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ITER IO Strategy on IM

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Topics

Two phases in the development of the ITER IM Programme:

- Phase 1: Infrastructure Development (2011-2021)
- Phase 2: Physics Development (2015-)

Strategic requirements

Plasma Simulator(s):

- Phase 1: (2012-2015)
- Phase 2: (2015-)

Progress and plans on design and implementation of supporting infrastructure

Development of the ITER IM Programme

Phase 1: Infrastructure Development (2011-2021)

- (Dec 2010) 3-year contract awarded to IM Design Team led by CEA/F. Imbeaux
- (2011-12) Design of an integrated modelling infrastructure that is able to address all anticipated Use Cases
- (2012-13) Initial implementation of the IM infrastructure
- (2012-13) Implementation of a prototype application (covering a subset of Use Cases) to test the infrastructure
- (2013-21) Refinement of the infrastructure to include all Physics Operation and Physics Research Support applications that need to be functional prior to significant operation

Phase 2: Physics Development (2015-)

- Implementation of a full range of physics models and components
- Address coupling between core, edge, SOL, divertor, wall, external systems
- Flexible implementation of a range of models from *ab initio* to 'reduced' depending on the Use Case

IO IM Strategic Requirements - I

Strategic Requirements:

- Being captured in ITER IM Programme doc https://user.iter.org/?uid=2EFR4K
- To be updated with IM Design Team recommendations in Report D1.1

General goal similar to goals of domestic programmes (e.g. ITM):

- SR01 The IM Programme shall establish an Integrated Modelling Analysis Suite (IMAS) of predictive and interpretive codes of varying complexity to describe the ITER plasma and its interactions with structures and auxiliary systems.

Must rely heavily on domestic programmes to minimize duplication:

- SR02 The IMAS shall build on the expertise of the ITER Members by adapting relevant elements developed under their fusion programmes.
- SR03 The IMAS shall build on the expertise of the ITER Members by providing links to supplementary modelling resources in their fusion programmes.
- SR04 The IM Programme shall establish a programme to address IM application needs in cooperation with the ITER Members.

IO IM Strategic Requirements - II

Must be coordinated with other IO efforts in support of Plasma Operations:

- SR05 The IM Programme shall develop plans, jointly with the CODAC Division, for computer hardware, software, data storage, and scientific communication needs specific to the IM Programme.
- SR06 The IM Programme shall establish the requirements, jointly with the CODAC Division, for physics information required for system validation of proposed pulses.
- SR07 The IM Programme shall develop a comprehensive Plasma Simulator for testing the Plasma Control System, with an interface jointly defined by the PCS and IM Programme.
- SR08 The IM Programme shall develop a plan, jointly with the Diagnostics Division, for establishing synthetic diagnostic elements to simulate measurements.
- SR09 The IM Programme shall develop a plan, jointly with the Diagnostics and CODAC Divisions, for establishing a suite of tools for comprehensive plasma reconstruction.

IO IM Strategic Requirements - III

Coordination requires well defined and documented standards, guidelines, and procedures:

- SR10 Procedures and conditions for accepting the results from independent modelling elements shall be established. https://user.iter.org/?uid=3LDNJ6
- SR11 A set of standards and guidelines shall be established for the IMAS. https://user.iter.org/?uid=2F5MKL
- SR12 A set of acceptance criteria and procedures shall be established for the IMAS. https://user.iter.org/?uid=3G2P53
- SR13 A website shall be developed and maintained to provide access to IM Programme documentation, to coordinate development efforts, and to facilitate communication. https://portal.iter.org/departments/POP/IMS
  - General information
  - Integrated Modelling Expert Group (IMEG) activities
  - IM Design Team activities
  - IM Workshops
  - ITPA activities (entire range, not just IM)

The information in the documents and on the website will evolve with the maturity of the IM Programme.

Plasma Operations and Plasma Research

Plasma Operations support:

- Integrated Modelling Analysis Suite (IMAS)
- IO has primary responsibility for development/adaptation and management
- Available to all ITER Parties
- Strong emphasis on robustness and efficiency in addition to physics fidelity

Plasma Research support:

- Extensions to IMAS (includes many computationally demanding *ab initio* models)
- ITER Parties have primary responsibility for development and validation of models (e.g. in the EU we have ITM, ISM, EUFORIA, …)
- Many extended physics elements will remain proprietary, particularly during their developmental phases

Priorities in implementation:

- 1st: Plasma Operations
  - Structure functioning to provide day 1 needs in 2021
- 2nd: Plasma Research
  - Increasing need for validation as plasmas push operating limits, and models are validated against prior ITER operation

Plasma Simulator(s) and Domain Coupling

Domain coupling includes core+edge+SOL+divertor+wall

Phase 1 (2012-2015):

- Plasma Simulator (PS) coupled to the Plasma Control System (PCS)
- Simplified plasma actuator/response models to allow PCS developers to focus on development of their control algorithms
- Present PS's for PCS testing are typically based on 0-D linear physics models for the core only (generally in Matlab/Simulink for ease of coupling to PCS), but we need to extend this to 1-D transport code + free-boundary equilibrium
- Because of the much higher heat fluxes in ITER, we need to extend the domain to include interaction with PFCs (add edge+SOL+divertor+wall)
- Initially, we can use idealized synthetic diagnostics (sensors) and sources (actuators), simplified transport and/or plasma responses described by macro-scale plasma characteristics, …

Phase 2 (2015-):

- Enhance PS physics capabilities with models of higher fidelity
- Cover more Use Cases in support of both Plasma Operation and Plasma Research

Plasma Simulator

Development of a Plasma Simulator as an initial application:

- Supports PCS testing of control algorithms
- Provides a prototype application for development of the IM infrastructure
- Can employ elementary plasma models for fast turn-around of initial test cases

Attention to extensibility will allow the PS to incorporate the comprehensive physics required for pulse simulation:

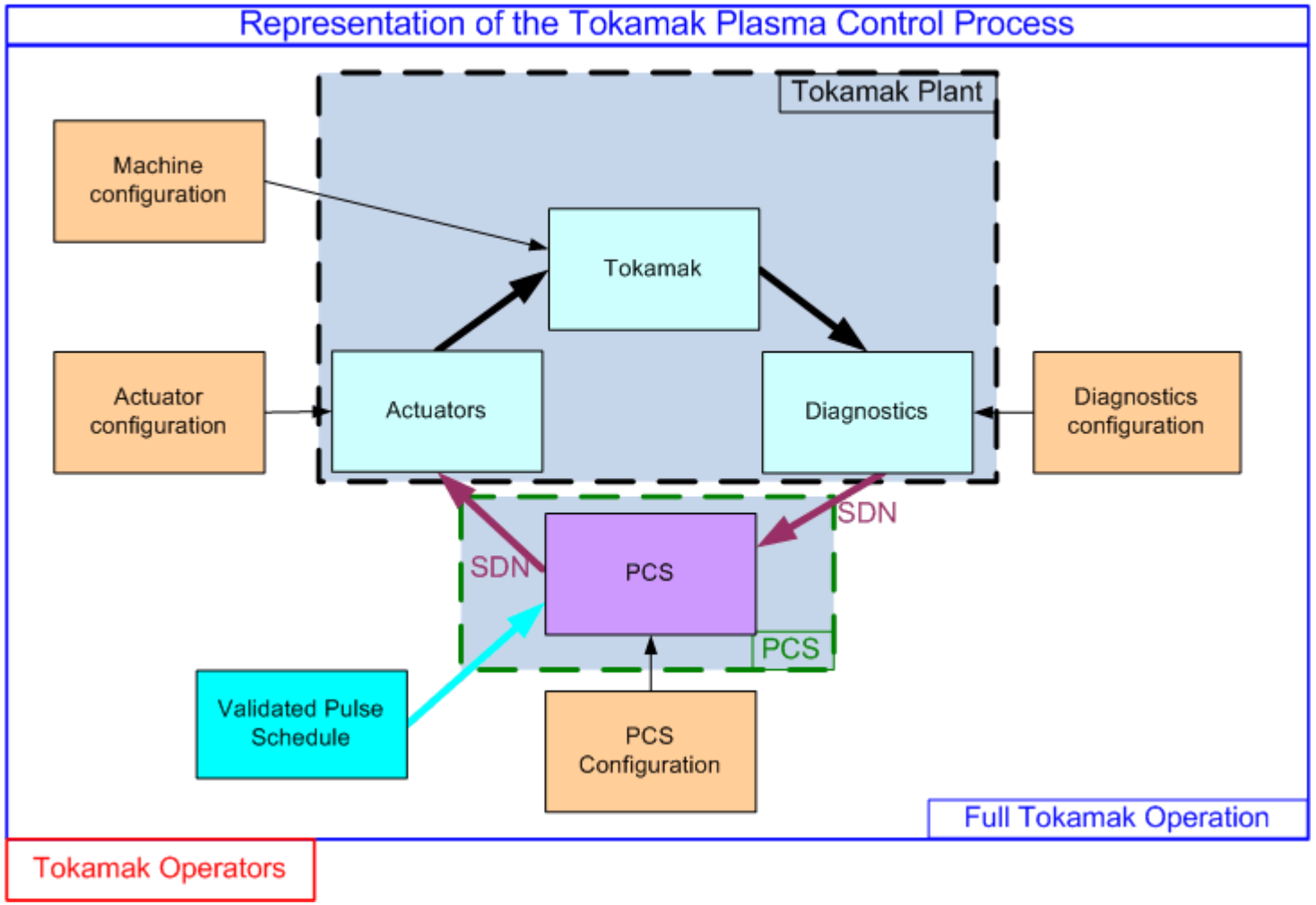
- Modularity
- Free boundary equilibrium
- Full set of transport equations
- Advanced CS methods (e.g. parallelization, grid computing)
- Core, SOL, divertor and PWI

Coupling to the PCS in pulse simulation mode would:

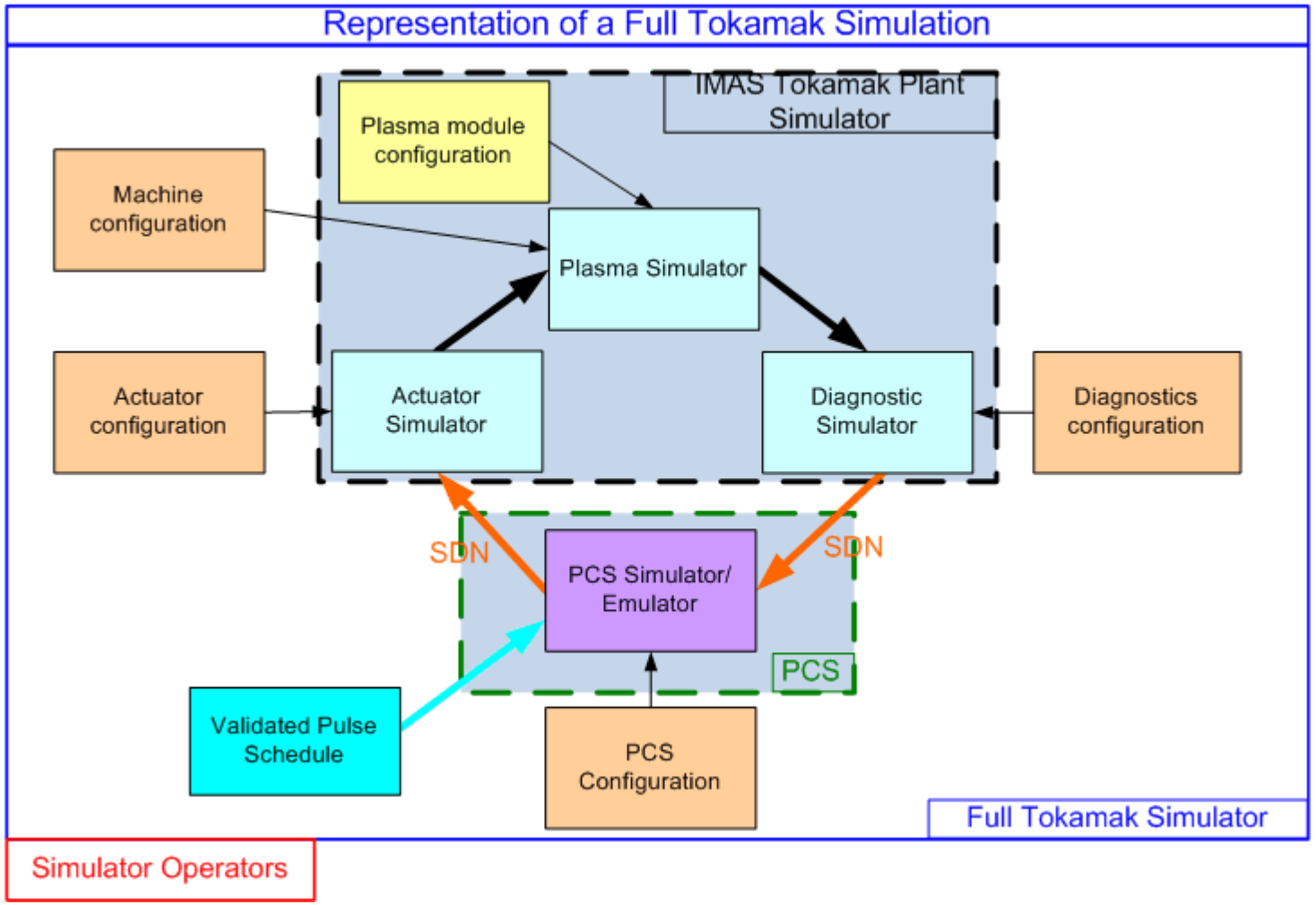
- Provide validation the that the PCS can control the pulse
- Eliminate the need to employ approximations to the control system that are typically employed in predictive modelling codes

Dynamic coupling to the systems validation tools may also be envisioned

PCS View of Tokamak

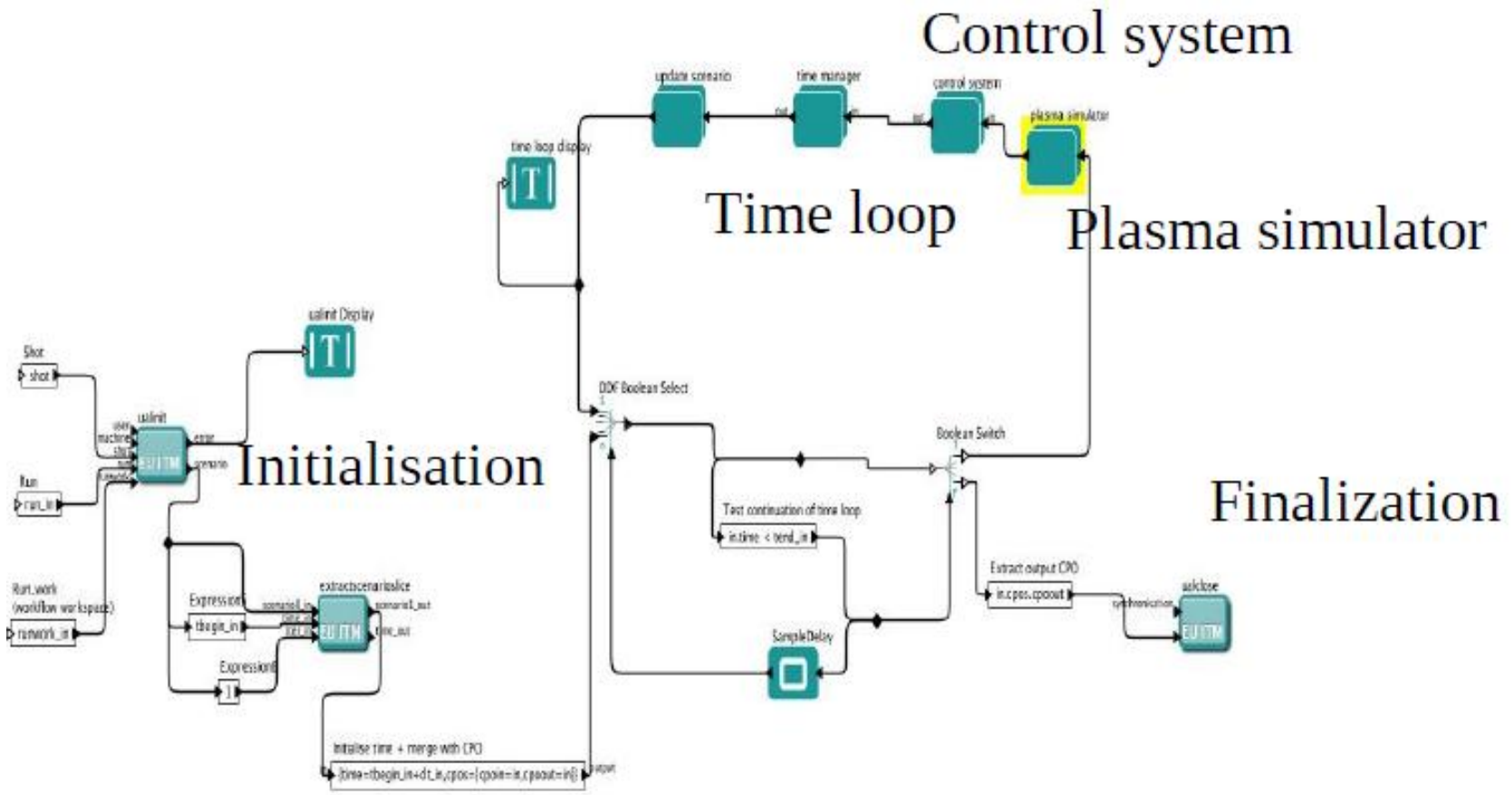


PCS View of Plasma Simulator



Integration of Plasma Simulator with Control - I

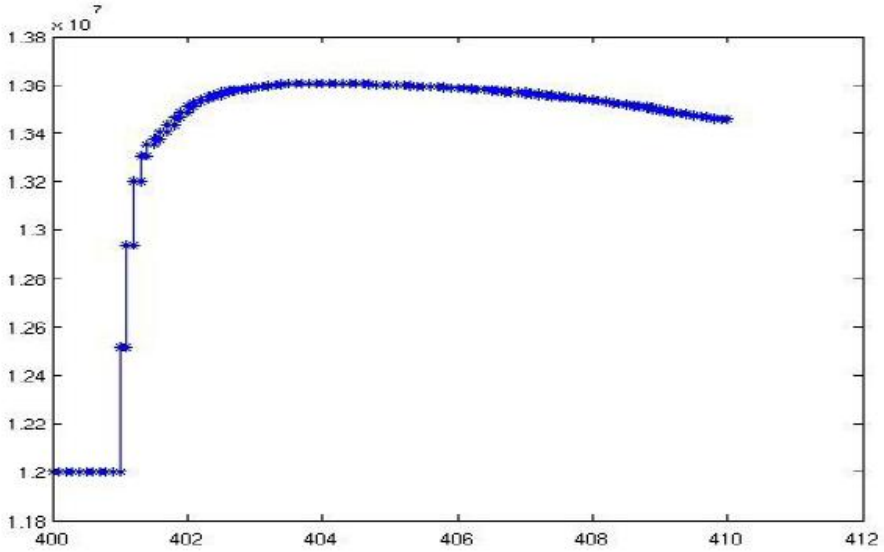
The Kepler framework developed under ITM was used as a prototype to demonstrate rapid construction of a coupled plasma simulator and PCS (Ph. Huynh, 1 week effort).

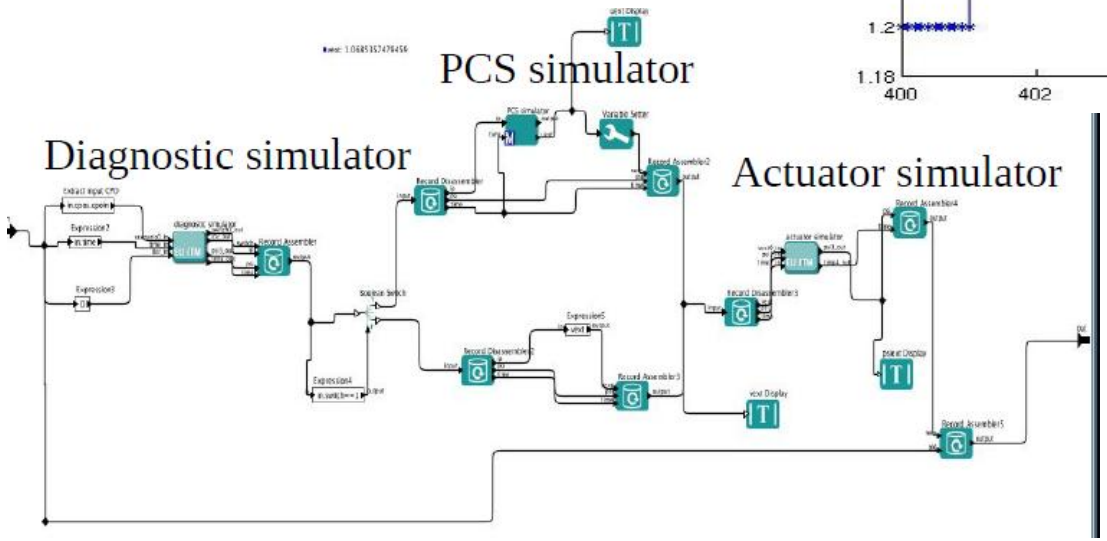


Integration of Plasma Simulator with Control - II

Demonstrated that Kepler can manage the PCS as either as a Simulink code or a Simulimk-generated C code

With a standardized list of I/O for the PCS, it should be easy to change from one PCS to another





ITER Data Model

ITER plans to use a common data model for all physics data:

- Experimental data
- Simulated data
- Machine data relevant to physics analysis

IM requires that the data model be defined soon, but requires consent of all affected ITER Departments:

- CODAC, IT, Diagnostics, H&CD, …

The IM Design Team is developing a proposal for a common ITER physics data model:

- Drafting the specifications
- Defining detailed model for PF data as example, to be used in conjunction with PS/PCS system modelling
- Proposed model to be reviewed by IMEG in late October
- Will be incorporated in CODAC document for approval by all Departments

The underlying data storage is expected to be HDF5

Integrated Modelling Expert Group Meeting

The IMEG will meet 25-27 October at the Château de Cadarache

- Chair: L. Lao
- EU representatives: G. Falchetto, D. McDonald, G. Saibene

Objectives:

- Overall progress and plans of ITER IM Programme
- Progress and plans of IM Infrastructure Design:
  - Use cases
  - Strategic and detailed requirements
  - Frameworks, including PS/PCS coupling
  - Data model, including PF system example
  - …
- Progress and plans of IM programmes in each ITER Party

Summary

Many Use Cases identified to cover the physics modelling support required by Plasma Operations and Plasma Research

Strong collaboration between ITER and the domestic IM programmes (e.g. ITM, FSP, TASK), which are expected to:

- Develop the experience with modern technologies to support efficiently the integration of our best physics models
- Assist the IO in identifying and implementing appropriate technologies for a wide range of applications
- Assist the IO in identifying and adapting appropriate physics codes and components to the Integrated Modelling Analysis Suite (IMAS), to support both Physics Operation and Research
- Augment the IMAS with additional (developmental) physics codes and components

The ITM has established an excellent start on this effort.

The ITER IM Programme will begin development of its IM infrastructure in 2012.