EFDA

EUROPEAN FUSION DEVELOPMENT AGREEMENT

Task Force
INTEGRATED TOKAMAK MODELLING

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ITER Integrated Modelling Expert Group - a brief overview

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Relying on input and material from
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Disclaimer

- I am presenting some material and comments from ITER IO and ITER FST (in particular)
  - Many thanks for input and reuse of slides
  - All misunderstandings and misrepresentations are *mine and mine alone*

General Background

- envisioned modelling needs for ITER

Modelling Applications and ITER developments

- Modelling applications during ITER design:
  - Design is based on a combination of theoretical understanding supplemented by experimental observations where theory/modelling is incomplete
  - Design stage is nearly complete
- Modelling applications during ITER construction:
  - Focus on enhancing the physics understanding through development of theoretical and computational models and validating them against experimental observations
  - Apply new understanding to planning the ITER experimental programme
  - Activity is increasing and will be the major effort of the domestic fusion programmes over the next 10+ years
- Modelling applications during ITER operation:
  - Predictive modelling of each plasma from beginning to end, including analysis of control requirements
  - Interpretive analysis of each plasma to evaluate/validate models
  - Ultimate emphasis of the ITER Integrated Modelling (IM) Programme

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Integrated Modelling – A Fusion-Relevant Definition

- A comprehensive system of codes interfaced together to model plasmas

- IM connects different physical regions:
  - Core and edge regions to the separatrix
  - The scrape off layer (SOL) region and its connection with the divertor
  - The effects of external circuits and systems in controlling the plasma
  - Interaction with the plasma facing components (PFCs)

- IM encompasses different levels of detail:
  - First principles models (e.g. microscale) to explore details of the physics
  - Reduced models (e.g. macroscale) for efficient computations suitable for control, scenario design and investigation of parameter variations; fidelity to first principles models, instead of being expressed empirically or heuristically

- IM covers:
  - The full discharge (initiation to termination)
  - And inter-discharge effects (e.g. conditioning and tritium retention)

- IM includes both predictive and interpretive capabilities

IM Support of the ITER Facility – Design

- Basis for the ITER facility:
  - Ability to affect baseline design decisions diminishes over the next two years
    - Plasma magnetic control schemes and requirements
    - Criteria for optimisation of the ferromagnetic inserts for TF ripple correction
    - Pellet injection system and gas introduction systems
    - First wall and blanket modules
    - In-vessel coils for ELM control and vertical position control
- Evolution:
  - Modifications may impact details of performance projections
- Upgrade options:
  - Long lead time may be needed between modelling input for a decision on an upgrade and implementation of the upgrade
    - Design, construction, and installation vary from system to system (e.g. LH system likely to take ~10 years)

IM Support of the ITER Facility – Scenarios

- ‘Scenario’ studies need to be expanded:
  - Studies to date have mostly addressed flat-top in DT
    - Need to include full discharge from initiation to termination, and the H/He and D Phases
- Scoping:
  - Simplified models acceptable, but should be a reasonable representation of more comprehensive calculations (i.e. benchmark capability is a necessity)
    - H&CD, fuelling, pumping, power handling and control requirements over a range of parameters using approximate representations of operating boundaries, idealized control
- Campaign development:
  - More detailed analyses using physics based models (qualified and verified) with high fidelity to experimental observations (validated)
    - Include stability and control requirements, diagnostics, alternatives based on subsystem availability, system limitations and fault amelioration techniques, sensitivity of operation to uncertainties in models

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IM Support of the ITER Facility – Control

- Control strategies:
  - Full discharge from initiation to flat-top to termination
    - Evaluate plasma response times, sensitivity of plasma parameters to actuators, impact of events
- Feedback models:
  - Test ideas for control
    - Evaluate control models, gains and response times using idealized sensors
- Input to control algorithms:
  - Effectiveness of sensors and actuators, response times, secondary responses
    - Estimated ranges for tunable parameters in various control algorithms (PID, SIMO, MIMO …) under a range of conditions
- Testing control algorithms:
  - Simulate plasma behaviour using control algorithms
    - Synthetic diagnostics linked to actuators

IM Support of the ITER Facility – Experimental Planning

- Campaign planning:
  - Experimental proposals are to be supported by modelling to demonstrate that expected results are within ITER's capability
    - May be a accomplished with a combination of in-house and domestic tools
- Session planning:
  - More detailed modelling assessment over the expected parameter range with results checked against more comprehensive models of critical systems
    - Investigation of alternatives to base sequence; in-house and domestic tools
- Pulse development:
  - Simulation from initiation to termination, including system limitations and fault amelioration techniques
    - Pulses expected to be composed of segments (e.g. start-up, several sequential flat-top, shutdown) with one or more conditions changed between segments
    - Requires systematic application of in-house modelling capabilities

IM Support of the ITER Facility – Analysis

- Real-time analysis:
  - Display of physics parameters using fast conversion of diagnostic signals
    - Systematic employment of in-house suite of validated tools
    - Simultaneous display of modelled results in control rooms (local and remote)
- Post-processing:
  - More rigorous conversion of diagnostic signals emphasizing consistency in analysis, uncertainties (error bars), …
    - Systematic employment of in-house suite of validated tools for inter-shot and overnight processing
- Model validation and improvement:
  - More detailed, long-term analyses
    - Relies heavily on more extensive modelling capabilities within the ITER Parties
- Forecasting:
  - Live prediction from present state (similar to weather forecasting)

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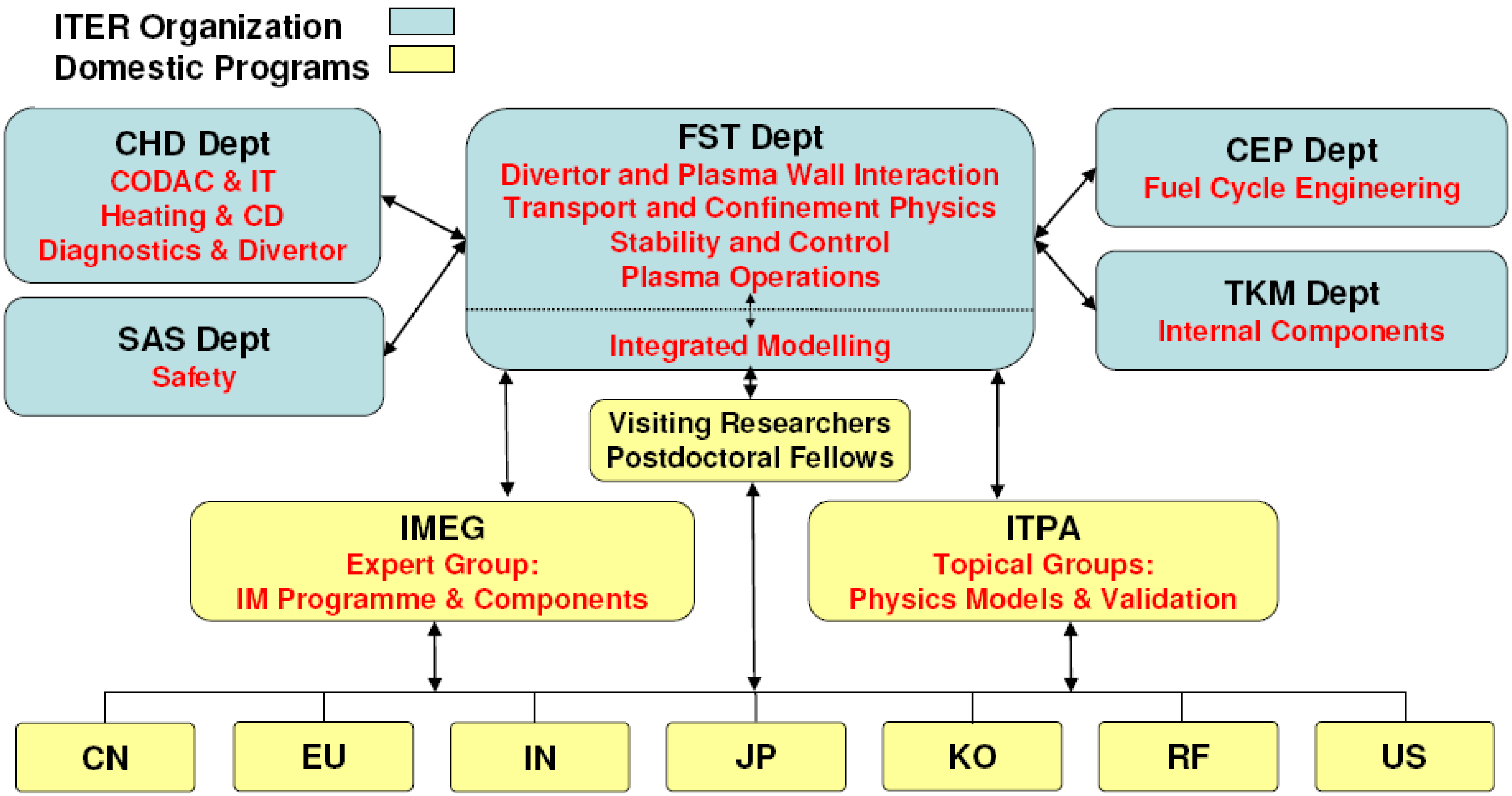
Coordination Between IO & Domestic Programmes



Integrated Modelling Expert Group (IMEG

IMEG Members (coordinator)

CN	Li, J.	Dong, J.	Zhu, S.
JA	Mori, M.	Fukuyama, A.	Ozeki, T. (Deputy Chair)
KO	Jhang, H.	Yoon, S.W.	
EU	Thomas, P.	McDonald, D.	Strand, P. (Chair)
RF	Konovalov, S.	Medvedev, S.	
IN	Bandyopadhyay, I.	Bisai, N.	Srinivasan, R.
US	Van Dam, J.	Batchelor, D.	Lao, L.

IMEG – Programme Definition

- The IMEG Charter identifies the following ITER IM Programme Definition responsibilities:
  - Establish core modelling requirements that cover a spectrum of applications
  - Establish documentation, verification and validation standards for core elements
  - Establish installation and acceptance testing procedures for core elements
  - Establish regression testing procedures for core elements
  - Identify IO hardware (e.g., grid and HPC) and software needs
  - Establish guidelines for the remote access environment

IMEG – Programme Development

- The IMEG Charter identifies the following ITER IM Programme Development responsibilities:
  - Identify candidate physics components for the core suite from elements in the Members' programs
  - Identify gaps in the coverage of the core physics capabilities
  - Establish schedules and tasks for development/adaptation of core components
  - Estimate resources required for execution of tasks
  - Develop links to supplemental modelling capabilities within the Domestic Programmes
  - Identify opportunities to use other experimental facilities as test beds for the core suite (e.g., control and data analyses)
  - Identify user support needs for the core suite
  - Establish schedules for workshops and training

Report of First IMEG Meeting

- **The Integrated Modelling Expert Group was established by the IO-DA CM in December 2008 to:**
  - review and advise on the progress of the ITER Integrated Modelling programme
  - develop priorities for tasks, user support, hardware and software infrastructure
- **The 1st Meeting of IMEG took place in Cadarache during 23-36 June 2009:**
  - 16 experts from ITER Members' DAs and fusion communities participated together with IO staff
  - presented reports on status of fusion plasma modelling activities in Members' fusion programmes
  - reviewed initial draft of documents specifying the scope of the IM programme, IM standards and guidelines, and near-term IM programme
- **Meeting report provides numerous recommendations on scope and near-term development of IM programme**

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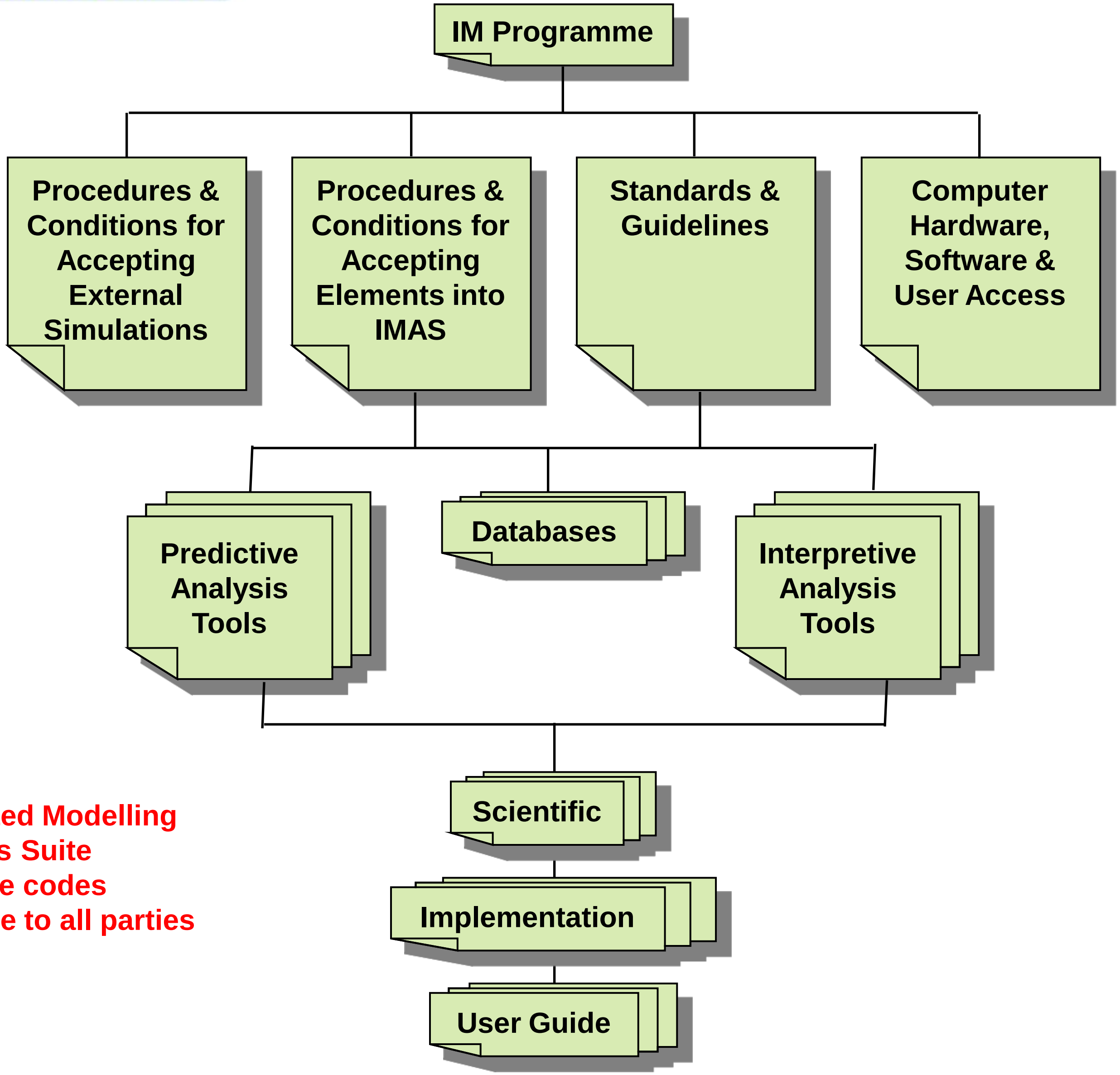
ITER IM Documentation

Near completion
Started
Initiate
Explore options



IMAS - Integrated Modelling Analysis Suite
- In-house codes available to all parties

Recommendations on Programme Scope

- **Clearer specification of technical content of programme needed:**
  - IM programme serves several purposes - needs to be resolved whether a single integrated development structure is appropriate
  - need for balance among needs of predictive modelling, interpretation and data analysis
  - lifecycle development and maintenance procedures need to be developed
  - mechanisms for code validation
- **More explicit definition of IM programme resource requirements, mechanisms and responsibilities is necessary:**
  - internal resources to be provided by IO
  - scope of resources required from ITER Members and implementing mechanisms
  - hardware resources required to support resultant modelling activities

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Recommendations on Standards/ Guidelines

- **IMEG approved overall of the approach to Standards and Guidelines proposed**
- **Need to balance constraints imposed by standards and guidelines with practical considerations:**
  - overall, the IM programme should move towards a more rigorous level of codes and standards than is currently common
  - need to obtain acceptance of approach by modelling community
  - "best practice" approach will expand the pool of existing codes available
  - scope of documentation requirements need to be appropriate to level of code integration
- **Software engineering should be included:**
  - proposed possibility of working groups composed of IMEG experts, IO physics and IO CODAC staff to develop appropriate guidelines
- **Documentation relating to procedures and conditions for the incorporation of External analysis and codes must be completed**

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Recommendations on Near-Term

- **Over-riding short-term need is for an adequate tool to allow exchange of data and simulation results among IO and fusion community**
  - this will allow modelling activities in the fusion community to more effectively complement IO modelling activities
  - need to finalize specification of (external) acceptance standards and procedures
- **Physics Work Programme should specify how ITER modelling requirements will be resourced**
- **Standards and Guidelines document is a priority**
  - to be developed via a collaboration between IO and IMEG
- **A small number of development cases should be identified to allow IMEG to better understand the practical implications of implementation of the IM programme**

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Ongoing Actions

- **IM documentation is being revised in response to IMEG recommendations**
  - target date for completion: 2nd IMEG meeting
- **MDSplus based database is being established on FST website for exchange of simulation results**
- **Pre-qualification phase of an external services contract on definition of IM infrastructure has been launched**
  - activity should be implemented by mid-2010
  - will draw on IMEG expertise for definition of infrastructure requirements
- **Physics Work Programme in Integrated Modelling will be revised on the basis of IMEG recommendations**
- **2nd IMEG meeting is planned for September 2010**

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