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WEST plasma reconstruction chain and IMAS related tools

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Introduction

The WEST^{1,2} Plasma Reconstruction Chain (PRC) is routinely executed after each shot of WEST plasma operation since end of 2017. Previous Tore Supra architecture has been improved and adapted to use key software components provided by the Integrated Modeling & Analysis Suite (IMAS³) infrastructure. These components include the IMAS Data Dictionary which specifies the ITER data model by defining a set of standardised Interface Data Structures (IDSs) which are both machine independent and extensible, and the IMAS data Access Layer which allows to read/write data in ITER format and enables Physics components to communicate by exchanging IDSs. WEST PRC Physics components are henceforth executed in parallel and produce/exchange IMAS compliant data which are made available from Internet through secured connection using Unified Data Access (UDA⁴) client/server solution. The post-pulse processing components for diagnostics and plasma equilibrium reconstruction are presented and some currently available WEST data are given. Few IMAS related tools are briefly presented.

WEST historical context

- Tore Supra stopped operation in 2012. New divertor coils for X point, divertor, new PFC (tungsten monoblocks or coatings) → WEST first plasma end of 2016
- ~40 diagnostics available, progressively adding new ones and also extending the processing chain with new treatments
- 12 infrared cameras
- Development of Plasma Reconstruction Chain started in 2016
- WEST diagnostics write in a SQL database inherited from Tore-Supra
- Raw/processed data consumed/handled by the new WEST PRC
- IMAS Data Dictionary (DD) allows for organizing fusion data
- IMAS Access Layer used by the PRC for reading/writing data

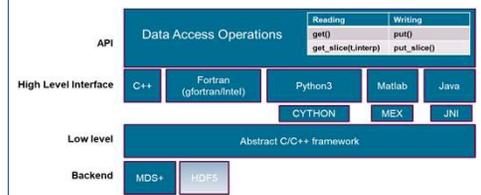
ITER Physics Data Model

- Fusion data organized by the IMAS Data Dictionary (DD) with 55 Interface Data Structures (IDS)
- IDS represents a diagnostics, subsystem (like 'ic_antennas') or plasma Physics concept like the 'equilibrium' IDS
- IMAS format adoption facilitates data exchange
- Enhanced code portability for Physics code which uses IMAS format

IMAS Access Layer

- IMAS Access Layer with layered model design
- API for reading/writing data specified by the IMAS DD
- 5 programming languages (so-called High Level Interfaces) available
- Common C/C++ abstract layer to all HLLs
 - Allows use of different native libraries (e.g. MDS+, HDF5,...)
- WEST uses MDS+ backend for storing experimental & simulation data
- Ongoing development of new HDF5 backend for IMAS
- Performances of Access Layer continuously improved

IMAS Access Layer architecture

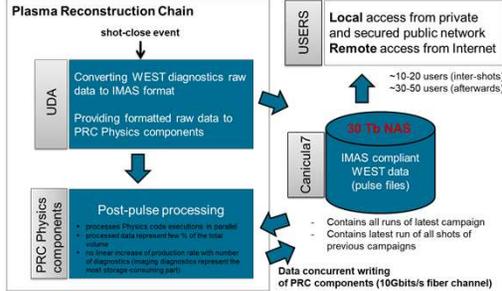


Layered model design of the IMAS access layer

WEST Plasma Reconstruction Chain

- ~40 diagnostics (IR imaging, X-rays and visible spectroscopy, magnetics and interferometry measurements, bolometry, calorimetry, ...)
- ~20 post-processing Physics modules managed by the PRC
- Home made task manager to orchestrate all WEST treatments
- All data handled in IMAS format, in the form of IMAS IDSs
- IDSs in IMAS pulse files stored on dedicated 30 Tb NAS
- NAS disk shared between private/public networks
- Raw data diagnostics first converted in IMAS format using a generic UDA (Unified Data Access) client/server solution
- Dedicated WEST UDA plugin converts diagnostics raw data stored in SQL database to IMAS format

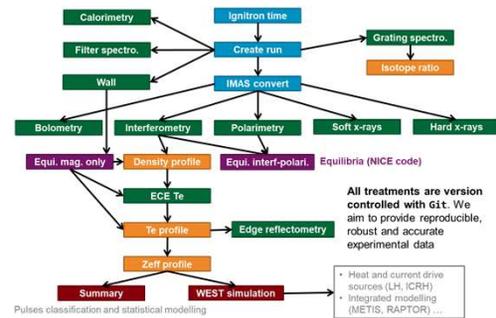
Plasma reconstruction chain overview



Workflow schematic involved in the PRC

- Physics code execution consumes raw data IDSs created in step 1
- Tasks Manager (TM) executes jobs in parallel
 - a major improvement compared to Tore-Supra
- TM submits jobs to PBS load sharing facility
- IMAS pulse file updated concurrently by all Physics code
- Physics code exchange IDSs through access to the NAS
- WEST exposes IDSs to Internet using a Unified Data Access server
 - WEST shots data provided in IMAS format to remote clients

Physics code workflow

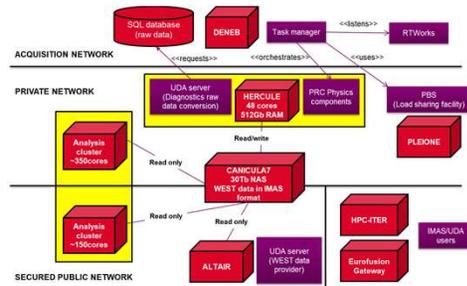


Pulses classification and statistical modelling
PRC workflow modules

- Diagnostics raw data conversion in IMAS format
- Post-processing with Physics code, computation of plasma equilibrium (NICE⁵) and core profiles (Te, Zeff,...)
- Summary IDS used for cataloguing WEST shots
- Execution of simulation programs (METIS⁶, RAPTOR⁷, HCD⁸ workflow)

WEST PRC deployment view

PRC deployment view



Nodes, servers and applications used by the PRC, running in different networks

- SQL database for storing raw data during shot acquisition
- Task Manager, listens acquisition events, triggers PRC execution
- Post processing Physics components
- UDA server for raw data conversion in IMAS format
- 30 Tb NAS for IMAS pulse files with raw and processed data shared between private/secured public area networks
- Two analysis clusters for users in private/public area networks
- UDA server in secured public network for remote data access

Data produced by the PRC

Example of IDSs produced by WEST

IDS name	Occ.	Description
core_profiles	0	Fitted density and temperature (from occurrences 2, 3)
	1	Fitted ne profile from interferometer (spline)
	2	Fitted ne profile from interferometer (hyperbolic tangent)
ece	0	Electron temperature
	0	Equilibrium reconstruction with magnetics only
	1	Equilibrium reconstruction with magnetics and interfero-polarimetry
interferometer	0	Line integrated electron density
	0	Lower hybrid antennas (power coupled to plasma...)
magnetics	0	Magnetic probes and flux loops
	0	Spectrometer visible and isotope ratio
spectrometer visible	0	Spectrometer visible and isotope ratio
	0	Summary of complete signals
summary	1	Summary statistics on plateaus
	0	Dynamic first wall (taking into account limiter movements)

The advantage of occurrences is that different types of the same data can be stored
Example of relevant IDSs produced by the PRC

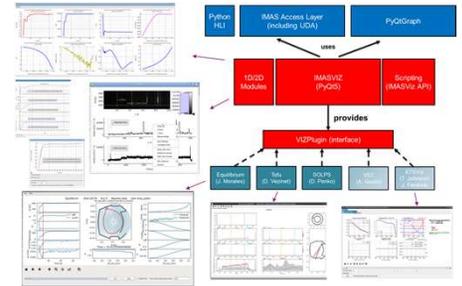
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IMAS related tools

- Tools not specifically designed for WEST, new/existing tools required only to be developed/adapted to use IMAS
- METIS⁶, a fast integrated tokamak modelling tool for scenario design
- Catalog_QT, a SQL database based catalog for shots. Catalog populated using public WEST UDA server
- TOFU⁹ (Tomography for Fusion), open-source toolbox for synthetic diagnostics modelling and data visualization
- Gaussian Process Regression¹⁰, a profile fitting tool for generation of profiles based on IDSs
- CHEASE¹¹, a code for computing plasma equilibrium
- Heating & Current Drive (HCD⁸), a tool for modelling heating sources for ICRH and NBI developed by ITER Organization
- IMAS_VIZ¹², a plugins based python tool for visualizing IDSs into plasma coordinates
- EQUI_MAP⁵, a library for mapping experiment coordinates (R,Z,phi) into plasma coordinates

IMAS_VIZ: a tool for visualizing IMAS data



IMAS_VIZ design and plot types examples

Conclusions

- WEST, first experiment to use IMAS in production
- Flexible new post pulse processing chain developed for WEST:
 - Eases workflow extension with new treatments
 - Allows replay of new/modified treatments on a given shot
 - Eases data exchange with other machines using the IMAS format
- These features drive the development of various IMAS-compliant tools that can be reused in other devices

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