E-TASC General Meeting #2

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Materials: https://indico.euro-fusion.org/e/E-TASC_GM2

This document was finalized by the E-TASC Scientific Board on February 23, 2026 and is based on the slides presented by Frank Jenko (DSO Head and E-TASC SB Co-Chair) and agreed upon by all participants on the final day of the meeting.

Overview

The E-TASC General Meeting #2 brought together more than 100 researchers to review progress, address challenges and opportunities, and outline future directions for the **EUROfusion Theory and Advanced Simulation Coordination (E-TASC)** initiative. The event featured a mix of plenary, breakout, poster, and hands-on sessions, fostering in-depth discussions across individual projects and strengthening collaboration among the various **Digital Twin Environment (DTE)** projects, **Theory, Simulation, Verification & Validation (TSVV)** projects, **Advanced Computing Hubs (ACHs)**, and theory- and modeling-oriented **Enabling Research (EnR)** projects.

The talks, posters, and discussions covered a wide range of topics in plasma physics and fusion engineering simulations, highlighting the challenges involved in developing predictive tools for the design, performance, and operation of future fusion devices. In this context, comprehensive and systematic validation activities play an essential role, supported by growing efforts in multi-fidelity techniques and **Uncertainty Quantification (UQ)**. Rapid advances in **Artificial Intelligence (AI)** are poised to transform the analysis of experimental and simulation data, data mining, code development, and the creation of **Digital Twins** of fusion systems.

Strategic Key Themes

Fusion Theory & Simulation: Needs and Opportunities

The meeting provided a platform for leaders of EUROfusion activities related to experiments and modeling to identify key needs and opportunities in fusion theory & simulation. Participants emphasized the importance of training and disseminating tools to a broader user base, as well as improving the use of experimental data across projects. In this context, there was a clear call for better documentation practices and the standardization of metadata to facilitate collaboration and enhance the interpretation of experimental results.

Numerous modeling needs were identified, particularly with regard to the interpretation of data from W7-X and TE devices, including JET, and to addressing physics gaps relevant to ITER, JT-60SA, FOAK, and tokamak/stellarator-based fusion pilot plant concepts. Existing prioritized lists of research gaps were recognized as an important basis for defining future research thrusts, particularly in the context of FP10 planning. At the same time, participants emphasized the importance of maintaining a balanced approach between application-driven modeling and the continued advancement of fundamental physical understanding, noting that the latter is crucial for ensuring model extrapolability, identifying missing physics, and reducing epistemic uncertainty in predictive tools. Concurrently, a deeper integration of plasma physics, fusion engineering, and materials science is essential to accelerate the transition from fusion research to viable power plants.

Addressing these challenges will require careful consideration of personnel and funding constraints at the EUROfusion level. Some activities related to model application and validation may be supported through IO-funded postdoctoral positions, while others could receive financial support from the IO through targeted implementing agreements or contracts.

Progress toward EUROfusion Standard Software (ESS)

The notion of EUROfusion Standard Software is built on the following principles and targets:

- Free availability (within EUROfusion) of an up-to-date release version of the source code used for production runs.
- Best practices for software development, including version control, regression/unit testing, and shared development rules.
- Technical documentation, including detailed user manuals and reference publications with descriptions of the underlying models.
- User support, providing assistance for users, co-developers, and support staff through designated contact points, mailing lists, issue trackers, and other tools.
- Plans for software verification and validation, involving third-party reviews and incorporating uncertainty quantification.
- User-friendly interfaces and visualization/post-processing tools, including intuitive designs and interfaces to the IMAS Data Dictionary (where applicable) to allow understanding and navigating through the application in an efficient way.
- Specific plans for dissemination and user training across EUROfusion.

Progress toward the establishment of ESS has been monitored through regular self-evaluations, which indicate tangible advances since 2021. The remaining gaps are expected to be addressed, as far as possible, by the end of 2027. In this context, an updated list of E-TASC codes — including brief descriptions and the respective code coordinators — will be compiled and made available.

An increasing number of E-TASC codes are being released as open-source software, in line with IO and EU policies. In this context, collaboration with fusion start-ups can be facilitated through appropriate licensing arrangements consistent with the EUROfusion Consortium Agreement.

Looking ahead, there is a growing need to shift the emphasis from software development to software use. This includes providing training opportunities for both occasional users and dedicated power users, offered in online and/or in-person formats, while taking into account the constraints of the available mission budget.

Facilitating Stellarator Collaborations

Amidst the growing momentum in EU and US stellarator research, active discussions and various research activities are taking place regarding the physics basis and design of future stellarator power plants. A recent assessment of critical physics gaps underscores the urgent need for deeper collaboration, both within the stellarator theory and modeling community and with its tokamak counterpart.

The possible extension of IMAS to stellarator applications was discussed as a means of enabling more objective comparisons between tokamak and stellarator concepts. Ideally, such an extension would be driven by the stellarator community, including relevant private-sector stakeholders, and would also facilitate the application of stellarator modeling tools to tokamak configurations. In this context, an extension of the existing 3D equilibrium capabilities within IMAS was identified as a key objective.

Two main tasks were outlined: first, the extension of the IMAS data model itself; and second, the integration ("IMASification") of experimental data from stellarator devices such as W7-X and LHD, as well as from tokamaks (for addressing 3D physics). It was agreed that further discussions are needed to better define relevant use cases which can motivate such efforts, and that this topic may represent a potential target for future activities within FP10 planning.

Towards Systematic and Reproducible VVUQ

The need for more systematic and reproducible approaches to verification, validation, and uncertainty quantification (VVUQ) was highlighted. Much of the existing validation work remains non-systematic, with workflows that are often poorly documented and not fully reproducible. As a result, individual modeling choices — including parameter tuning to improve agreement with experimental observations — can lead to differing outcomes, even when addressing the same problem.

This lack of systematic validation presents a significant challenge for uncertainty quantification (UQ), which can only be meaningfully performed if the underlying workflows are reproducible. While a number of positive examples already exist, broader adoption of UQ remains limited. Potential barriers include the absence of widely applicable multi-fidelity methodologies, insufficient model realism in some application domains, and the high dimensionality of relevant parameter spaces.

Increasing visibility of these challenges and promoting best practices — for example, through dedicated sessions at future EUROfusion Science Meetings — may help to foster wider adoption of systematic VVUQ approaches.

Enabling Data-Driven Fusion Science

The implementation of the Data Management Plan (DMP) represents a key step toward enabling data-driven fusion science. The long-term objective is the establishment of a production-ready, federated data management ecosystem that provides harmonized access to both experimental and simulation data across EUROfusion sites and user communities. A staged approach toward FAIR data access is being pursued, with current efforts focused on transitioning from prototyping to production-level use.

In this context, the "IMASification" of experimental and simulation data should be accelerated. The development of standardized tools for curating fusion data at scale — potentially leveraging AI and building on existing solutions — could be transformative. For instance, mapping the current JET PPF data description to the IMAS format could be streamlined through the use of AI-based conversion tools (not least because the IMAS framework is openly accessible). Similarly, the adoption of standardized metadata across devices and modeling codes would support advanced validation and UQ activities, as well as facilitate the integration of simulation and modeling outputs.

Moving toward open data access remains an important objective. Candidate devices for initial implementation includes WEST and TCV, with the potential involvement of WPTE. (WEST data is already open, subject to a two-year embargo period.) The possible inclusion of non-EU devices may also be considered in the longer term.

From Open Source to Open Data

Recent developments point to a growing transition from open-source software toward open data practices within the fusion community. In particular, the IO has begun making IMAS datasets publicly available via Zenodo in support of ITER modeling activities, in line with FAIR principles. These include, for example, partial ITER machine descriptions and simulation results provided in the IMAS data format.

Looking ahead, there is a growing expectation to publish curated datasets alongside journal publications and ITPA benchmark activities. Simulation data — structured using the IMAS data model and accompanied by appropriate metadata — could be made available via platforms such as LTDSF or Zenodo. A more detailed plan outlining such practices is expected to be proposed in the coming months.

The adoption of open data practices will require the establishment of evolving working procedures, including considerations such as potential embargo periods. Existing open data policies should be reviewed, and their alignment with EUROfusion publication rules — particularly in the context of FP10 planning — should be explored. In addition, there is a need to provide training in open data practices for experimentalists across the EUROfusion program, beyond the E-TASC community.

Promoting the Reproducibility of Published Scientific Results

The implementation of FAIR principles within WPTE — and, more broadly, across EUROfusion — was identified as a key step toward improving the traceability and reproducibility of experimental and modeling results. In particular, publications should be accompanied by accessible repositories containing the relevant data, processing workflows, and modeling inputs required to reproduce the reported findings.

During 2026–2027, WPTE plans to strengthen the traceability and reproducibility of FP9 analysis activities in preparation for FP10. This will include the development of a citable repository framework to support the transparent documentation of results. In this context, WPTE is seeking support from E-TASC in the development of appropriate tools and workflows.

Taking Advantage of the AI Revolution

Rapid advances in AI offer new opportunities for fusion research, including the development and application of agentic AI models. The IO plans to initiate related activities in 2026, building in part on large language model (LLM) technologies. AI-based tools may support a range of tasks, including software development, data mapping, and the adaptation of existing codes to the IMAS data model.

Pilot projects — such as the AI-assisted integration ("IMASification") of JET data — could serve to demonstrate the potential of these approaches. EUROfusion may also consider providing access to suitable AI tools and associated training opportunities. The IO has expressed its willingness to support such efforts, which are expected to be discussed further at the March 2026 meeting.

More broadly, there is a need to explore optimized combinations of model-based and data-driven approaches to enable the development of Digital Twins of fusion systems. In doing so, it is important to recognize that fusion research operates under constraints that differ significantly from those of large technology companies, with comparatively limited data availability but substantial prior physical knowledge.

Crucially, AI-based techniques and Digital Twin development should be explicitly coupled with targeted theoretical efforts: improved fundamental understanding must guide model selection, surrogate construction, and interpretability criteria, ensuring that data-driven approaches capture and take into account known physical mechanisms.

E-TASC: Next Steps and Future Directions

TSVV discussions

Ongoing TSVV activities continue to support the ITER Research Plan, with a formal collaboration agreement having been signed between EUROfusion and the IO. A dedicated first IMAS data mapping workshop is planned for March 2026 at ITER, and E-TASC will continue to contribute to the IMEG activities.

The establishment of a common repository for data from simulations and experiments is foreseen, enabling multi-machine VVUQ and AI-based techniques. LTDSF is expected to define usage rules for such a repository, with simDB representing a possible implementation platform; appropriate guidelines will be required.

Further efforts will also focus on training activities and the dissemination of simulation codes. Prospective users are expected to engage proactively, with WPTE providing mission support where appropriate. TSVV-H will organize a session on HFPS, which will require access to the Gateway infrastructure. Additional relevant codes include GENE-X, JOREK, SOLEDGE, GRILLIX, and various stellarator optimization tools.

Closer links to ACHs will be important. Requests for ACH support should involve both the relevant code coordinator and the TSVV PI(s). The allocation of ACH support across TSVV activities in 2026–2027 remains to be clarified.

WPTM management will need to account for budget constraints in terms of personnel effort and mission funding. These resource limitations have implications for the 2027 work plan, with some deliverables at risk unless additional resources can be secured.

ACH discussions

ACHs are expected to retain indicative budget allocations for each TSVV activity, while continuing to provide support for selected codes beyond the TSVV ecosystem where appropriate. Travel funding should ideally allow for at least one in-person meeting per year. The need for appropriate recognition of ACH contributions — for example through co-authorship or acknowledgments — was emphasized. Several ACHs also emphasized the value of organizing training for new staff, noting that sufficient time is required to cultivate the necessary expertise.

The current situation regarding the Pitagora system was also discussed and recognized as challenging. Users are strongly encouraged to submit support tickets for any issues encountered; if these are not adequately addressed, users may contact the chair of the ticket committee directly or via an ACH representative. CINECA maintains a dedicated webpage listing known issues and solutions. Should problems persist, EUROfusion may need to engage further with CINECA, including requesting increased interaction with the hardware provider.

DTE discussions

It was proposed to hold regular virtual meetings at intervals of two to three weeks and to invite international Digital Twin experts for targeted presentations. New communication channels — such as Mattermost or dedicated Wiki platforms — will be established to facilitate collaboration. Mission funding for DTE-related activities is currently very limited and needs to be increased.

Discussions also highlighted the need and willingness to adopt ESS standards and pursue IMASification efforts. Looking ahead to FP10, there is a strong interest in establishing a more integrated DTE framework. In this context, the DTE should be viewed less as a monolithic system and more as a flexible, multi-fidelity toolbox within a joint framework.

Opportunities for collaboration with private-sector stakeholders should be explored where mutual benefits can be identified, potentially via public–private partnership (PPP) models.

Evolution of the E-TASC Ecosystem (2026–2027)

The transition to the 2026–2027 extension of the EUROfusion work program introduced several important developments within the E-TASC ecosystem. In particular, the newly established Digital Solutions for Fusion Office (DSO) will focus on advancing fusion research through Digital Twin technologies and other emerging digital approaches, while continuing to support expertise in large-scale HPC simulation and integrated modeling frameworks.

Meanwhile, TSVV activities have been consolidated under the new Work Package for Theory and Modeling. This structure will support the continued development of TSVV research software, with an increased emphasis on bridging existing gaps and strengthening validation and verification of modeling tools.

Preparation for FP10

FP10 may place increased emphasis on supporting future FOAK or FPP devices, while preparing for ITER operation will remain a central objective. The role of EUROfusion may evolve significantly in this context, and appropriate strategic preparation will be required.

Digital solutions offer a promising means of mitigating risks and reducing costs and timelines, with theory-based approaches representing relatively low-cost but high-impact contributions. To this aim, a "team-of-teams" approach across E-TASC activities will continue to be pursued during FP9 and carried forward into FP10.

Fundamental theory and simulation efforts should remain an important component of the program, and continued support for ACHs will be essential to leverage existing HPC investments. At the same time, greater integration of plasma physics with fusion engineering and materials science will be essential to bridge the gap toward FOAK or FPP devices, necessitating improved communication between the respective communities.

Engagement with the private sector should follow a coordinated, win–win approach at the EUROfusion level. In this context, additional EC funding may be most effective when public funding supports public institutions in activities that indirectly benefit private-sector stakeholders.

Methodologically, VVUQ, AI, and Digital Twins are expected to play central roles in future programmatic objectives.

For Reference: New Approach of the U.S. Fusion Program

The U.S. fusion program has recently restructured its research approach to focus more directly on closing critical gaps in the fusion roadmap. The current framework operates on a 4.5-year planning horizon, subject to annual funding renewal, and reflects a transition toward greater emphasis on systematic validation, UQ, and the integration of AI.

The program is now organized as a hybrid structure that combines hierarchical coordination with a "team-of-teams" approach. Research coordinators oversee key topical areas such as sustaining burning plasmas, exhaust management, and the control of damaging transients. Six guiding principles underpin the new structure: extrapolability, extensibility, control, reactor relevance, quantified uncertainty, and optimized integration of first-principles and data-driven modeling.

The revised framework also includes strengthened project management and coordination of major experimental facilities, while fostering engagement with private-sector stakeholders and international partners. In parallel, the development of new data infrastructure — notably the Fusion Data Platform (FDP) and its planned expansion (FEDER) — aims to provide a unified system for managing, accessing, and analyzing both experimental and simulation data through distributed caching, standardized metadata, and reproducible workflow tools.

Conclusions

The E-TASC General Meeting #2 played an important role in aligning the efforts of the EUROfusion theory and simulation community with existing gaps and emerging opportunities on the experimental side. By emphasizing collaboration and strategic priority areas, the meeting established a strong foundation for addressing key scientific and engineering challenges in fusion energy research.

Discussions highlighted substantial progress toward EUROfusion Standard Software, improvements in data availability and formats (enabling new forms of data-driven fusion science), the growing need for systematic VVUQ approaches, the significant progress in code development and exploitation on existing EUROfusion facilities, the integration of modern AI methods, and the development of Digital Twins of fusion systems. These developments are complemented by the promotion of Open Science standards and enhanced reproducibility of published scientific results.

A recurring theme throughout the meeting was the shift from development-focused activities toward impact-driven and strategically aligned modeling efforts. These efforts will be supported by FAIR data practices, AI-based tools, robust computing infrastructure, and strengthened collaboration both within EUROfusion and with external partners.

Another conclusion of the meeting was that sustained investment in fundamental theory remains essential, since it underpins model fidelity and extrapolability, informs VVUQ priorities, and enables robust interpretation of data-driven results. FP10 planning should therefore include dedicated support for fundamental physics alongside applied modeling. Meanwhile, closer synergy between plasma physics, fusion engineering, and materials science will be crucial to accelerating the transition from fusion research to viable FOAK and FPP devices.

The next General Meeting in 2027 is expected to build on these discussions and further shape the direction of the E-TASC initiative in preparation for FP10.