ITER Modelling Needs and Plans

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Resources used in this presentation

Although the ITER Team is just getting organized and the modelling needs have not been planned in detail, there have been various discussions of the needs and community interaction that will shape the program

Scope and schedule for ITER modelling needs

- Report of the Fusion Simulation Project Steering Committee
- D.E. Post, et al, *J. Fusion Energy* **23** (2004) 1; Appendix C, "A US-ITER Perspective on Fusion Simulation," N. Sauthoff

ITER in-house needs and community interaction

- Discussions with ITER Fusion Science and Technology Department
- D. Campbell, V. Chuyanov

Coordination of the international modelling effort

- Minutes of the 10th ITPA Confinement Database and Modelling Topical Group
- Initial formation of the Working Group: **I**ntegrated **M**odelling – **A** **G**lobal **E**ffort (IMAGE)

Code validation needs

- K. Burrell, "An Experimentalist's View of Code Validation," presented at JIFT Workshop, U.C. San Diego, January 2007

Integration needs to address both physics and the range of modelling applications

Applications needed as the ITER project evolves (Sauthoff):

- Facility design
  - Immediate needs for ITER Design Review, 2007-
- Plasma scenario development
  - Heating and current drive needs, 2007-
  - Detailed scenario development, ~2012 -
- Control system
  - Design and tuning, ~2008 -
  - Operation, ~2016 -
- Experimental shot design
  - Planning detailed experimental programme, ~2012 -
- Data analysis
  - Design with simulated parameters, ~2008 -
  - Analysis of ITER results, ~2016 –

It is obvious that there will be much overlap in the physics components needed for each of these applications

Comprehensive physics capabilities are needed for Facility Design

Recognize new burning plasma physics (size-scaling, energetic particles, and strong self-heating)

Transport prediction, especially the integrated core and pedestal

Power and particle loads, and assessment of mitigation methods

ELMs and their mitigation

NTM stability/thresholds/mode-characteristics/saturation techniques (e.g., driven currents in the islands, delta-prime modification)

Rotation drives and damping (including ripple and error fields)

Energetic particles modes in positive, weak and reversed magnetic shear profiles

Heating and current drive (both actuators and plasma responses) for NB, IC, EC, and LH

More integrated issues like EC-system requirements for NTM stabilization, RWM stabilization by rotation and feedback, disruptions in the 3D vessel structure

Diagnostics specifications (measurement requirements) based on simulations to prototype synthetic diagnostics and data analysis

Plasma Scenario Development begins to address control issues and integration with diagnostics

Plasma scenario development will contribute to choices of plasma control tools (heating and current drive, fueling, …) and diagnostics

Prediction and optimization of performance within operational boundaries of stability, confinement, wall interactions, AC losses in cold structures, actuator limits, diagnostic limits

Design of experiments that focus on desired physics and minimize interference from other phenomena (e.g., energetic particle modes with minimum damping from the slowing-down beam distribution; transport experiments that avoid domination by MHD)

Compelling visualizations to enable understanding at many levels

The Control System requires detailed algorithms that can be tuned as operating experience dictates

- Develop, benchmark, and refine control algorithms based on the standard model of plasma, actuators, and diagnostics
- Full-detail/resolution models likely will not be needed in real-time; reduced models will likely be sufficient
- However, the reduced models will involve parameters to tune algorithms, program state-dependent gains, etc., which could be tuned by off-line use of the full-detail/resolution models

Comprehensive modelling for Experimental Shot Design will optimize use of machine time

ITER shots are too valuable to "play by ear"; a simulation is warranted and may be needed in the more-self-organized burning plasma

A faithful model of the ITER plasma/actuator/sensor system will be needed to design the shot, to focus on desired objectives and to avoid encounters with limits of plasma and control tools

The model should enable tuning of the algorithms as well as derivation of reference waveforms

Data Analysis requires interpretive codes with predictive elements (e.g., sources)

Derive results with flexible application of measured data and simulated parameters, as well as comparisons of measured data and predictions

Benchmark integrated model and embedded sub-models by means of flexible mix of measured data and predicted/extrapolated quantities

Similar to present codes used to analyze present devices: ASTRA, CRONOS, ONETWO, TOPICS, TRANSP, …

In-house tools will be required
- Supported by similar tools within the parties

All of these applications require in-house codes to:

- Facilitate design and analysis by the central team
- Establish reference cases

The central team will not be large enough to develop the in-house capabilities from scratch:

- Requires a strong partnership between the central team and all ITER parties

Each of the parties is expected to develop their own capabilities to:

- Guide their contributions to ITER
- Be free to explore new ideas for operation and control
- Serve as a resource for maintaining and upgrading the in-house codes

Development of the modeling tools will reside primarily with the parties

ITER will not have the super computer resources to explore the most advanced modelling of integrated physics

Such capabilities will reside with the modeling programmes of the parties, e.g.:

- Computational Simulation Center of the Japanese ‘Broader Approach’ and the Burning Plasma Simulation Initiative
- European Integrated Modeling Task Force
- US Fusion Simulation Initiative and the Burning Plasma Organization

The interaction between these programmes and the ITER Integrated Modelling effort needs to be well-coordinated to ensure the highest quality physics is used in the design, operation and analysis

Establishing the Integrated Modelling infrastructure

The initial meeting of the ITPA IMAGE Working Group identified many common infrastructure issues being addressed by the parties' integrated modelling programmes:

- The development of standardized component interfaces
- Standardized data structures, storage and communication between components
- Interfaces to machine data
- Documentation, verification and validation procedures

Coordination of these efforts will:

- Facilitate initial development of the ITER Integrated Modelling tools
- Simplify maintenance and speed the process of upgrading as physics understanding is advanced

ITER in-house modeling components need clear documentation and meet well-defined verification standards before validation against ITER data

Documentation – Clear explanation of all I/O, strengths and limitations of models, verification, and validation procedures

- Standardized units (MKSA), definitions of quantities, equations in forms more easily evaluated by experimental users

Verification - Assurance that a computational model correctly represents a theoretical or empirical expression of the physics

- Usually accomplished by comparing code results to a hand calculation, an analytical solution or approximation, or a verified code designed to perform the same type of analysis

Validation - Assurance that a computational model represents the experimentally observed physics

- Usually accomplished by comparing code results to physical data or a validated code designed to perform the same type of analysis

A coordinated community effort is needed to help establish standards and procedures that will actually be used

All three presently open positions in the ITER Fusion Science and Technology Department emphasize modelling

Chief Scientific Officer, Integrated Modelling (excerpts):

- Leading contributions to the definition of ITER requirements for an integrated plasma modelling capability for the analysis of ITER plasma operation scenarios and of physics processes determining plasma behaviour and fusion performance
- Definition and management of a programme of modelling and theory R&D activities to support the development of a comprehensive integrated modelling capability for tokamak plasmas
- Major contributions to the specification and analysis of ITER plasma operation scenarios through a leading role in the provision of an integrated plasma modelling capability
- Integration of R&D results and analysis from the ITER Parties on all aspects of integrated plasma modelling and the exploitation of the results for the enhancement of ITER's integrated plasma modelling capability
- Interaction with and co-ordination of experts in the ITER Parties in the definition, implementation and monitoring of activities in this area
- Contributions to the preparation of documentation defining operational performance requirements for ITER plasma scenarios and synthesizing predictions of ITER performance
- Supervision of ITER staff and visiting researchers contributing to activities in the area of integrated tokamak plasma modelling

Senior Scientific Officer, Transport and Confinement Physics (similar, supporting role)

Senior Scientific Officer, Integrated Scenarios (similar, supporting role)

Summary

ITER Integrated Modelling needs span a diverse range of applications as well as new physics regimes

Direct involvement of the community is required to ensure:

- The best tools are used in the design, definition of the experimental program, operation, and analysis
- The in-house tools are supported by a broader programme within the parties

The ITER team recognizes the urgency of establishing a coordinated Integrated Modelling programme to meets these needs

- Workshops (such as this), bi-lateral exchanges, the ITER central team, ITER party programmes, and visiting researchers to the ITER Project site are envisioned as contributing to the effort