# Integrated Modelling & Analysis Suite: Developments to Address ITER Needs


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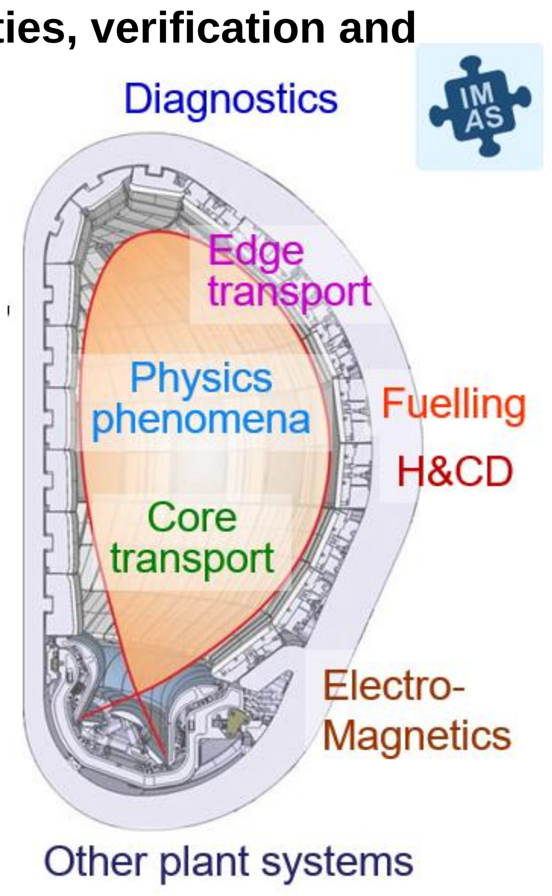
## The ITER Integrated Modelling & Analysis Suite IMAS

- Covers **all physics modelling** to support planning and execution of ITER Research Plan (IRP) [1]
- Successful development and implementation requires **close collaboration with ITER Members' domestic fusion programmes**
  - Particularly for integration of **new physics capabilities, verification and validation**
- Based around a **standardized representation of data** described by a **Data Dictionary (DD)** that is both **machine independent** and **extensible**
  - **Allows tools and workflows** developed in IMAS for ITER to be **tested and refined on existing devices**
  - Comprises **Interface Data Structures (IDSs)** which foster the creation of **modular physics components** and **(sub-)workflows**
  - **DD grows and evolves** as more Use Cases are addressed

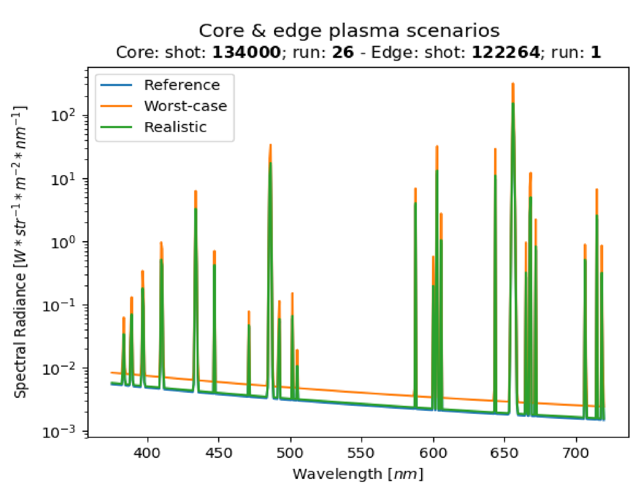



## IMAS Infrastructure

- IMAS Access Layer (AL) enables storing and retrieving IDSs
  - Interfaces available in Fortran, C++, Python, Java and MATLAB
- DD has evolved through strict release cycle to now contain **68 distinct IDSs**, mainly through expansion of **diagnostic systems** that can be represented
  - Latest version is 3.32.0
- **New MEX-based MATLAB interface** offers **improved performance**
- **New Python interface** that **dynamically interprets DD at run time**
  - Allows improved flexibility with respect to working with different versions of DD
  - Additional metadata in DD allows to handle non-backwards compatible changes
- Introduction of **Hierarchical Dynamic Containers** (HDCs) **allows runtime interpretation of DD in all languages**
- **New HDF5 backend** allows IMAS datasets to be efficiently stored using a tensorized representation in a self-describing portable binary format
  - Other backends include: MDS+, UDA, ASCII, memory
- **Remote data access** possible using UDA client-server
  - Currently only possible from whitelisted IP addresses until authentication developments are completed
- Simulation management tools (SimDB) under development
  - Will replace current simple YAML-based catalogue and scripts

## Diagnostic Models

- Growing set of **synthetic diagnostics** and tools developed to **predict measurements** (make performance assessments), **test controllers** and **support analysis & interpretation**
- Generic CAmera and SPectroscopy Emission Ray-Tracer, CASPER
  - Provides raw and first level of analysed data for visible spectrometers and cameras
    - Spectrum, bremsstrahlung level and line intensities
  - Support models for Visible Spectroscopy Reference System, Charge Exchange Reference System, H-alpha, and Divertor Impurity Monitor
    - Used to support calculations of ion temperature, ion rotation velocity, electron density, $Z_{eff}$, etc.




*VSRS spectral radiance including impurity line emissivities and bremsstrahlung calculated using SOLPS-ITER [10] and JINTRAC datasets*

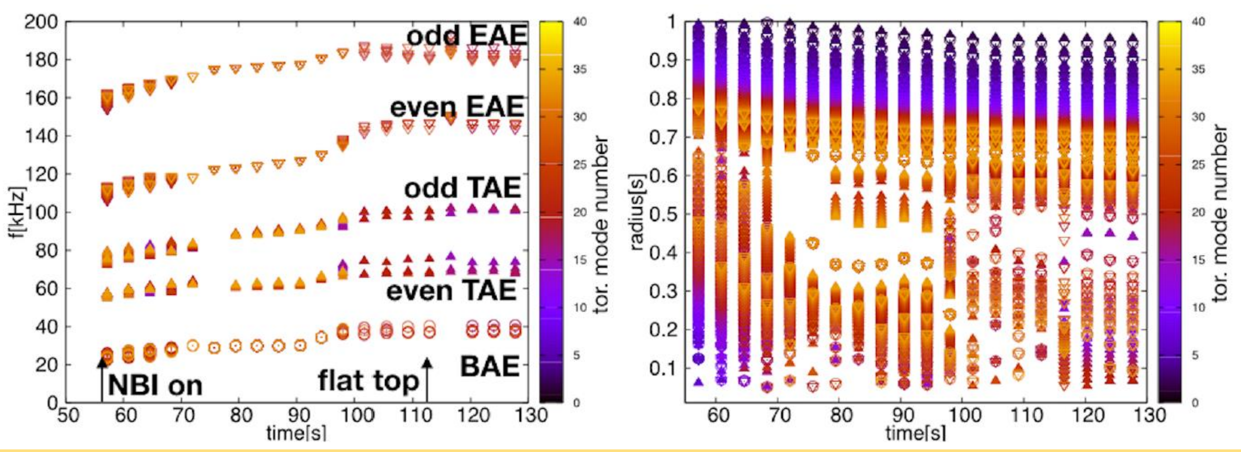
## High-Fidelity Plasma Simulator

- **HFPS based upon DINA [2,3] and JINTRAC [4] code suites** which have both been adapted to IMAS [5] so native components exchange IDSs
  - DINA used to validate capability of ITER poloidal field system to support the plasma scenarios foreseen in IRP: **Free-boundary equilibrium evolution solver** with **feedback control of plasma current, position and shape**, taking into account **eddy currents in the vacuum vessel** plus **engineering limits** imposed on the coils, their **power supplies**, and **plasma-wall gaps**
  - JINTRAC describes time-dependent **coupled plasma core-edge-SOL transport, heating, fuelling and transient behaviour and divertor power loads**
  - A comprehensive **IMAS H&CD workflow** has been developed [6] and **coupled with JINTRAC** allowing **all ITER H&CD sources** and **synergistic effects** between them to be described → See M. Schneider *et al.* P8.1 for more details

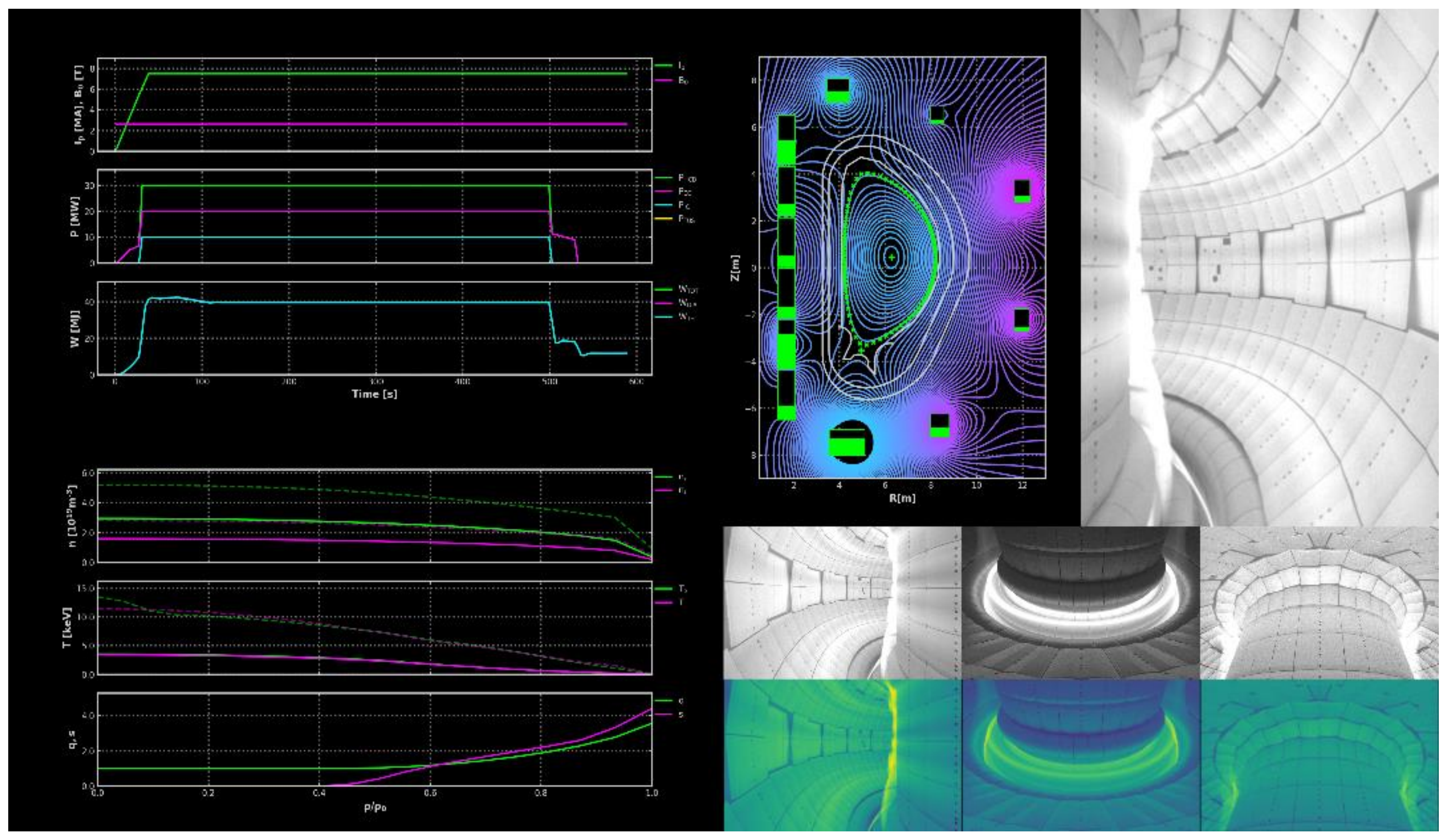
## Energetic Particle Stability

- A **workflow to assess EP stability** of plasma scenarios [7] has been developed based upon the LIGKA [8] and HAGIS [9] physics codes

*Evolution of Alfvén eigenmode frequencies (stable and unstable) (left) and radial location (right) as a function of time during ramp-up of a PFPO-2 H-plasma from IMAS scenario database (#100015,1; 5 MA/1.8T). All modes in negative EP gradient region between 0.35 < rho_pol < 0.55 are shown.*




## Live Display



*Example control-room Live Display calculated using ITER scenario database and showing plasma equilibrium, waveforms and profiles (based on shot=110005; run=1) [11], together with synthetic views from the Wide Angle Viewing System (WAVS) (based on shot=122264, run=1) [10].*

## Conclusion

- **IMAS** has **improved its robustness, flexibility and capabilities**
- Progress has been made towards building a **comprehensive HFPS** bringing together state-of-the-art capabilities for the integrated **prediction of ITER scenarios**, including advanced **treatment of H&CD elements**
- **EP stability** has been captured in a **hierarchical workflow** that ranges from **analytic estimates** to **nonlinear gyro/drift-kinetic** calculations
- An **expanding set of diagnostic models** have been implemented and used to generate **synthetic signals** and make **diagnostic performance assessments**

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