2024 E-TASC General Meeting

Date: November 11–15, 2024

Location: Max Planck Institute for Plasma Physics (IPP), Garching, Germany

Materials: https://indico.euro-fusion.org/event/3034/

This document has been written by the E-TASC Scientific Board and is based on the slides presented by Frank Jenko (E-TASC SB Chair) on the last day of the 2024 E-TASC General Meeting.

SUMMARY

The 2024 E-TASC General Meeting brought together nearly 80 researchers to review the progress, address challenges, and outline future directions for the EUROfusion Theory and Advanced Simulation Coordination (E-TASC) initiative. The event featured a mix of plenary and breakout sessions, promoting in-depth discussions across projects and enhancing collaboration between the various Theory, Simulation, Verification, and Validation (TSVV) projects and Advanced Computing Hubs (ACHs).

Key Themes and Discussions

Networking and Strategic Planning

The participants highlighted the importance of further strengthening collaborations between TSVVs and ACHs, as well as with the WPs through the Thrusts. Many discussions centered on strategies to ensure the timely delivery of simulation tools and considered potential adjustments to the objectives of TSVVs and ACHs beyond 2025. It was also noted that fundamental research – from theoretical investigations to the development of novel frameworks for deploying predictive capabilities for next-generation, reactor-relevant plasmas – should receive sufficient support.

Updates from the US and UK

During the meeting, representatives from the United States and the United Kingdom shared valuable insights into their national strategies for fusion-related software development. Key takeaways included:

United States: The Fusion Energy Sciences (FES) program under the U.S. Department of Energy (DOE) allocates an annual budget of approximately $50 million dedicated to theory and simulation efforts. This significant investment highlights the U.S.'s robust commitment to advancing fusion energy research through cutting-edge computational and theoretical advancements.

United Kingdom: The UK has made notable progress in developing Digital Twins for fusion applications, covering areas such as plasma physics, materials science, and engineering technologies. These initiatives are supported by the UK's strong commitment to open science and open-source software development, reflecting global trends towards collaboration and transparency in research.

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

Discussions concluded that the E-TASC ecosystem, after an initially challenging phase due to budget cuts and the pandemic, has now reached a productive and steady state. Significant progress has been made, and the development for 2026–2027 should build upon this foundation with an evolutionary approach, focusing on:

- **Code Development:** Further strengthening collaborations with ACHs.
- **Validation and Applications:** Enhancing coordination with Work Packages (WPs).
- **Code Deployment:** Advancing user training and support.
- **Fundamental Research:** Theories and frameworks supporting predictive capabilities.

Key prerequisites include establishing an accessible data environment (e.g., IMAS interfaces) and ensuring open access for the EUROfusion community. Future evolution could involve merging and/or redirecting existing TSVVs and piloting new ones, particularly in fusion engineering and technology. Concrete steps to evolve the E-TASC ecosystem will be taken in the first half of 2025.

TSVV Developments: Key Priority Areas

For the final two years (2026–2027) of the current EU Framework Programme, key priority areas will include (but are not limited to):

- Core transport and edge physics for ITER, DEMO, and optimized stellarators.
- Disruptions and runaway electrons.
- Plasma exhaust and divertor solutions.
- Predictive capabilities (including VVUQ) and reduced models for "flight simulators."
- Expansion into fusion engineering and materials research.

ACH Developments: Addressing Key Challenges

Concerns were raised regarding continuity beyond 2025, particularly in relation to the ACHs' ability to attract and retain top-tier personnel amid uncertainties about contract extensions. Providing clear and positive signals will be essential for shaping their future trajectory. To address these challenges, the ACHs plan to:

- Strengthen collaboration on data and AI/ML initiatives.
- Share detailed code requirements to enhance HPC compatibility.
- Organize regular inter-ACH meetings to tackle common challenges effectively.

Enabling Research & Theory

To promote innovative theoretical advancements, the Enabling Research (EnR) program could be expanded to complement activities currently within the TSVV framework that are less directly aligned with developing EUROfusion standard software. This expansion would facilitate the creation of new mathematical models, additional physics capabilities, and diverse code applications critical for advancing fusion science.

The bottom-up approach of the EnR program, with its focus on scientific excellence, serves as a valuable incubator for novel ideas. However, relying solely on this model may not sufficiently address long-term theoretical gaps necessary to achieve EUROfusion's strategic objectives. To bridge these gaps effectively, a structured framework similar to the TSVV model could be implemented.

By integrating the flexibility of the EnR program with the structured methodology of the TSVVs, EUROfusion can strengthen its ability to foster innovation while systematically addressing critical theoretical challenges. It is imperative to preserve the role of the EnR program as a gateway for fostering new analytical theory and exploratory concepts, which are essential for fusion research.

Emphasis on Verification & Validation (V&V)

Emphasis was placed on improving data publication clearance processes and fostering stronger collaboration with experimental groups. A proposal was made for the establishment of a dedicated forum for theory engagement, designed to facilitate bidirectional learning and the development of strategic initiatives.

Collaboration with the PSD on Code Dissemination and Training

To ensure effective code dissemination, it was agreed that the optimal strategy is to integrate these codes into the scientific analysis of experiments, thereby maximizing their usage and impact. A collaborative approach was proposed to achieve this through pilot projects supported under the PSD program. The following streamlined process was outlined:

- **Identification of Modeling Needs**: WP leaders define specific modeling requirements, ensuring alignment with high-priority scientific objectives.
- **Matching Codes with Users**: Relevant TSVV codes are identified and connected with end-users through established community channels such as the WPTE or TSVV networks.
- **Flexible Training Scheduling**: Training sessions will be organized according to the availability of trainers and trainees, with Research Topic Coordinators (RTCs) or sub-project leaders offering support throughout. Various training schemes will be explored depending on the nature of the respective code(s).
- **Funding Support via PSD Scheme**: Funding for these initiatives will be allocated through the newly established PSD program to ensure effective implementation of the projects.

This collaboration aims to better integrate simulation tools into practical applications, promoting broader adoption and creating a feedback loop to refine these very tools. The strategy also emphasizes capacity-building through user training and support, ultimately enhancing the impact of TSVV-developed codes within the EUROfusion research community.

Implementation of EUROfusion Software Standards

Efforts to formalize EUROfusion standard software include ensuring open-source availability, developing validation plans, and implementing clear user training strategies. A proposed priority framework from the ACHs was discussed, although refinements are needed in areas such as verification and user access. The following list, revised and agreed upon by the community, outlines the key points:

1. **SOFTWARE ENGINEERING**
   - 1.1. Version control implemented
   - 1.2. Software engineering standards (incl. CI with regression and/or units tests) established
   - 1.3. Coding standards (facilitating code maintainability and portability) established
   - 1.4. Can be run on EUROfusion HPC and cluster systems
   - 1.5. Code was performance profiled and optimized
   - 1.6. Code was parallelized
   - 1.7. Code was ported to accelerated platforms

2. **CODE INTERFACES**
   - 2.1. User-friendly interface (e.g., GUI) for easy code handling
   - 2.2. Post-processing and visualisation tools as a part of the code releases
   - 2.3. Interface to IMAS Data Dictionary
     - 2.3.1. Uses standardized IDS input
     - 2.3.2. Produces standardized IDS output
     - 2.3.3. Can be used as part of IMAS workflows
3. **VVUQ**
   - 3.1. Code verification reports/papers available
   - 3.2. Inter-code benchmarking reports/papers available
   - 3.3. Code validation reports/papers available
   - 3.4. Uncertainty Quantification reports/papers available
4. **CODE DISSEMINATION**
   - 4.1. Stable up-to-date release version of the source code available on EUROfusion gitlab
   - 4.2. Trainings provided to code users within EUROfusion
   - 4.3. Code has an appropriate user license
5. **CODE DOCUMENTATION**
   - 5.1. High-quality technical documentation (including a detailed description of the underlying model) available on EUROfusion gitlab
   - 5.2. User manual available on EUROfusion gitlab
6. **USER SUPPORT**
   - 6.1. Responsive support team (involving code developers) in place
   - 6.2. Tools for managing support requests (mailing list, issue tracker etc.) in place

Providing Open-Source Software

The benefits of open-source software, including transparency and reproducibility, were widely acknowledged. Proposals were made to simplify access to repositories and establish clear licensing frameworks, while reducing dependencies on third-party software. The planned release of IMAS software as open source by the IO was also emphasized in this context.

Data Management Progress

Significant progress was made in the development of the Data Management Plan (DMP), ensuring adherence to FAIR data principles and the establishment of uniform access policies.

Perspective of Digital Solutions for fusion Department (DSD)

Innovative technologies developed in the digital domain, such as Artificial Intelligence (AI), Machine Learning (ML), and Digital Twins, must be embraced to enable comprehensive, fully integrated simulations and analyses. These simulations should span various levels of abstraction, complexity, and reliability, incorporating not only the plasma but also external systems, control actuators, wall interfaces, and other engineering components. Coupling (validated) advances in high fidelity simulations and theoretical understanding together with AI/ML and Digital Engineering tools, will be essential to enhance the foundation for extrapolations and predictions for future fusion experiments and power plants, such as ITER and DEMO, while also accelerating optimization cycles in plant design and operations. In 2025, DSD plans to initiate several Proof of Concept (POC) projects that integrate data from both fusion engineering and plasma science. These projects will be defined based on a gap analysis addressing identified needs and opportunities.

Conclusion

The 2024 E-TASC General Meeting played a crucial role in aligning the efforts of the EUROfusion theory and simulation community with the challenges and opportunities on the experimental side. By emphasizing collaboration, open science standards, and strategic key priority areas, the meeting established a strong foundation for advancing EUROfusion's mission to tackle both scientific and engineering challenges in fusion energy. The next General Meeting in 2025 is expected to build on these discussions and further shape the direction of the E-TASC initiative.