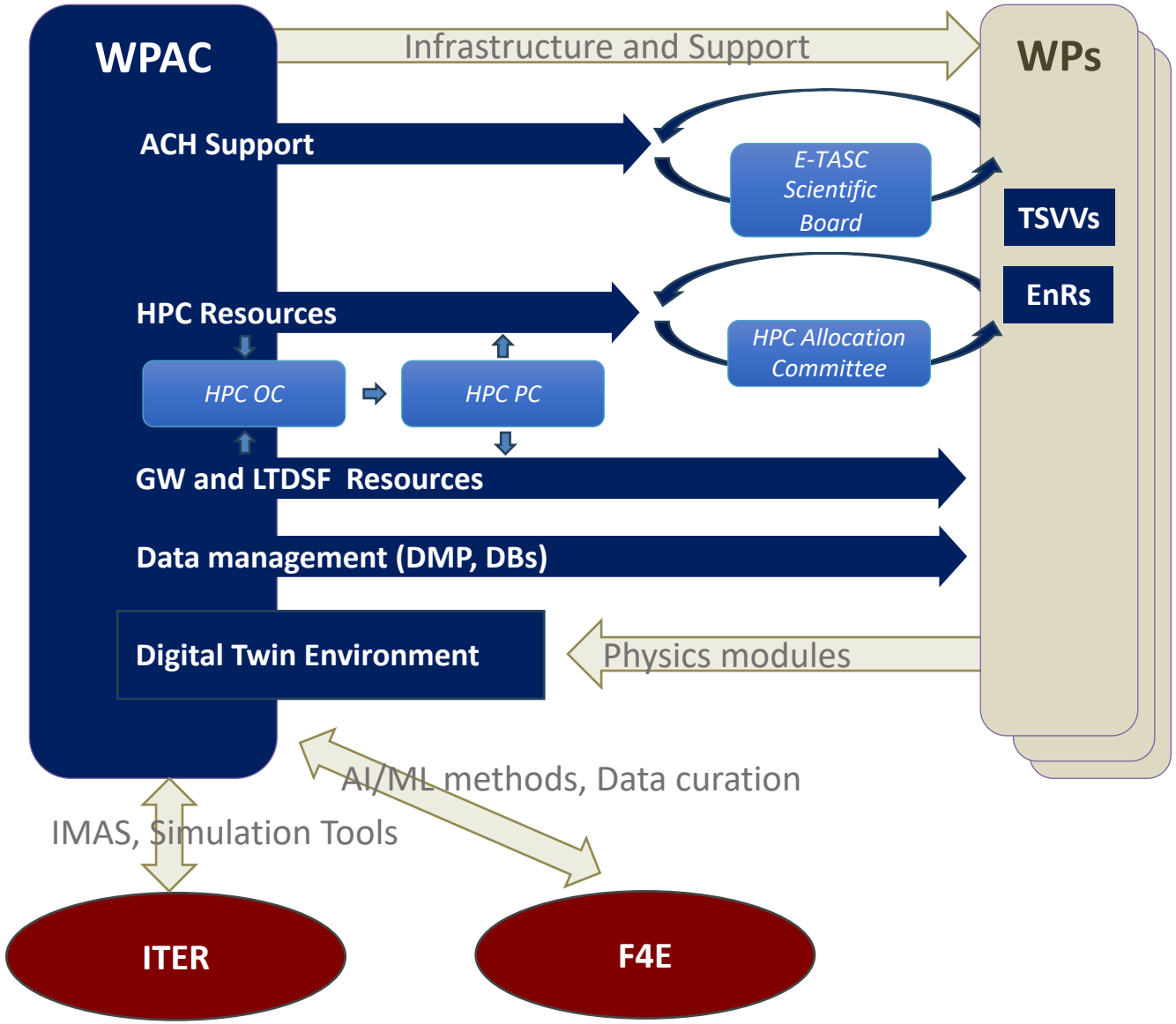
Computing & Data Storage Systems

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

Key goals

- Build a vibrant **ecosystem that integrates physics, engineering, new digital technologies and HPC resources**
- Develop and employ **digital twins of fusion systems (helping to save cost and time)**
- **Provide and utilize computational and data storage resources** in most efficient way
- 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 ITER, F4E, the UK and the USA**

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.

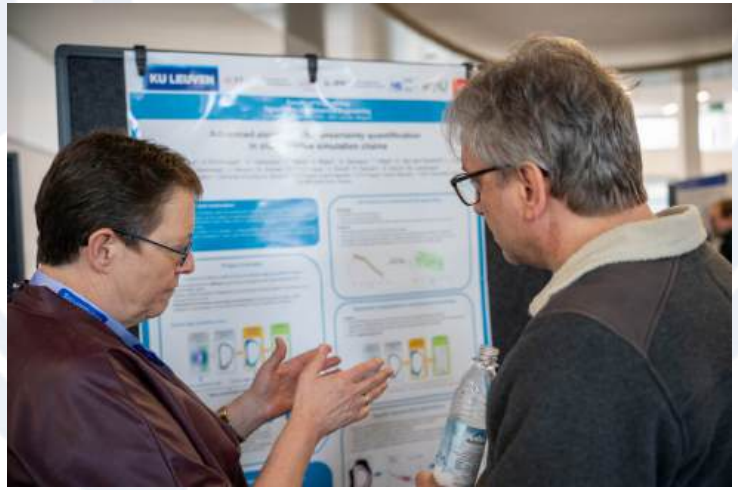
Liaison to ITER and F4E

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

2nd E-TASC General Meeting (February 9-13, 2026)







Credit: Tamás Szabolics, EUROfusion

News and Events since previous FSD PB#8

- **18th IMEG Meeting (Sept 8-10, 2026)**
  - Significant progress in IMAS ecosystem development, **AI integration**, and community deployment
  - **AI/LLMs** are a high-value **enabler for software development and VVUQ processes**
  - **DD4 migration** (requires coordinated effort from EUROfusion codes)

- **EIROforum AI workshop (and Task & Finish Group (Nov 12-13, 2026)**
  - **Access to European AI infrastructure** (AI factories, EuroHPC, RAISE) – *some hosted by EUROfusion beneficiaries*
  - EIRO coordination on **AI utilization, policy and knowledge development**

- **Call for Tasks to be carried by Advanced Computing Hubs in 2027 (Deadline: Oct 30, 2026)**

- **Call for Proposals for the use of the EUROfusion High Performance Computer (Deadline: Nov 13, 2026)**
  - **Cycle #10 will be reduced to 10 months**

- **Pitagora HPC operation is stable**
  - **Availability KPI is reached by both partitions for several sequential months**

- **LTDSF is opened for public use (training on Sept 29, 2026)**
  - **Policy is under discussions**

Towards Digital Twins of Fusion Systems

Digital Twin Development

Nuclear Fusion
https://doi.org/10.1088/1741-4326/ae8037
OPEN ACCESS
IOP Publishing | International Atomic Energy Agency
Nucl. Fusion 66 (2026) 116014 (17pp)

of fusion systems

Towards d

F. Jenko[1,*], J. Ball[2]
J.M. García-Regaña[6]
A. Mishchenko[7], E

https://doi.org/10.1038/s41567-026-03485-z

Fusion digital twins from imperfect models

Nature Physics 2026

Ionuț-Gabriel Farcaș & Frank Jenko

Check for updates

Digital twins could transform how fusion plasmas are predicted, designed and controlled. We argue that realizing this promise requires multi-fidelity frameworks that systematically combine imperfect models and data while quantifying uncertainty.

Digital twins

Following a recent National Academies report[3], a digital twin is a virtual representation of a specific physical system that is dynamically synchronized with measurements from its physical counterpart, has predictive capabilities and supports decision-making. Information flows in both directions: measurements from the physical system periodically or continuously update the virtual representation, whereas predictions from it inform decisions that affect how the physical system is operated, controlled or modified. Under a commonly used integration-based taxonomy, a virtual representation automatically updated with data

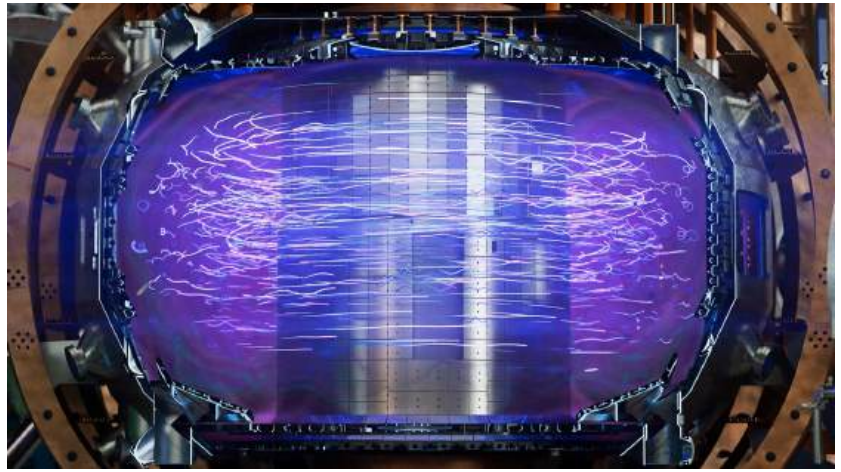
rg/10.1038/s42254-025-00837-1

Check for updates

via supercomputing

Frank Jenko 1,2

DIGITAL TWINS FOR FUSION DEVICES

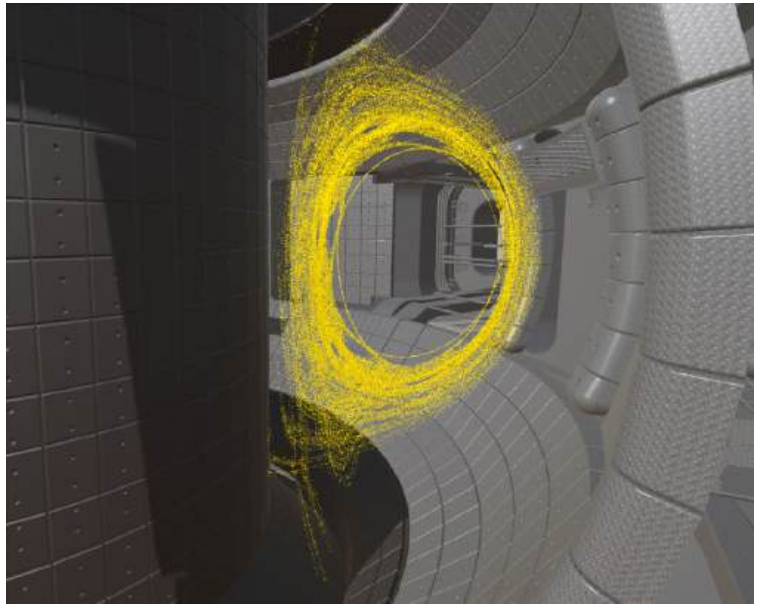


DIII-D Digital Twin [1]

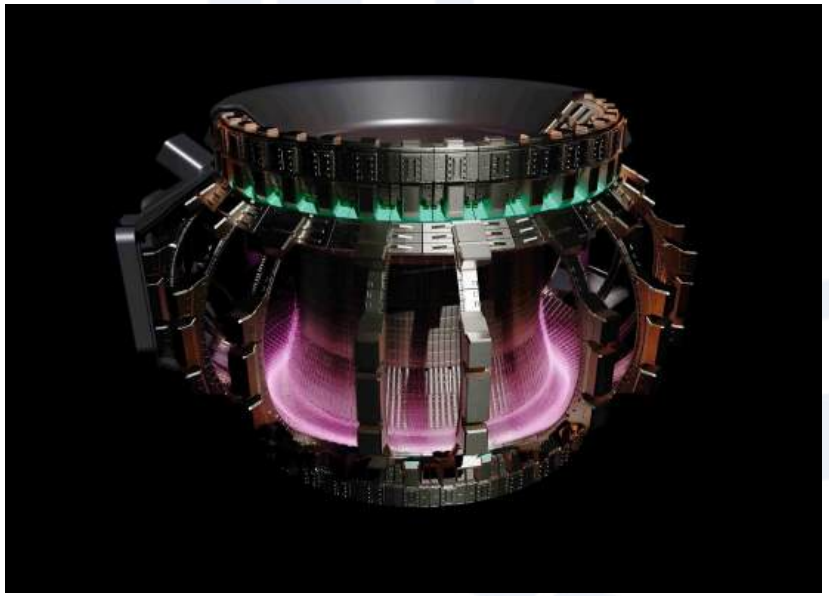
Digital Twins

- Dynamic virtual representations of a complex real-world systems
- Combine numerical simulation, real-world data, AI surrogate models and visualization tools to analyze and test scenarios independently of the physical systems
- Examples of DTs outside of Europe: DIII-D, KSTAR, SPARC

[1] https://blogs.nvidia.com/blog/nvidia-general-atomics-fusion
[2] J.M. Kwon et al., Fusion Engineering and Design, 184, 113281 (2022)
[3] https://blog.cfs.energy/how-nvidia-ai-and-simulation-libraries-and-siemens-tools-can-accelerate-fusion-energy

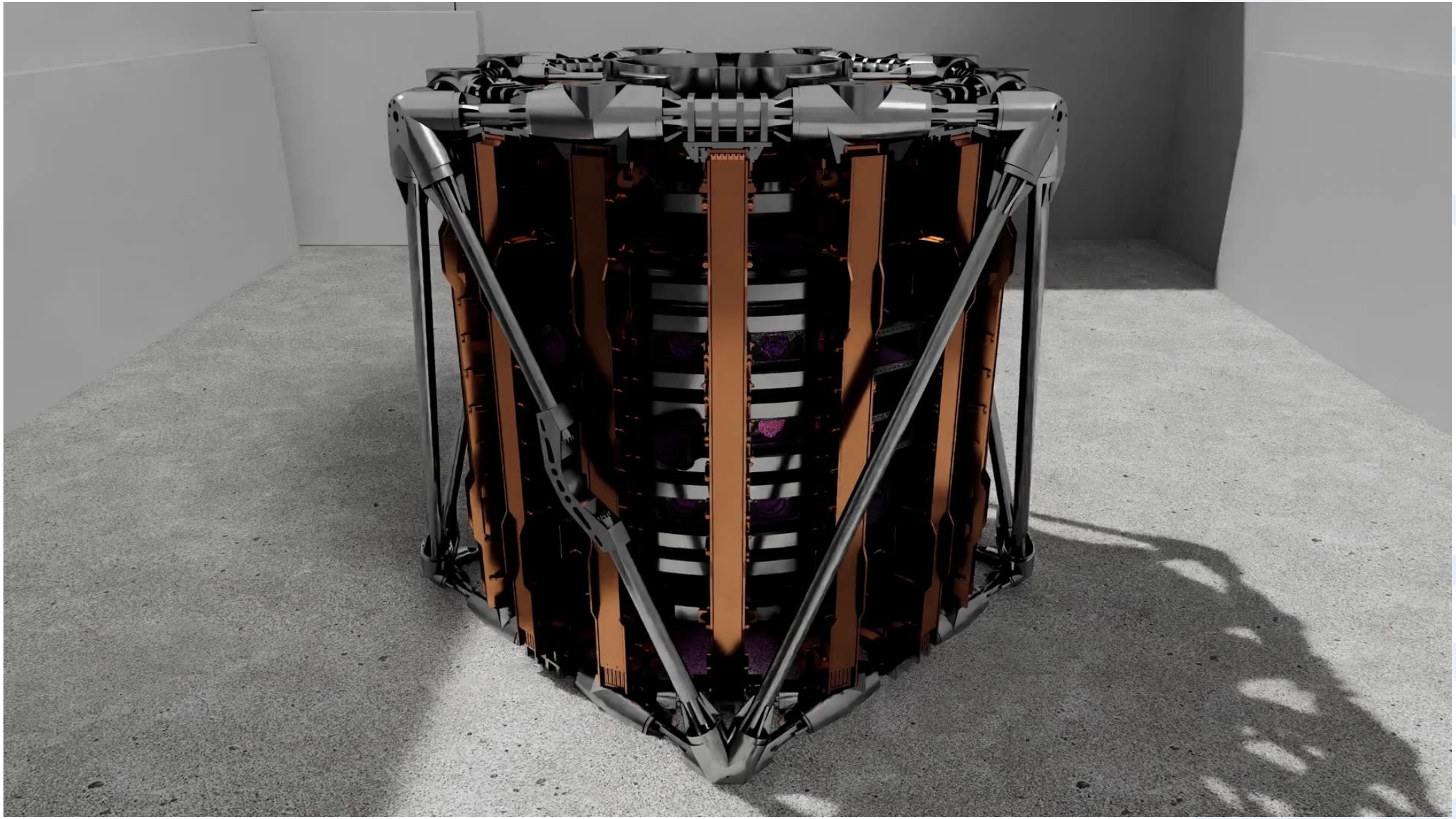


KSTAR Digital Twin [2]



SPARC Digital Twin [3]

FUSION DIGITAL TWIN: INITIAL VISUALIZATION RESULTS



WPAC: Digital Twin Environment (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

WPAC: Digital Twin Environment (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 (**Withdrawn on request from UKAEA**)
  - Andrew Davis, UKAEA

WPAC: Data

Data Management Plan (DMP)

- Ensure FAIR access to EUROfusion experimental and simulation data.
- Implement Scenario C: traceable data access via Persistent Identifiers (PIDs).
- Develop software solutions for: *1) Data storage and management; 2) Analysis and access control; 3) Account provisioning and resource allocation (supported by ACHs)*
- Promote AI/ML technologies for data validation, analysis, and optimization.

EUROfusion Multi-Machine Databases

- Maintain and extend databases: *pedestal, disruption, transport, L-H transition*
- Updates and developments: *TCV pedestal database with WPTE data; Develop L-H transition database; Coordinate transport database; Standardize Infrared Imaging Systems database; Update CICLOP long pulse database*

AMNS Database

- Continued support and maintenance: *Align with latest IMAS Data Dictionary (DD) releases; Extend datasets included*

Embracing the AI Revolution

Perspectives on agentic AI

UK Atomic Energy Authority

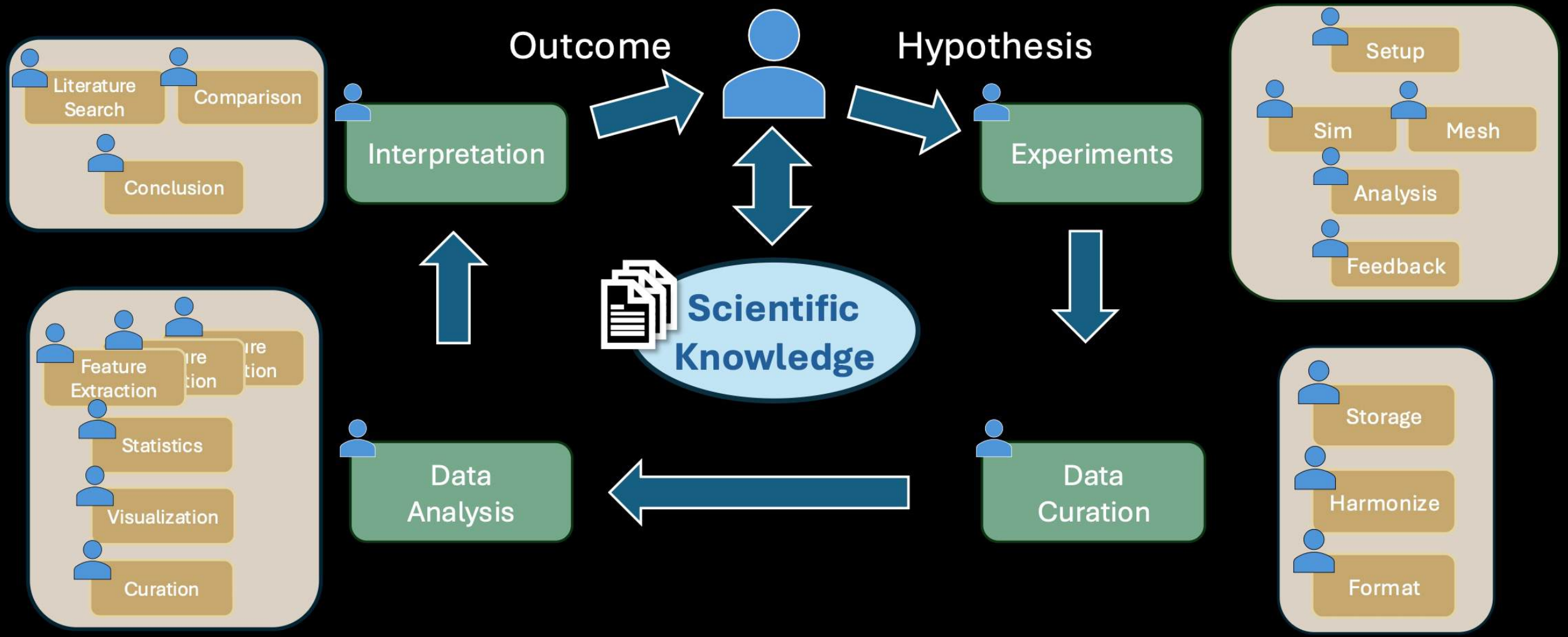
Coding agents accelerate research software development

- Coding agents, used competently, are huge productivity boosts for simulation code developers
- They are also useful for users, who can use them to query and understand complex codebases
- Research cycles can be made much faster

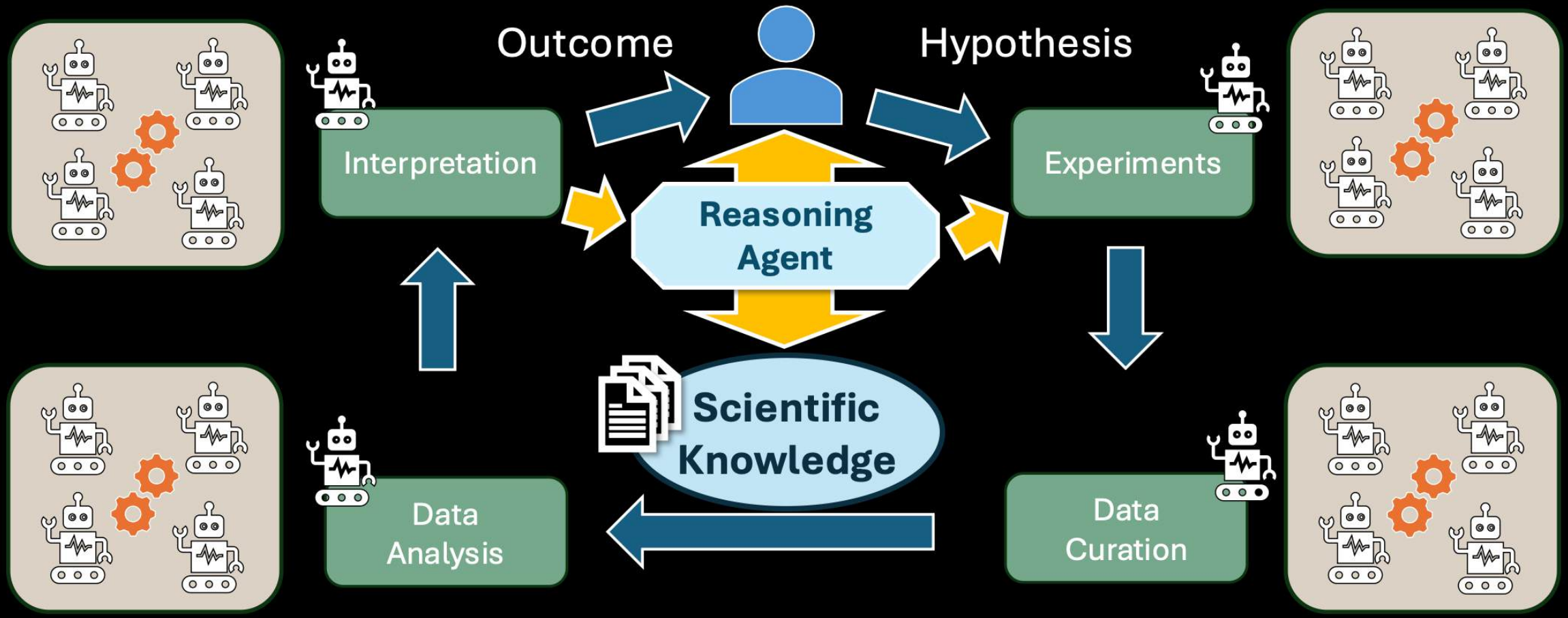
Agents are emerging as capable closed-loop researchers

- Given broad research goals, agents can make autonomous progress and report methods and findings
- Requires access to data and suitable computational resources
- Potential to increase the scope of research

AI has the potential to transform the largely manual scientific knowledge discovery and engineering design optimization processes

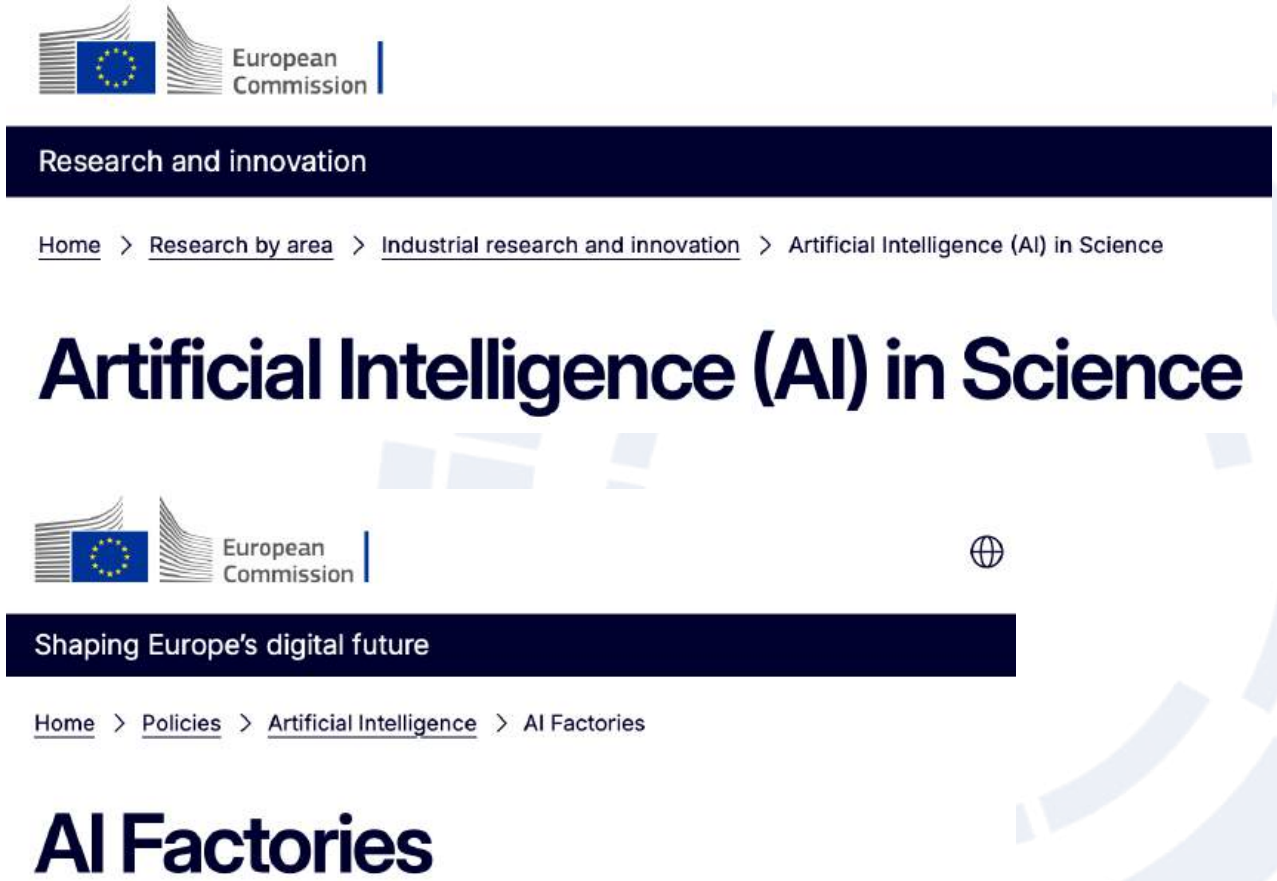


Genesis Mission's goal is to create an agile discovery, design, and decision framework using AI/ML to address our mission needs



AI for Science and Engineering in Europe

AI has become a strategic priority for European policy-makers, including through the EC's **AI in Science Strategy**[1], **Apply AI Strategy**[2], the expansion of the EuroHPC ecosystem with **AI Factories**[3], as well as emerging member state led coordinated actions such as the **Frontier AI Initiative**[4].



[1]https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/artificial-intelligence-ai-science_en
[2]https://digital-strategy.ec.europa.eu/en/policies/apply-ai
[3]https://digital-strategy.ec.europa.eu/en/policies/ai-factories
[4]https://www.elysee.fr/en/emmanuel-macron/2025/11/18/germany-france-and-the-european-commission-launch-frontier-ai-initiative-at-the-summit-on-european-digital-sovereignty

Software Development & ACHs

Determining software standards

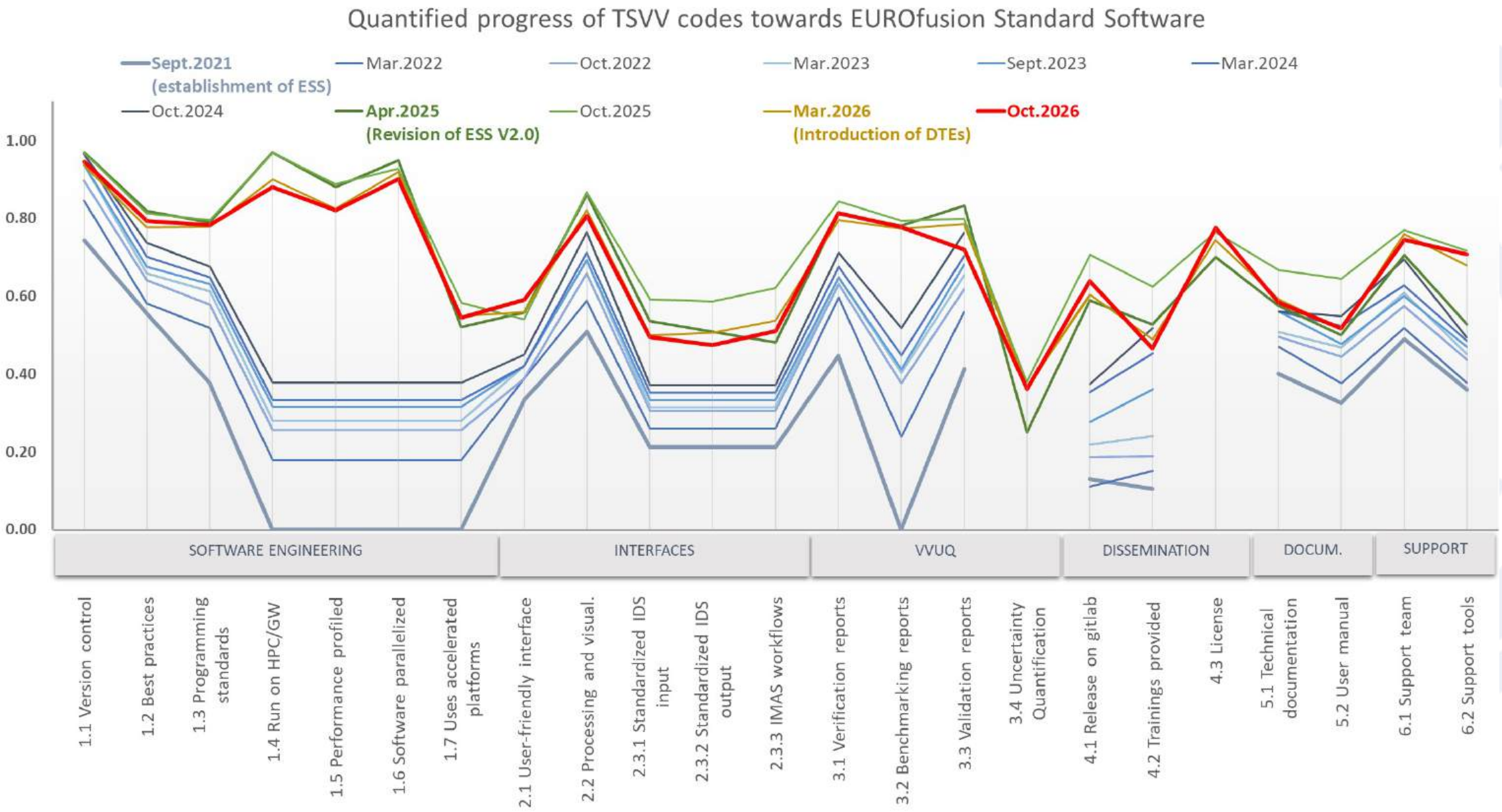
The quality assurance framework for EUROfusion Standard Software (ESS)

https://idm.euro-fusion.org/?uid=2Q72WQ&version=v2.2

(endorsed by the E-TASC SB on March 12, 2025)

- Progress toward ESS establishment has been regularly monitored, showing clear advances since 2021; remaining gaps are expected to be addressed during 2026-27.
- Increasing numbers of codes are being released as open source, aligned with IO/EU policies and enabling collaboration with start-ups under appropriate licensing.
- Strategic focus is shifting from software development to software use, with targeted training for users within mission budget constraints.

Progress towards EUROfusion Standard Software



WPAC: Advanced Computing Hubs

4 ACHs recommended for 2026/27, aiming at broad competence coverage within available resources:

- Cat1 (HPC): **CIEMAT**, **EPFL**, **MPG**
- Cat2 (MFSW): **IPPLM**

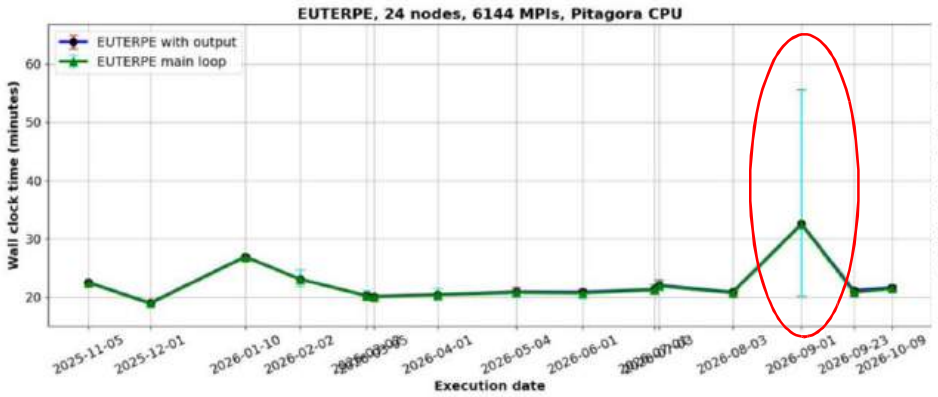
VTT (AI/ML focus): not funded as standalone activity due to budget constraints, but competences to be integrated under **ACH-MPG**

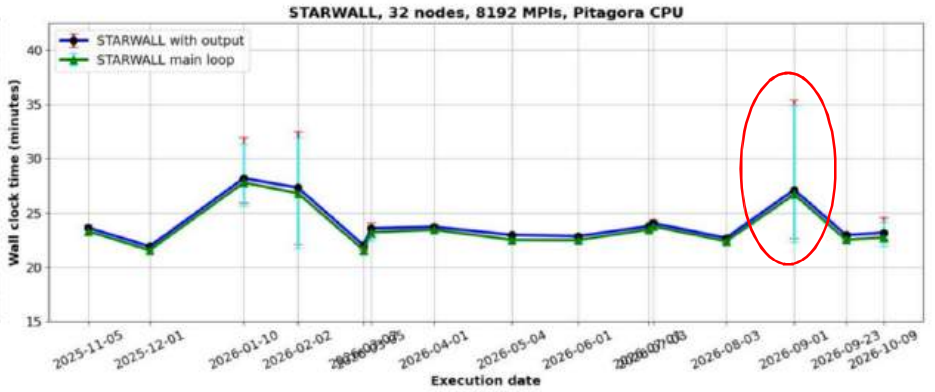
Category 1: High Performance Computing (HPC)	Category 2: Modeling Frameworks and Standardized Workflows (MFSW)
Tasks under the category include:	
• Enabling effective GPU usage of a selected set of codes on EUROfusion's HPC platforms with expanded GPU partitions • Selecting and implementing scalable 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

Role of ACHs for the efficient use of EUROfusion HPC systems

4th ACH annual meeting, Oct. 2026 (https://indico.euro-fusion.org/event/4160/):

- Code optimization for HPC
- Increasing use of LLMs for code development
- Support to HPC operation and use





Computational Hardware

WPAC: Computational Hardware - Pitagora

- **Critical issues impacting codes on Pitagora:** Firmware upgrade on all GPU racks together with a system software and communication transport layers upgrade on both partitions (April 14-15)
  - GPU direct RDMA problem solved
  - Network issues mostly solved (together with a new setting of UCX transport layers for intel-oneapi-mpi)
- **Amendment to the PIA signed in July 2026**
  - Schedule aligned with the deployment of Pitagora and new GW
  - Provision for dealing with security issues – no impact on “regular” maintenance time allowed
- **Security issues (affecting all HPC centers) with the need to apply urgently fixes to Pitagora and GW**
  - April: 1, May: 5, June: 2, July: 1
- **Back-up (home + GW storage) still not provided as specified in the PIA**
  - Expected end of 2026
- **HPCMD has been installed as a systemd service on test compute nodes:**
  - Pitagora GPU –Booster: Nodes=r309c01s[01-04]
  - Pitagora CPU (DCGP): Nodes=r355c01s[01-04]

WPAC: Computational Hardware - Pitagora

Main KPIs

PITAGORA-DCGP (A6), [%]	Sep. 2025	Oct. 2025	Nov. 2025	Dec. 2025	Jan. 2026	Feb. 2026	Mar. 2026	Apr. 2026	May 2026	Jun. 2026	Jul. 2026	Aug. 2026
Availability	96,59	93,80	96,82	97,22	98,15	97,83	97,88	98,52	98,58	97,55	97,40	97,22
SLA	*90,0*	*90,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*
Usage	45,98	61,50	79,80	72,10	76,10	92,20	86,50	85,80	79,70	76,20	83,10	79,3
SLA	*60,0*	*60,0*	*85,0*	*85,0*	*85,0*	*85,0*	*85,0*	*85,0*	*85,0*	*85,0*	*85,0*	*85,0*

PITAGORA-Booster (C3), [%]	Sep. 2025	Oct. 2025	Nov. 2025	Dec. 2025	Jan. 2026	Feb. 2026	Mar. 2026	Apr. 2026	May 2026	Jun. 2026	Jul. 2026	Aug. 2026
Availability	98,22	96,17	95,43	95,82	96,44	95,59	94,52	94,68	97,54	97,70	98,67	98.89
SLA	*90,0*	*90,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*	*97,0*
Usage	45,9	74,7	88,2	57,0	67,9	97,1	89,10	89,40	85,40	82,60	63,20	90,1
SLA	*none*	*none*	*70,0*	*70,0*	*70,0*	*70,0*	*70,0*	*70,0*	*70,0*	*70,0*	*70,0*	*70,0*

- **CPU:** low usage, below the SLA for several sequential months
  - *PIs are encouraged to use low-priority queue;*
  - *Increase of quotas for projects used initial allocation*

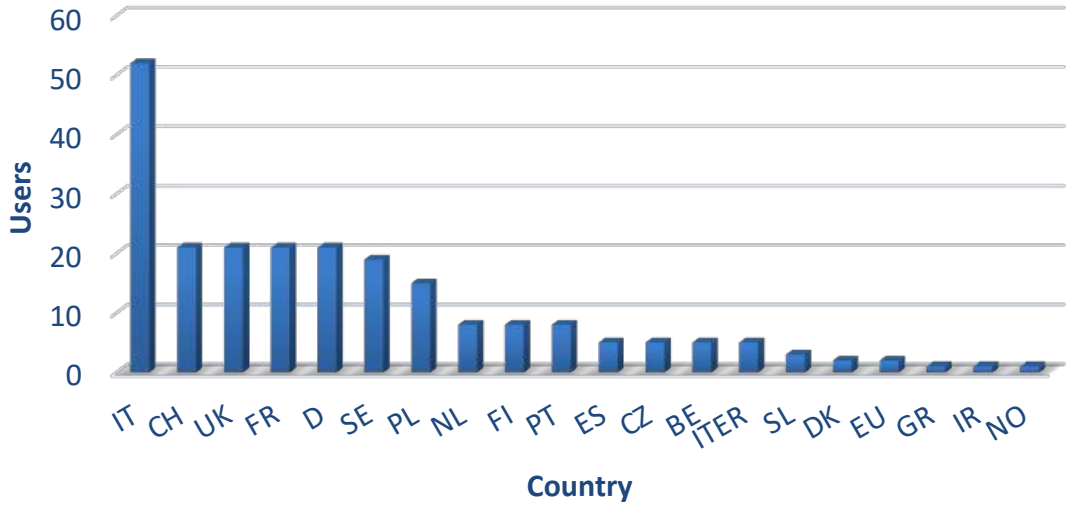
- **GPU:** partition stabilization after one year of production
  - *Availability compliant with target (KPI) since May 2026*
  - *Good usage profile (many users are able to submit highly parallel jobs)*

WPAC: Computational Hardware - EFGW

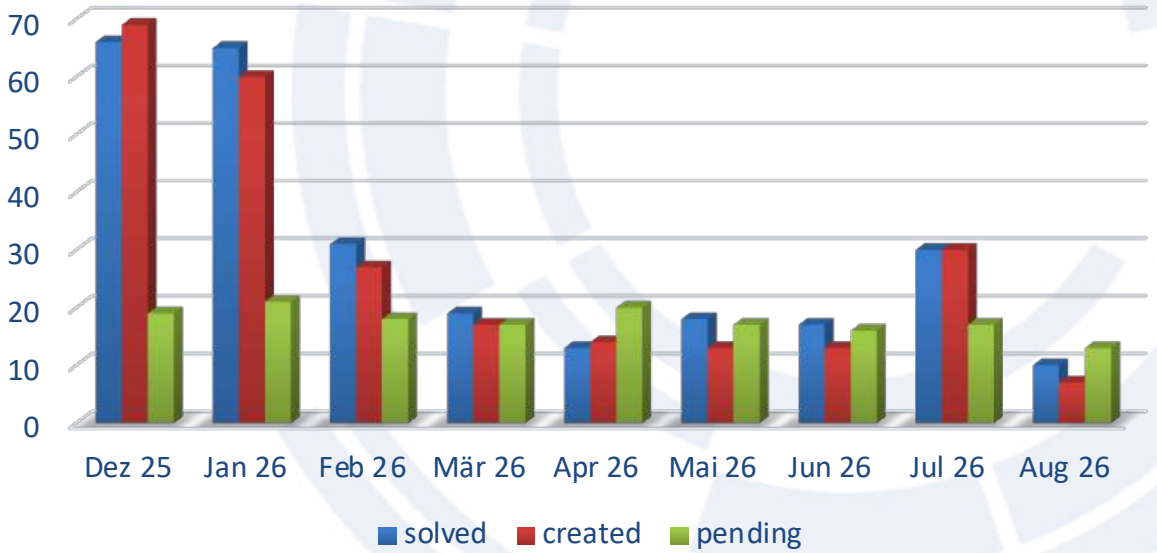
Main KPIs

EFGW, [%]	Sep. 2025	Oct. 2025	Nov. 2025	Dec. 2025	Jan. 2026	Feb. 2026	Mar. 2026	Apr. 2026	May 2026	Jun. 2026	Jul. 2026	Aug. 2026
Availability	97,05	94,95	99,89	99,32	94,28	100	98,75	98,01	99,18	99,99	100	97
SLA	97	97	97	97	97	97	97	97	97	97	97	97

224 Gateway Users (September 2026)



EFGW Tickets number



- **Compute Nodes: average monthly usage ~60-70%**
- **Storage: 2.4 PB (usage 37%)**
- **Upgrade to the last version of NX server** (next GW maintenance)

WPAC: Computational Hardware - LTDSF

- **8PB LONG-TERM DATA STORAG at PSNC:**
  - **S3 storage available since 07.2025**
  - **Open for data retrieval:**
    - Policy discussions continued within EUROfusion LTDSF Policy WG
    - Technically users /experiments may start copying data to PSNC
  - **Documentation and training:**
    - Full end-user **documentation on storage service usage** available [1])
    - **Training for ACHs was performed in April 2026**
    - **Training to EUROfusion users is essential** (first event: https://indico.euro-fusion.org/event/4180/)

- **Open topics (prioritized):**
  - **1PB IMMEDIATE STORAGE BUFFER**
    - **Enable broadband transfers from CINECA to PSNC**
    - Largely progressed on technical level
    - **waiting for GARR final arrangements and administrative issues**

  - **Make usage more convenient**
    - Find ways to map EUROfusion users/groups and federated AAI to S3 credentials
    - Collect feedback from users on documentation and training to improve documentations

Grant deliverables and milestones (2026)

Grant Deliverables

Deliverables Title	Date	Comments
Consolidated report including uptime KPIs, usage statistics, GPU/CPU utilisation, user feedback, and incident logs for HPC, EFGW, and LTDSF	12.2026	Produce consolidated report including uptime KPIs, usage statistics, queue times, GPU/CPU utilisation, user feedback, and incident logs for HPC, Gateway, and LTDSF by Dec 2026 [CHW]
Advanced Visualisation Toolkit	12.2026	Release version 1.0 of an interactive visualisation toolkit supporting IMAS data and DTE validation, including documentation and 2 demonstrator use cases. [DTE]

Grant Milestones

Milestones Title	Date	Comments
IMAS platform enabled for the use on Pitagora HPC	12.2026	Provide a containerised IMAS execution environment enabling the latest two IMAS releases on EUROfusion HPC systems, validated via at least three reference workflows (transport, equilibrium, turbulence). [CHW]
Allocation of HPC resources for Cycle 10 of production runs	03.2026	Completed project selection and resource allocation for the use of the EUROfusion HPC during Cycle 10 [CHW]
Achievement of KPIs on availability to users of EUROfusion computational resources	12.2026	Availability of HPC, Gateway and LTDSF in support of simulation programme as set by the Key Performance Indicators [CHW]

Planning of 2027

The big picture

EUROfusion role evolves, with implications for DSO strategies:

- Support the **development of future FOAK/FPP devices**
- **Support of ITER operations** remains a central objective
- Leverage digital solutions to **mitigate risks** and **reduce costs & timelines**
- Digital solutions provide **moderate-cost, high-impact contributions** to Europe's fusion program

DSO key objectives:

- Maintain **fundamental theory and simulation** as core program components
- **Integrate plasma physics with fusion engineering and materials science** to support FOAK/FPP readiness
- Strengthen **communication and collaboration between scientific and engineering communities**
- Prioritize key methodologies – **VVUQ, AI, and Digital Twins** – as central elements of FP10 objectives
- Provide state-of-the-art **computational resources** dedicated for fusion
- Enable **ACHs** to fully leverage EUROfusion's HPC investments

Priorities 2027

- **Development and dissemination of EUROfusion Standard Software**
- **From Open Source to Open Data**
- **Enabling Data-Driven Fusion Science**
- **Taking Advantage of the AI Revolution**
- **Supporting VVUQ, Open Data & AI in fusion**
  - Enable federated, FAIR, and AI-supported fusion data ecosystems
  - Accelerate IMASification of experimental and simulation data
  - Promote open data publication alongside scientific results
  - Strengthen transparency and reproducibility via citable repositories
  - Combine AI with physics-based models toward Digital Twins
- **Facilitating Stellarator Collaborations**

2027 Work Plan Context

- Following the call launched in 2025, WPAC activities were planned and approved as a two-year programme (2026-2027).
- The work plan, resources and objectives for 2027 were defined as part of this agreed programme.
- 2027 therefore represents the second implementation year of the approved plan

New and reinforced activities

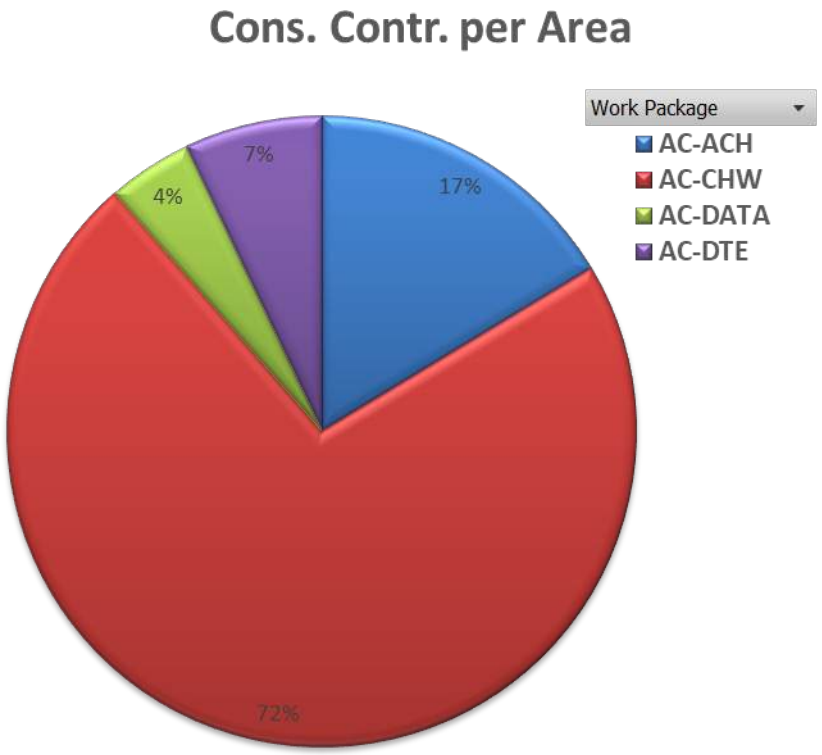
(Response to the evaluation of the EUROfusion 2026-27 Work Plan proposal)

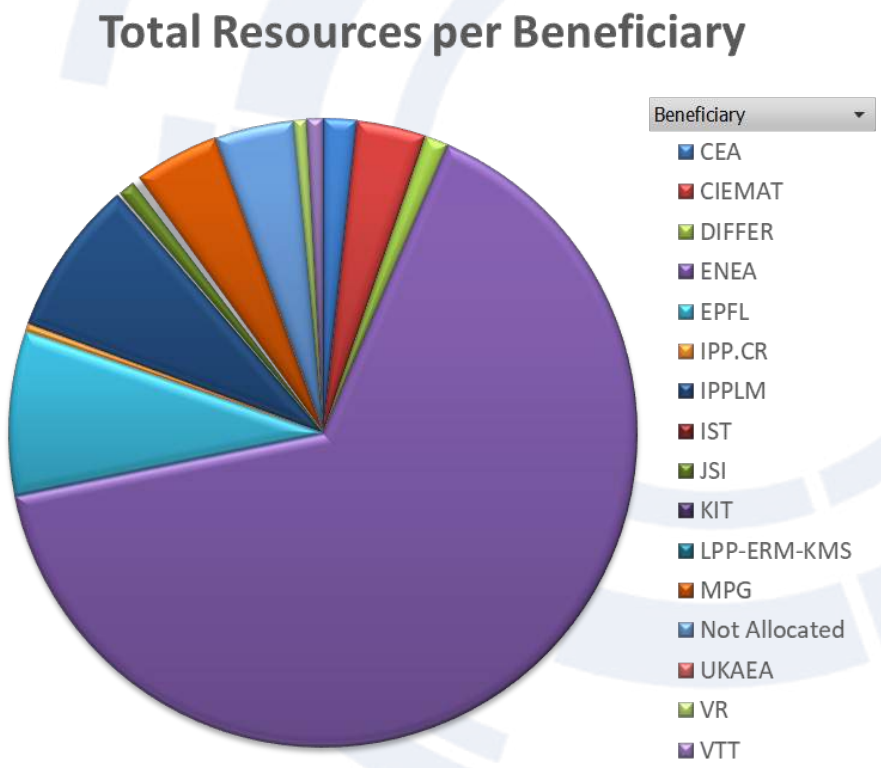
Steps towards the establishment of a unified experimental data platform as a 2027 global objective:

- AI-assisted IMASification of JET data (NEW)
- DMP acceleration of development towards scenarios “C” and “D” (extension of WPAC-DATA-DMP)
- Integration of stellarator data into IMAS (NEW)

DSO Resources

- Dominated by Infrastructure and Support activities (CHW + ACH)
- Resources are covered to 72% by the budget 2021-2025 (CHW)
- Shortage of travel funds (expected to be increased following the GA(26)-56)





Pitagora HPC: Project Selection 11th Cycle

- Call launched: **20.Sept.2026**
- Call closed: **13.Nov.2026**
- Referee evaluation reports received by **Jan.2027**
- **16th Allocation Committee Meeting Feb.2027**
- **Start of Cycle #11 – 1.March.2027**

	Partition		Nodes (for EUROfusion)	Reserved for JA collaboration (*)	Nodes to allocate	Duration	Number of months	Number of days	Production to be expected (minimum)	Node hours without over allocation*
Cycle 11	Pitagora-CPU	CPU AMD Turin	1008	15	993	March 1, 2027 Dec. 31, 2027	10.0	306	82.45%	**5,951,828**
Cycle 11	Pitagora-GPU	GPU Nvidia H100	168	5	163	March 1, 2027 Dec. 31, 2027	10.0	306	67.9%	**976,987**

** 10% of resources in March 2027 are reserved for EU-JA projects*

An extension of the allocation period until 29 February 2028 is dependent on the continuation of EUROfusion activities under FP10. Should such an extension be approved, all projects endorsed under this call will automatically receive a corresponding extension of their allocations. The additional resources will be made available at the same average monthly allocation rate as granted during the initial allocation period, unless otherwise decided by the Allocation Committee due to operational constraints.

Meetings and Events planned

E-TASC SB review of progress in 2026

The review **should assess the progress of E-TASC as a whole**, rather than separating the evaluation into DSO and WPTM activities:

- *Review of progress achieved in 2026;*
- *Adjustments and outlook for 2027;*
- *Preparation for the E-TASC General Meeting #3 (Autumn 2027);*
- *Outlook beyond 2027, when we hopefully have greater clarity regarding EUROfusion activities under FP10.*

E-TASC General Meeting #3 (September 2027)

2027 GDs and GMs

ID	Deliverable Title	Date	Comments
AC.D.10	Consolidated report including uptime KPIs, usage statistics, GPU/CPU utilisation, user feedback, and incident logs for HPC, EFGW, and LTDSF.	31.12.2027	CHW
AC.D.12	Summary report of deployment and validation of Pulse Design Tool including trainings	31.12.2027	DTE
AC.D.13	Report on implementation of the EUROfusion Data Management Plan	31.12.2027	DATA *(Activity reinforced)*
AC.D.14	Report on simulation framework for fusion devices, focused on divertor system	31.12.2027	DTE

ID	Milestone Title	Date	Comments
AC.M.14	Allocation of HPC resources for Cycle 11 of production runs	31.03.2027	CHW
AC.M.10	Demonstrated DMP infrastructure readiness for “Scenario C”	31.07.2027	DATA *(Activity reinforced)*
AC.M.11	Implement automated scenario optimization and discharge forecasting capabilities in Pulse Design Tool.	31.12.2027	DTE