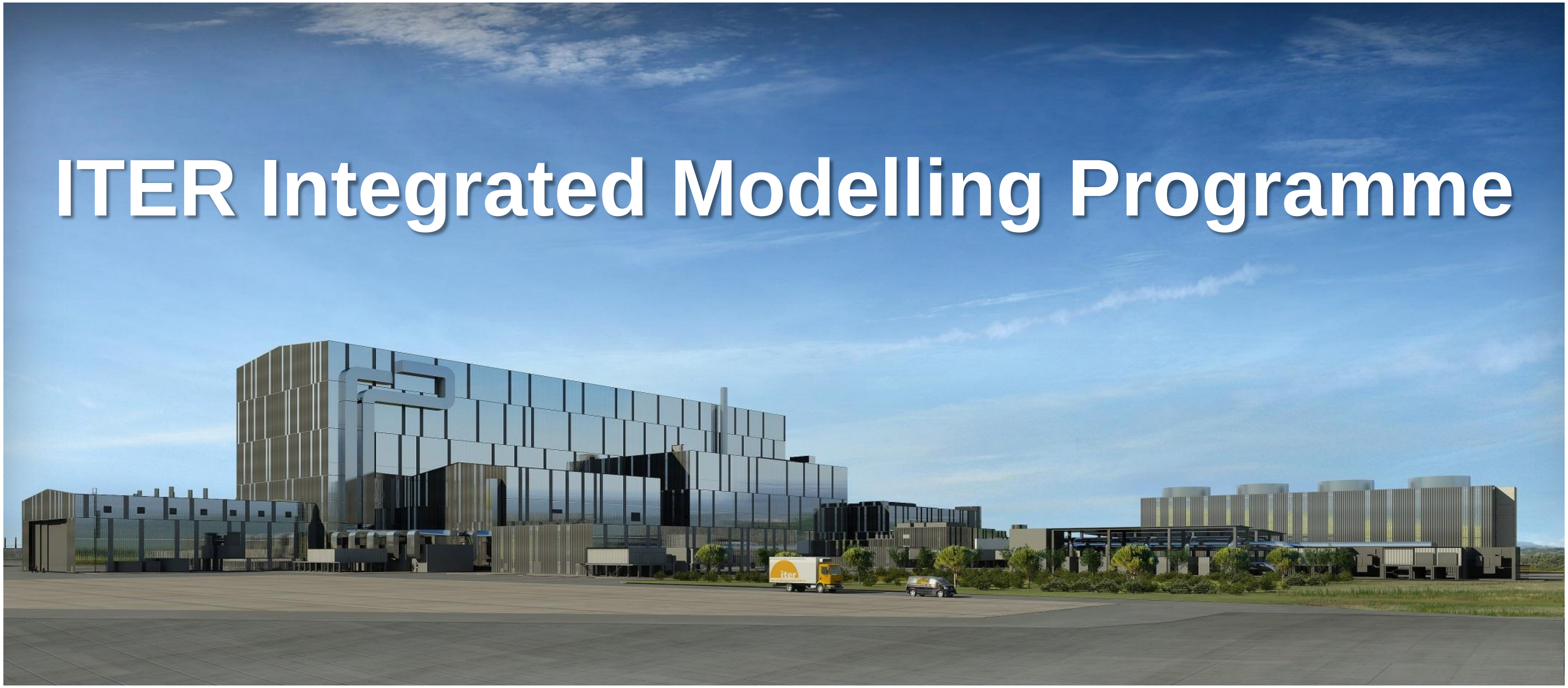
ITER Integrated Modelling Programme



SD Pinches on behalf of contributors to IM Programme

ITER Organization

The views and opinions expressed herein do not necessarily reflect those of the ITER Organization

ITER Integrated Modelling Programme

- A programme on integrated modelling and control of fusion plasmas, including benchmarking and validation activities, co-ordinated by the ITER Organization, but developed using relevant expertise within the Members' fusion programmes
- Overall aims of programme are to meet initial needs of ITER Project for more accurate predictions of ITER fusion performance and for efficient control of ITER plasmas, to support the preparation for ITER operation and, in the longer term, to provide the modelling and control tools required for the ITER exploitation phase

Endorsed by 1st ITER Council, November 2007

ITER Integrated Modelling Programme

- Two primary functions to aid planning and executing ITER Research Plan
  - Support Plasma Operations
  - Support Plasma Research
- Successful development and implementation requires:
  - Close collaboration across Directorates within ITER Organization
  - Close collaboration between ITER Organization and ITER Members' domestic fusion programmes

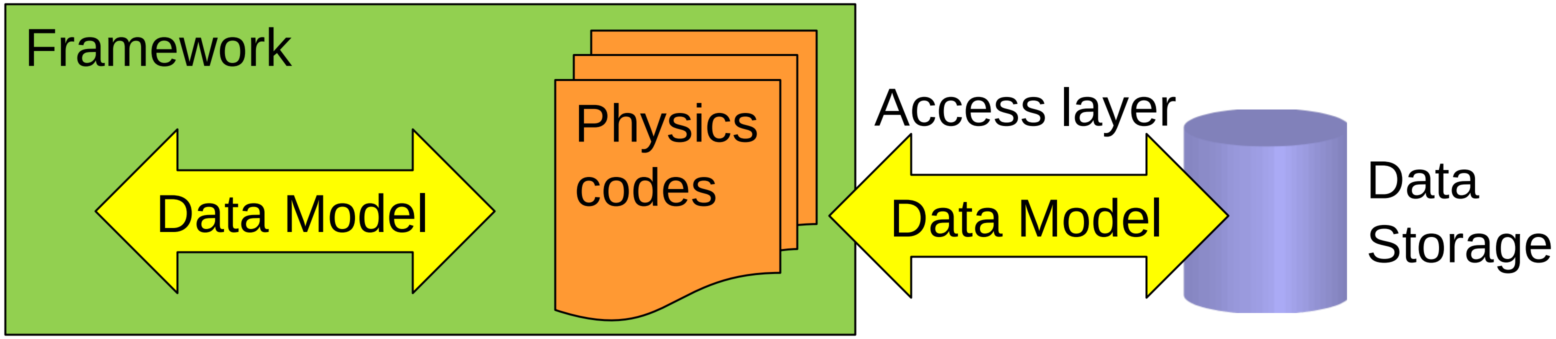
Supporting Plasma Operations

- Requires physics modelling tools for:
  - Validation of pulses prior to operation
  - During shots for plasma control (forecasting) and live display
  - Post-pulse for comprehensive reconstruction using full set of diagnostic measurements
- Tools must be computationally efficient, robust, well-documented and interface with other systems
  - Must be validated and have associated regressions tests
- Managed by IO and accessible to all ITER Members
- Describe macroscopic behaviour that improves as ITER explores new physics domain of burning plasmas

Integrated Modelling & Analysis Suite (IMAS)

Integrated Modelling & Analysis Suite (IMAS)

- ITER Physics Data Model
  - Applicable for all physics usages
- Physics Codes
  - To support Plasma Operations and Plasma Research
  - Contributed and validated by ITER Members
- Workflow Engine
  - To orchestrate execution of integrated modelling workflows



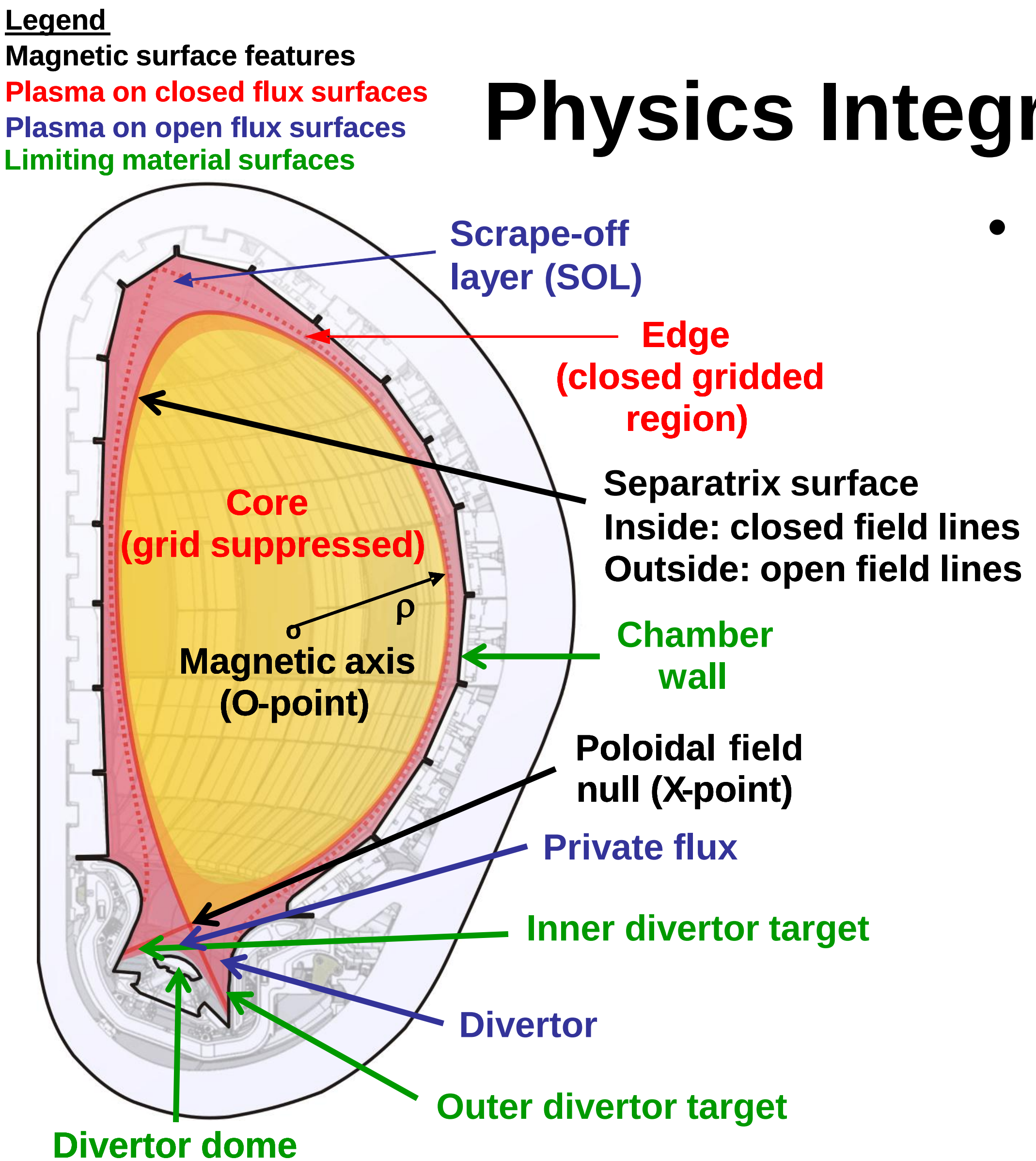
ITER Physics Data Model

- Used for both experimental (all devices) and simulation data
- Used between physics codes and from/to storage
- Data Dictionary defines structuring and naming of data
  - Rules & Guidelines agreed following internal/external review (v2.0)
  - Uses a tree structure (allows re-use of names)
  - Automated definition of data structures for all supported languages
    - C/C++, Fortran, Java, Python, Matlab and IDL
- Interface Data Structures (IDSs)
  - Standardised entities for use between physics components
    - E.g. Diagnostic, heating system, equilibrium, core plasma profiles
  - Contains traceability (provenance) and self-description information

Supporting Plasma Research

- Requires much more extensive set of modelling tools to be used both prior to operation and post-operation
  - Examination of microscopic behaviour
  - Investigation of more rigorous theoretical or computational behaviour
  - Exploration of new physics
- Primary basis for model improvement and validation
- Applied to selected shots, segments or time-slices
- Will often require significant high performance computing (HPC) facilities
- Emphasis on incorporating these development components during construction of IMAS

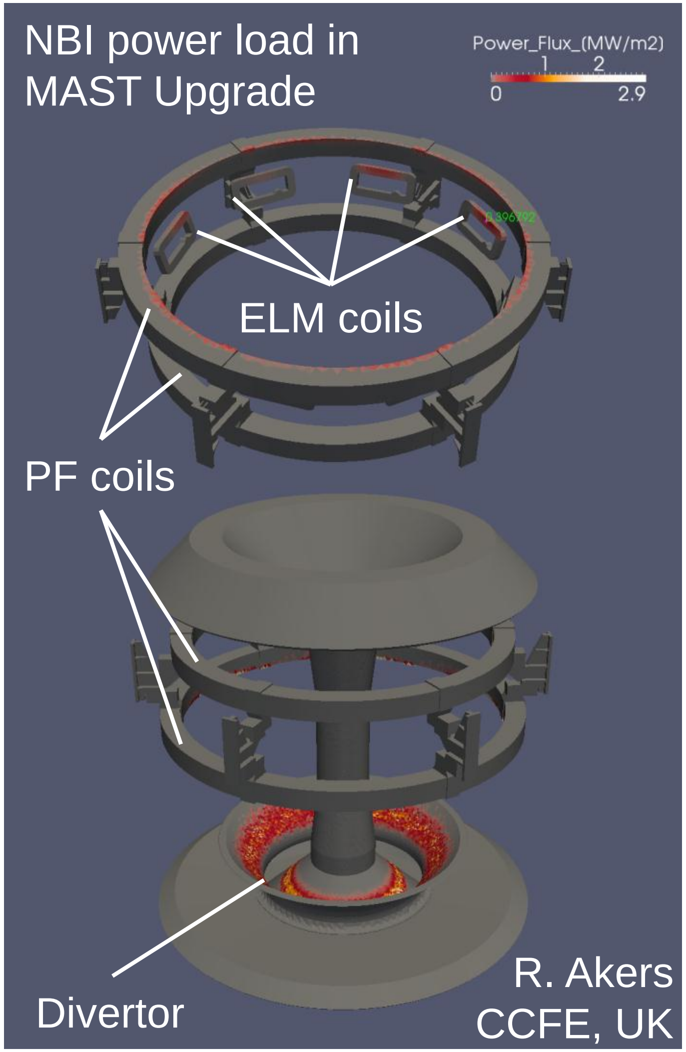
Physics Integration Challenges



- Will ultimately require:
  - Coupling of all spatial plasma domains (core, edge, scrape-off layer & divertor)
  - Dynamic coupling of individual physics models relevant to each domain
  - Interaction between plasma and PFCs
  - Coupling of plasma with external circuits, H&CD, fuelling, pumping and other systems to confine and control plasma

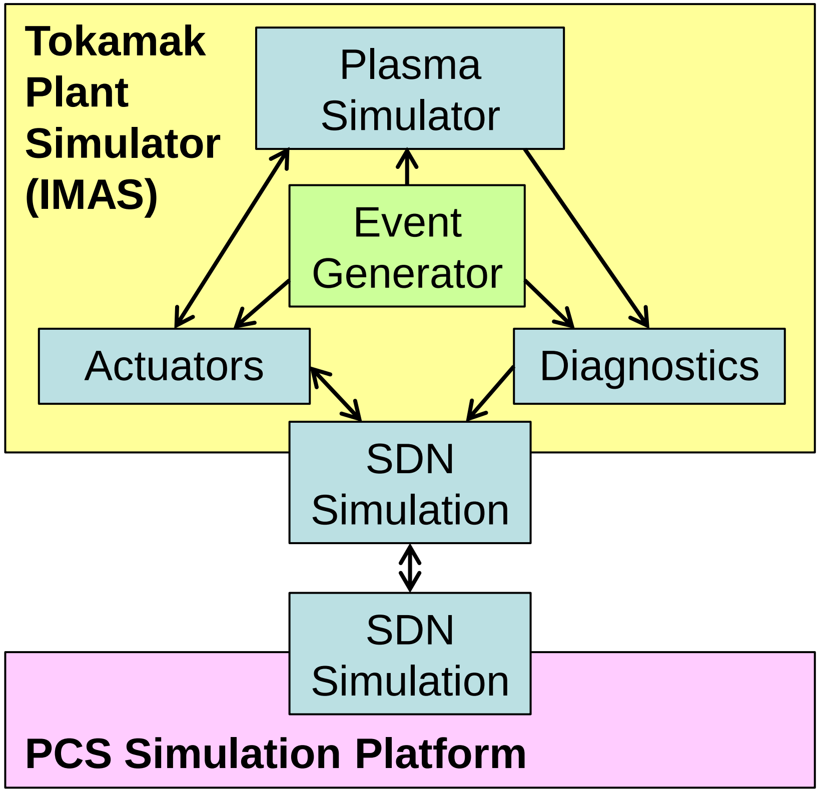
Computational Challenges

- Explore new algorithms and techniques as hardware evolves
  - Re-examine traditional approaches
- Exploit advances in architecture
  - E.g. Speed-up ×50 over single core by using GPU to follow fast ions → ×200 using four GPU cards
- Separate machine data from physics codes
  - Use Data Model to access machine/engineering/CAD data
    - Improved portability
- Validate physics codes towards use in engineering calculations



IMAS Plasma Simulator

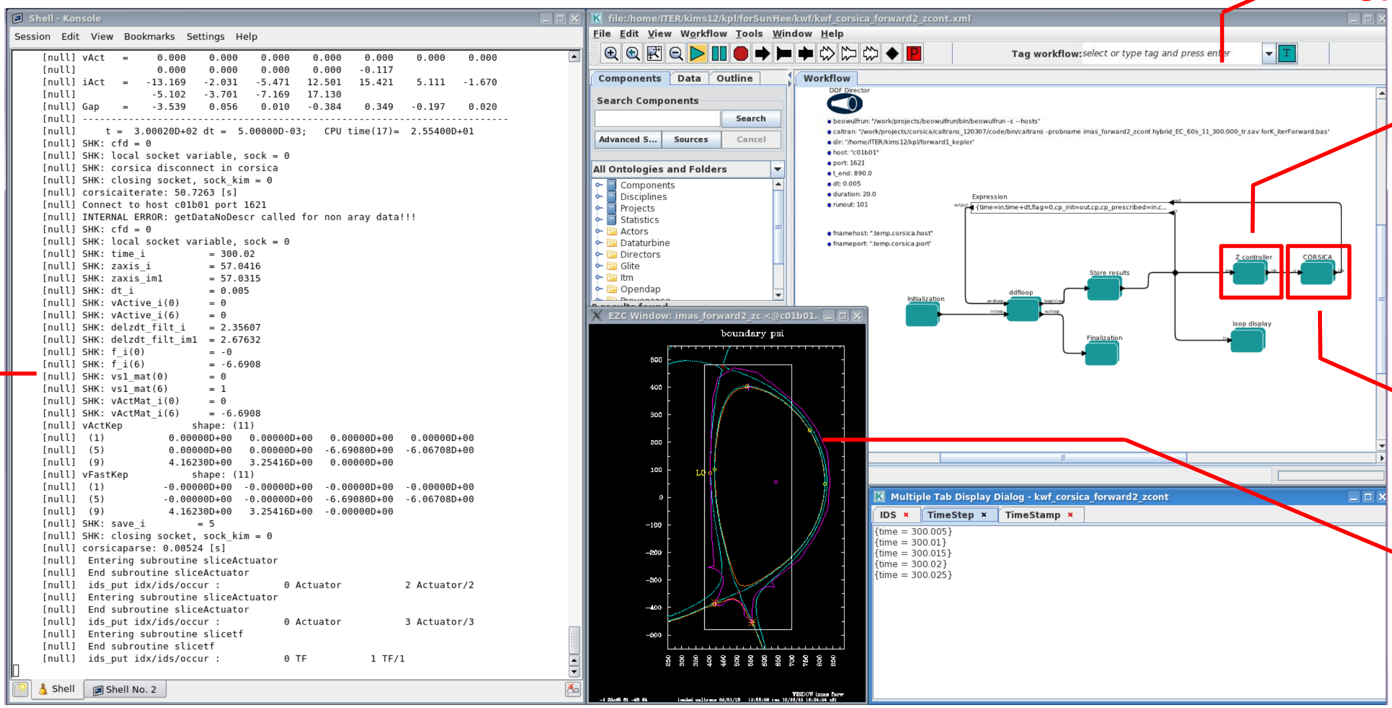
- Initial application for prototyping IM infrastructure and developing tools required for pulse preparation
- Co-simulations of Plasma Simulator and Plasma Control System Simulation Platform
  - Basis for pulse validation
  - Develop control strategies from plasma initiation to burn control
  - Refine response to events
    - L-H transition
    - Power supply interruption
    - Diagnostic degradation / failure
  - Troubleshoot PCS during operations
  - Coupled system can guide physics model development



CORSICA-based Plasma Simulator

- CORSICA implemented as single workflow component
- Example: Free-boundary 12.5 MA hybrid scenario
  - Realistic sources and external Z controller

Kepler workflow engine



Z controller
- Z position
- PF I & V

CORSICA

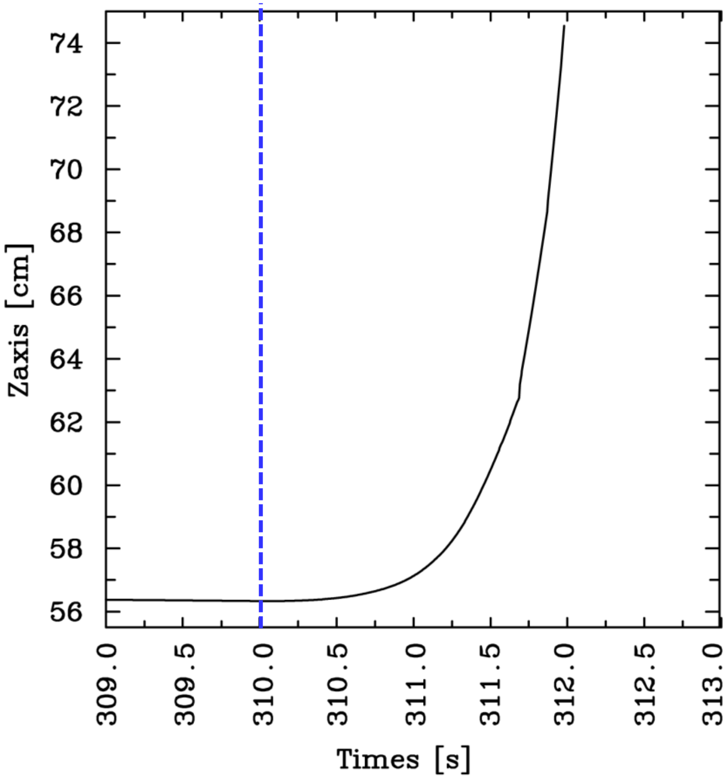
Text output

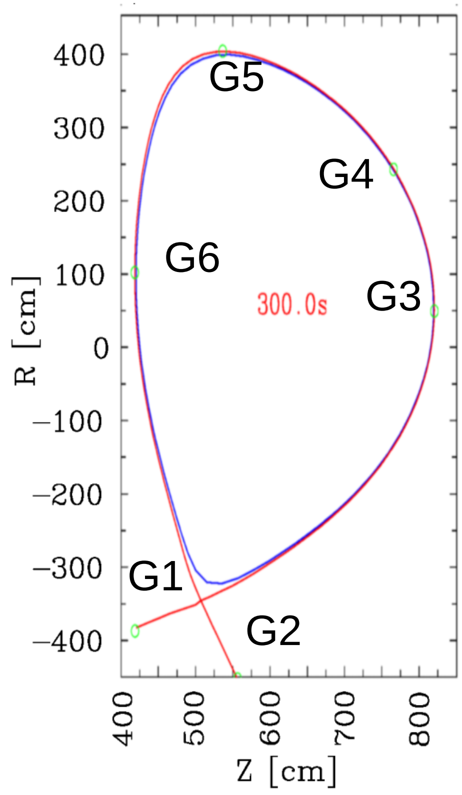
Graphical output

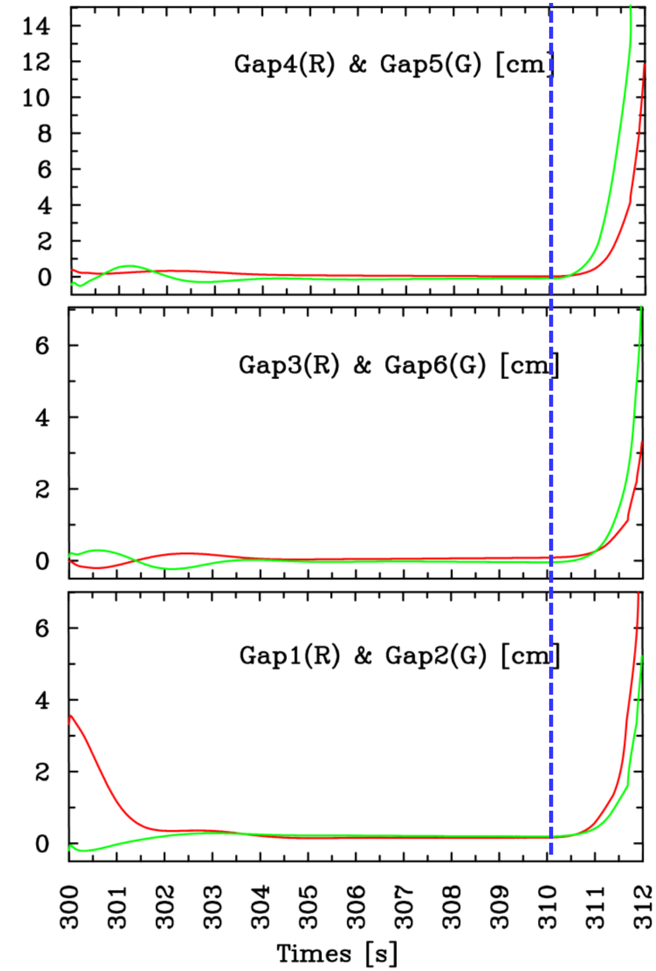
M Hosokawa, S H Kim, T Casper & LLNL CORSICA colleagues

CORSICA-based PS: Free-boundary plasma evolution with external Z controller

- VDE triggered at 310s by switching off feedback



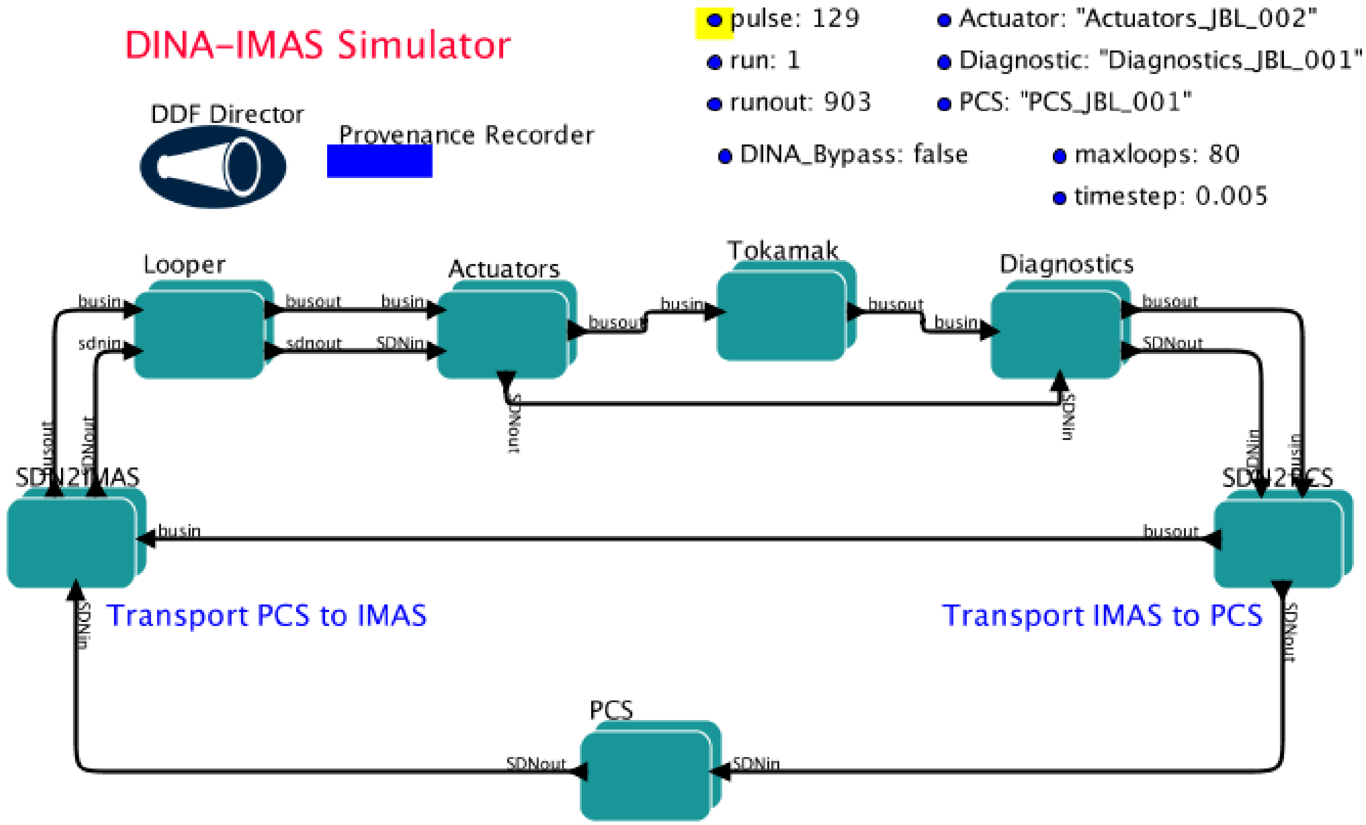




M Hosokawa, S H Kim, T Casper & LLNL CORSICA colleagues

DINA-based Plasma Simulator

- DINA integrated into IMAS in modular fashion



J Lister, V Lukash, R Khayrutdinov and DINA colleagues

Status and Outlook for ITER Integrated Modelling Programme

- Prototype IMAS Framework now running on ITER's HPC cluster
  - Physics Data Model
    - IDSs for majority of foreseen workflows (v1.0)
    - Revised set of Rules & Guidelines for Data Dictionary agreed (v2.0)
  - First workflows based on integrating ITER's existing physics codes
  - Workflow engine (Kepler)
  - Revision control (Git) and issue tracking (JIRA) for all components
- Future developments
  - Revise and approve IDSs (v2.0) to comply with new R&Gs (≤ July 2014)
  - Modularise existing workflows and extend physics capabilities
  - Start to support remote use by limited number of beta testers
  - Package framework for local use within domestic programmes