Overview of the European Integrated Tokamak Modelling Task Force

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EU Integrated Tokamak Modeling Task Force

The Integrated Tokamak Modeling Task Force (ITM-TF) was set up in 2004 to coordinate the European modeling effort with the ultimate target of providing a complete European modeling structure for ITER, with the highest degree of flexibility, confidence and reliability.

**AIM:** coordinate the development of a coherent set of validated simulation tools

**PURPOSE:** benchmarking on existing tokamak experiments

**ULTIMATE AIM:** provide a comprehensive simulation package for ITER plasmas

**REMIT:** development of the necessary standardized software tools for interfacing code modules and for accessing experimental data

**Medium term:** support the development of ITER-relevant scenarios in current experiments

**Long term:** provide a validated set of European modelling tools for ITER exploitation

*EFDA SC (03)-21/4.9.2 (June 24th, 2003)*
Comprehensive integrated tokamak modelling:
- complete description: physics+machine
- standardized interfaces
- completely generic workflow

Objectives
- Develop an ideal framework for validation and integration of tokamak models
- Develop and validate models and tools (simulation platform) on the existing experiments, in view of the exploitation of ITER
- Use the developed tools for modelling ITER
  ➔ ambitious Integrated Modelling effort on a wide scale
The EU ITM-TF approach

- Infrastructure describing the tokamak physics AND technology within a unique framework
- A new paradigm for integrated modelling: the physical/technological problem solved by the Simulator is defined by graphical workflows
- Fully modular and flexible simulation platform
  - Modularity: Integrates together modular pieces of physics and technology
  - Flexibility: simulator can be used for a variety of applications
  - Independent of programming language (F90, C++, Java, Python, Matlab)
  - Link to High Performance Computing / GRID

- Standardized interfaces for physics (transport, equilibrium, MHD, turbulence, …) and technology (PF systems, antennas, diagnostics)
  - Abstract and generic machine description → generic data structure relevant for all tokamaks
  - Consistent Physical Object concept (CPO) [F. Imbeaux et al, Comp. Phys. Comm. 2010]

- Completely generic workflow: much more versatile than present transport codes
Coupling codes and applications

N modules integrated in N different applications

N modules coupled into a dynamic application framework

Work balance is different:
- Incremental exploitation possible in N*N approach \(\rightarrow\) scales poorly with project size and has sustainability issues
- Payoff in efficiency, usability, manpower cost and increased collaborations is large for 2*N (ITM) approach BUT requires an operational framework for exploitation.

Adapted from David De Roure
Generic Application Structure

Workflow Orchestration
- I/O
- Organisation
- Resource Interfaces (cluster, grid, HPC,...)

“Global” Ontology
- Code Interfaces
- Data transport
- Data structures

Modelling Tools/Modules
- Physics
- Statistics
- Numerics
ITM Implementation

**KEPLER**
- I/O
- Organisation
- Resource Interfaces (cluster, grid, HPC,...)

**UAL/CPO**
- Code Interfaces
- Data transport
- Data structures

**Integrated Modelling Projects**
- Physics
- Statistics
- Numerics
Fusion base research program – EFDA associations
First principles modelling and detailed physics development
EFDA TGs – TFs – WGs  ITER-IMEG

Gateway/Portal
Code platform, data and database access,
Access to Computing platforms and ITM tools

Infrastructure & Software Integration Project (ISIP)

4 Integrated Modelling Projects (IMPs) + Iter Scenario Modelling + 2 (under TFL)

H&CD
ISM
EDRG
AMNS

MHD
Transport

Turbulence

EDF ORIA
GRID HPC

CS training & collaborations
GOTIT & EUFORIA

ITM TF

USER COMMUNITY

ITM schematics

Strand, Falchetto
ITM-TF timeline

**Preparatory phase**
- ~50 people
- 14 Associations
- 2004: Expert Working Groups
- 2005: 5 IM +data coord.+platform projects

**Development Phase**
- EURATOM funding schemes
- "Task Agreement"
- first prototype version of a working platform
- 2004
- 2006: ITM server (EFDA CSU, Garching)
- 2008
- 2010: GATEWAY ENEA/CRESO,IT
- 2009: HPC-FF FZJ,DE
- 2010

**Deployment phase**
- Starting
- 2010: 60ppy, 240 individuals

**EU review of ITM & fusion modelling**

Elaborated from P. Strand
ITM-TF Overall Milestones

2009
• Extended set of platform tools forming a predictive core physics capacity for ITER

2011
• Whole device modelling capability including comprehensive core-edge coupling and first principles elements

2014
• A complete modelling platform and integrated modelling structure for fusion plasmas capable of full range whole device modelling as well as detailed physics studies employing a comprehensive range of validated physics models.
ITM Achievements

• What has been provided:
  ✓ An advanced set of data-structures (Ontology)
  ✓ A structured approach to standardized code interfaces (CPO’s)
  ✓ A tool set/structure for language agnostic physics code integration
  ✓ A suite of access tools and technologies (Universal Access Layer)
  ✓ A workflow technology (Kepler+ ITM & EUFORIA extensions)
  ✓ Transparent access to both grid and HPC resources (EUFORIA)
  ✓ A robust infrastructure – local clusters, grid and HPC access.
  ✓ Provisions for advanced visualization (EUFORIA)
  ✓ Basic toolset for exploitation of ITM tools on experimental devices (exp2ITM, Machine descriptions, data mappings,..)
  ✓ A first set of ”Release Candidate” codes – ready for V&V
    ✓ ~65 codes in the ITM catalogue, being adapted to CPO interfaces
  ✓ An emerging exploitation component (with experiments):
    ✓ Full equilibrium, MHD analysis chain
    ✓ ETS (European Transport Solver)
  ✓ A user community – actively trained
Summary

✓ A first mature installation of the code platform is available
✓ Physics components are becoming available. Now in a position to push ahead on physics exploitation and V&V
  – Associations support and commitments needed
    ✓ “Code camps” and Working sessions key
    ✓ Training and exploration
  – Experiments support / strong collaborations necessary for utilization
    • Machine independence – test bed (MD, DM and Data Access)
    • V&V – supporting a predictive capability
✓ Coordination with Associations, EFDA Topical Groups, International partners - synergy and “dual” support
  – Building a broadened user community
  – Promoting EU toolset on ITER and ITER partner level
A pan-european simulation environment:

- Open ended, flexible and extensible simulation framework (ISIP – Kepler)
- Multi device databases (ISIP – EDRG)
  - “Closer” to experiments – improved V&V,
  - Assisting Experimental campaigns
  - Allowing for synthetic diagnostics
- Device independent State of the art physics modules
  - Broad application basis – Broad user base
  - Proper V&V basis to secure quality and applicability

EFDA based:

- A jointly owned and operated infrastructure
- A jointly developed physics capability
  - Organic growth towards improved state of the art tools
  - ”Darwinian” selection and development of models

Courtesy of P. Strand