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Introduction to IMAS: A Comprehensive guide to access IMAS on ANTYA

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Integrated Modelling and Analysis Suite (IMAS) [1] is a comprehensive tool set developed to meet the growing demands of the magnetic fusion research community. As ITER and similar projects expand, there is a clear need for standardized, adaptable tools that enable scientists across the world to simulate, analyze, and interpret a wide array of magnetic fusion relevant data. IMAS provides an organized framework for developing and executing magnetic fusion related simulations. With its extensive library of modules, tools, and data models, it bridges gaps between experiments and theory, making data reproducible, shareable, and easier to interpret.

Why IMAS?
Over the decades, magnetic fusion community conducted large number of experiments and developed complex models and simulations. However, most of the simulations were developed with a **"self-centered"** approach and the data generated out of these experiments/simulations are heterogenous, meaning the inputs and outputs of these programs have unique semantics and stored in various file formats. Hence, there is a need to integrate all these into a single platform and analyse the experimental data in a structured format. To address these challenges and for ease of exchanging data within the magnetic fusion community, ITER developed the IMAS [1-7]. The IMAS is a classic example of solving complex modelling problems in an integrated approach.

IMAS consists of:

A) Data Structures: IMAS provides unified and standardized data models for various fusion phenomena, enabling the storage and sharing of data in a consistent manner. For example, IMAS provides a standard definition of machine data and an interface for exchanging data in an integrated modelling, known as the **Interface Data Structure** (IDS). IDS files are designed to handle a vast amount of data ranging from magnetic equilibrium to plasma profiles and diagnostics [1-7].

B) Tools: IMAS includes analysis tools, data retrieval systems, and visualization packages designed to operate on a common set of data structures. For instance, for experimental data, a novel tool has been developed to map fusion data into IMAS, called the universal data access (UDA) component. The UDA project provides plugins for each fusion machine [8].

C) Interfaces: IMAS provides Application Programming Interfaces (APIs) to various simulation codes ensuring they can easily communicate and use IMAS data. Its data model-aware API, enables access to data in various programming languages (FORTRAN, C++, MATLAB, PYTHON and JAVA). The IMAS environment also includes numerous libraries, low-level routines, known as the universal access layer (UAL) for reading and writing IDSs and defining or allocating IDS variables in simulation codes such as JINTRAC, ASTRA, CORSICA, DINA, SOLPS, METIS, HCD etc [3-7].

IMAS is built around a common data representation and strives to make fusion data more FAIR (Findable, Accessible, Interoperable and Reproducible) [2]. The following flow chart shows structure of IMAS .

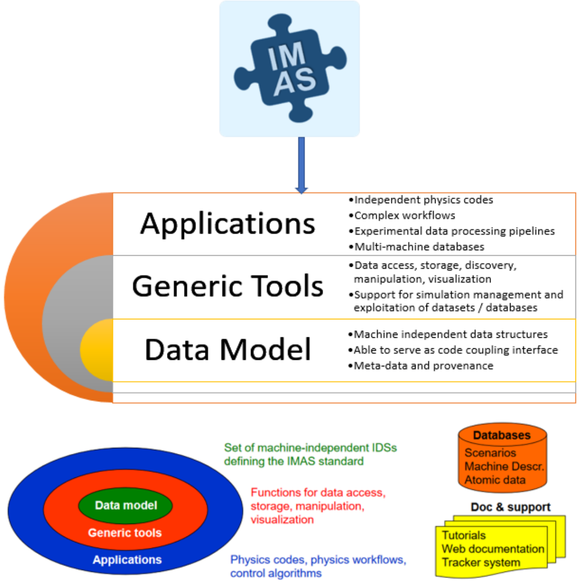

Figure.1. *The typical flow chart of IMAS.*

Key Benefits of IMAS:

A) Consistency: A single platform for magnetic fusion simulations and analyses.
B) Scalability: Suited for handling both small and large-scale magnetic fusion data.
C) Collaboration: Facilitates collaboration between researchers working on different aspects of fusion science .
D) Adaptability: Can be extended with new codes and models as needed.

Working with IDS:
The heart of IMAS is its IDS system. Each IDS contains various categories of data (e.g., equilibrium, magnetics, profiles, etc.). To start working with these data structures, you can load a specific dataset using the Python API.

IMAS Python API allows you to interact with simulation data efficiently, providing tools for manipulation, visualization, and storage. The following figure shows list of IDS in IMAS .

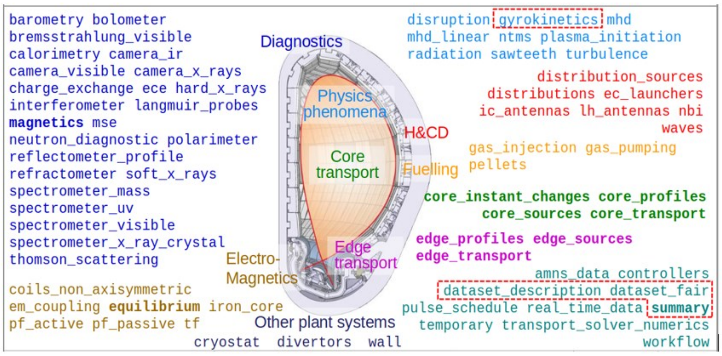

Figure 2. *List of IDS in IMAS*

Additional Resources:

IMAS Documentation: The official IMAS documentation is available at https://confluence.iter.org/display/IMP

Getting Started with IMAS on ANTYA

ANTYA is a state-of-the-art HPC cluster designed to support large-scale computations in plasma physics and fusion energy research at IPR. Here is a step-by-step guide to running IMAS on ANTYA:

1. Access to ANTYA:

To start using ANTYA, you will need an HPC account with the appropriate permissions. If you do not have access yet, contact the HPC administration team. Make sure you have SSH access configured.

```
ssh -X username@antya.ipr.res.in
```

2. Setting Up the IMAS Environment for MATLAB Users:

The MATLAB code users aiming to adapt their codes within the IMAS framework, access to the visualization node is required. Users working with programming languages other than MATLAB (e.g., FORTRAN, PYTHON, and C++) can skip this step . To ensure compatibility and functionality, MATLAB users need to use visualization node.

```
[user@login1 ~]$ ssh -X visualization
```

3. IMAS Usage:

Integrated Modelling & Analysis Suite (https://imas.iter.org/) is the infrastructure used to build on ANTYA. To use IMAS on ANTYA, one should load the following IMAS module.

```
[user@visualization ~]$ module load IMAS-3.42/3.42.0
```

4. Data Dictionary:

Data dictionary (DD) is the basis of IMAS, which describes the physical data model for tokamak devices. To view its HTML documentation of DD, type **"dd_doc"** in the terminal. Using the following command, one can see the list of IDSs available in IMAS.

```
[user@visualization ~]$ dd_doc &
```

5. Adaption of inputs and outputs of the physics code and using IDS to couple physics codes:

A model is considered as adapted to IMAS when its input and output are IDSs exclusively [3-7]. For example, an IMAS-adapted code will be called as follows:

ids_out1, ids_out2 = model (ids_in1, ids_in2, ids_in3)

Optionally, there can be an input xml file which contain user-defined code parameters for the model to be run. These parameters should be constant during the simulation:

ids_out1, ids_out2 = model (ids_in1, ids_in2, ids_in3.xml_codeparam_file)

The model should not depend on any other external file. The following flow charts show that the adaption of inputs and outputs of the physics code and using IDS to couple physics codes [3-7].

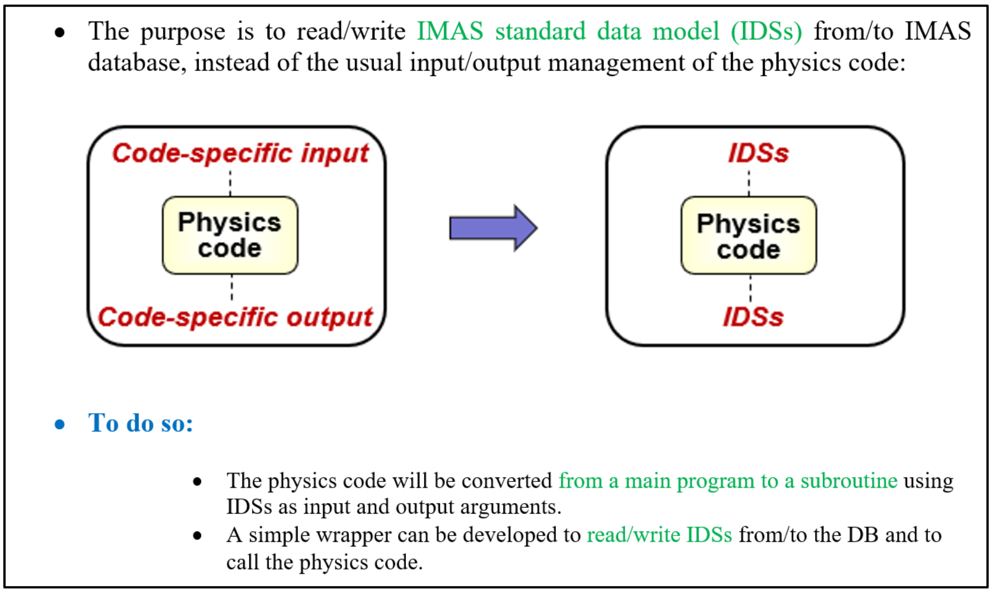

Figure 3. ***Adaption of inputs and outputs to the physics code***

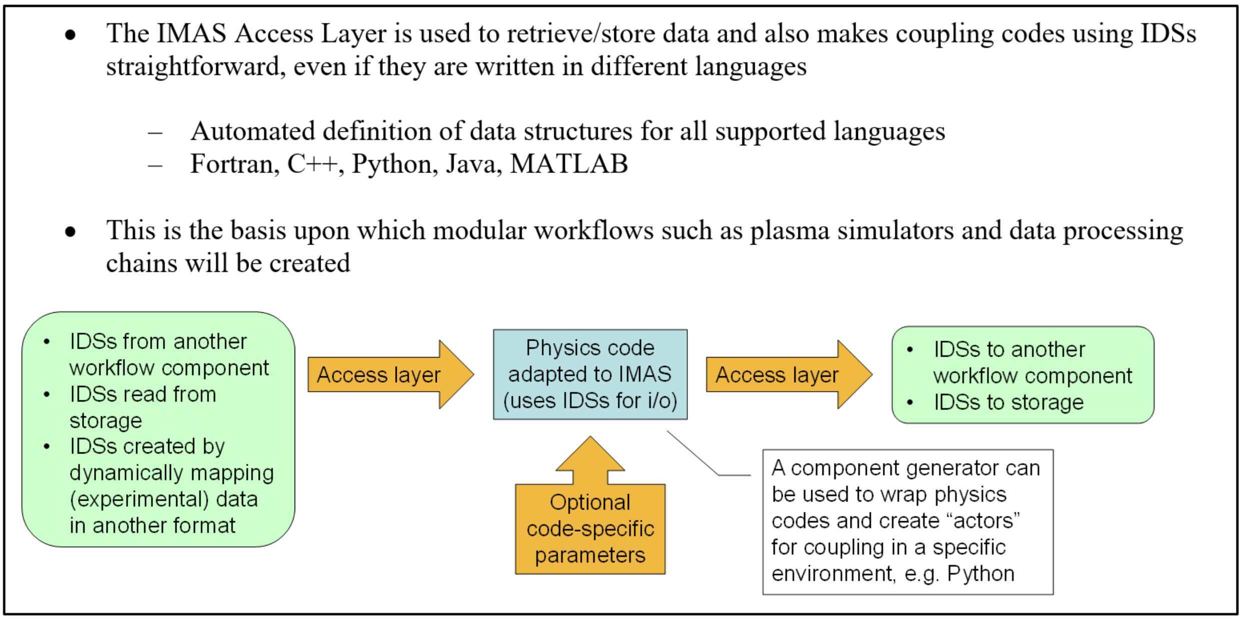

Figure 4. *Using IDS to couple physics codes*

6. IMAS Examples:

IMAS examples are good tutorials to learn how to use IMAS and adapt their codes in IMAS. Copy the IMAS examples into your directory by using **"cp -rf /scratch/scratch_run/imas/imasexamples user_directory"**. This folder contains IMAS examples across various programming languages, including PYTHON, FORTRAN, MATLAB, and C++ and an ITER scenario data generated from JINTRAC/DINA simulations for ITER. Step by step instructions to run these examples is available at local intranet link **here**.

7. List of Codes Adapted in IMAS on ANTYA:

The adaptation of in-house developed codes into the IMAS framework on the ANTYA cluster represents a step toward integrating other codes developed/available at IPR into IMAS. Below is an overview of the progress made with two codes, INDUCT and OOPS, and their integration status within the IMAS:

- **INDUCT Code:** The INDUCT code (INDUCTance calculation) [9], a computational tool developed at IPR, has been successfully adapted into the IMAS framework on ANTYA. This code is developed to calculate eddy currents in passive structures such as the vacuum vessel (VV) and cryostat, as well as to simulate flux loop and magnetic probe signals in tokamak operations. As part of the adaptation, the input and output data for INDUCT were structured using IMAS Interface Data Structures (IDSs), including **pf_active, pf_passive,** and **magnetics**. After adaption, the code has been tested using experimental data from SST-1 discharges. For further details, please refer to Section 8 of the newsletter.

- **OOPS Code:** The OOPS (0D Optimization of Plasma Start-up) code [10], another indigenous code developed at IPR, is currently being adapted to the IMAS framework on ANTYA. This code is specialized for analyzing and optimizing plasma start-up scenarios. It supports offline analysis of experimental data and facilitates parameter optimization for improved plasma evolution efficiency.

In the near future, more and more tokamak modeling codes developed at IPR, as well as collaboration codes officially allowed to be used by IPR, can be integrated into the IMAS framework.

8. Example of adaption of in-house developed INDUCT code in IMAS:

The INDUCT code [9] has been successfully adapted within IMAS, and its simulation results have been validated against experimental data from flux loops. INDUCT is built on a filamentary model of both active and passive coils, and is primarily used to calculate eddy currents, as well as signals from flux loops and magnetic probes in tokamaks. The simulated data has been cross-validated with a range of SST-1 experimental discharges [9].

Machine description for SST-1 was adapted to IDS, and the cross-sectional view with the PF coils and Ohmic transformer sections is shown on the left side in the Figure 5 (with 11 in-vessel and 12 out-vessel flux loops shown with the cross-mark symbols).

These loop voltages are estimated and validated with detailed experimental measurements from a suite of magnetic diagnostics in SST-1as shown on the right side in the Figure 5 (for a Vacuum shot #4364 - OH + BV).

The next step in this effort involves the ongoing adaption of OOPS code [10], developed at IPR to analyze and optimize start-up experiments in IMAS. OOPS has been benchmarked with codes such as DYON, SCENPLINT, and BKD0 for burn-through simulations for both the ITER and JET tokamaks. Following bench-marking, the code is used to analyze and optimize the plasma start-up scenario during the initial campaigns of the SST-1 tokamak [10]. The OOPS code has its own advantages. The most important aspect of OOPS is that it is integrated with the INDUCT code which enables OOPS to self-consistently use simulated loop voltages for any given discharge.

The following flowchart (Figure 6) demonstrates the integration of INDUCT into IMAS via IDSs (**pf_active, pf_passive, and magnetics**) and highlights the ongoing efforts to couple OOPS with INDUCT in the IMAS environment with **plasma_initiation, pulse_schedule, ec_launchers** and **magnetics** IDSs.

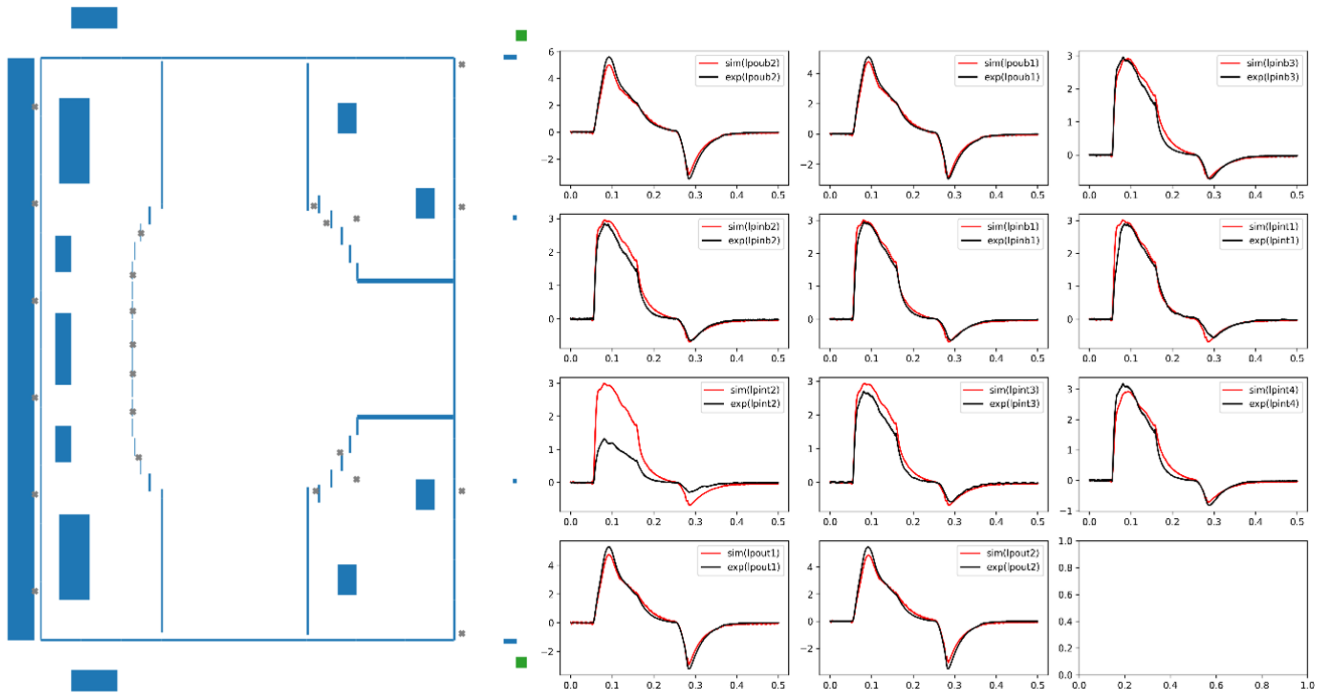

Figure 5. ***a) Cross-sectional view of SST-1 with the PF coils and Ohmic transformer sections shown. Also 11 in-vessel and 12 out-vessel flux loops are shown (displays in cross mark symbol) b). The comparison between experimental measured flux loop signals (in-vessel flux loops) with simulated for vacuum shot #4364 – OH + BV of SST-1***.

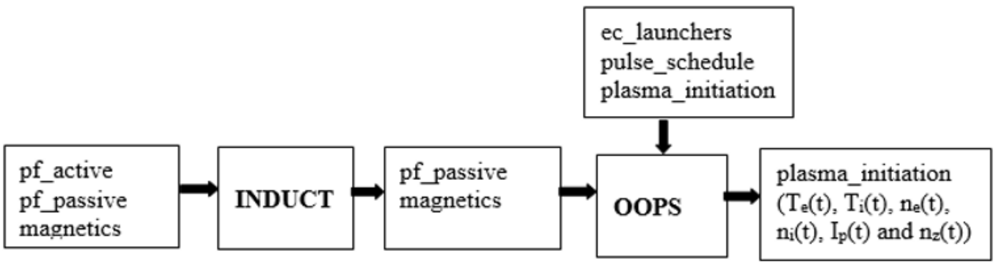

Figure 6. ***Flow-chart of integration of INDUCT and OOPS into IMAS via IDSs***

IMAS Access and Assistance Contact Information:

Currently, access to imas examples folder has been granted to some ANTYA users. Users interested in accessing IMAS or encountering any difficulties with the examples provided are welcome to reach out at amit.singh@iterindia.in or amitks@ipr.res.in.

Acknowledgement:

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Disclaimer:

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

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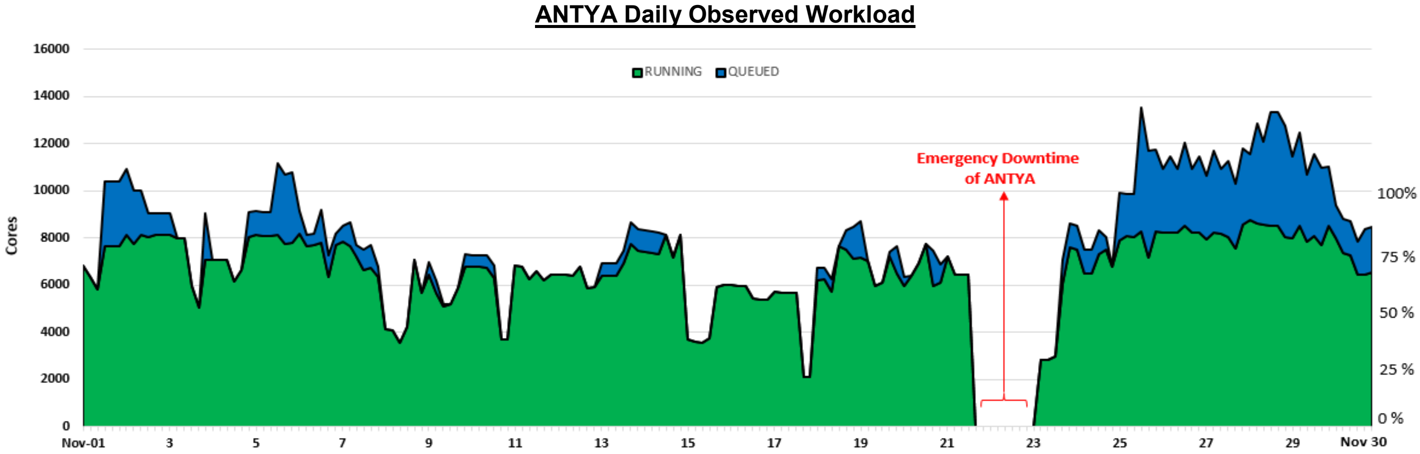
ANTYA Utilization: NOVEMBER 2024



Other Recent Work on HPC

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Effect of Multiple Detonations on the Detonation Parameters in Rotating Detonation Engine	Sunil Bassi
Thermal Hydraulics Studies and Optimization of an ECRH Launcher Mirror For Long Pulse Operation	Hardik Girishbhai Mistry
Subcritical Transition to Turbulence Induced by Columnar Vortex in a Plane Couette Flow	Suruj Jyoti Kalita
Liquid metal flow analysis in a duct with sudden expansion under inclined magnetic field	Arpita Vipat
Artificial Simulation of Pulmonary Disease Progression in Chest X-Rays Based on Localized Climatic Conditions	Bhanu Dutta Parashar
Behaviour of magneto-convective fluctuations in MHD duct flow under differently heated walls and applied magnetic field direction	Srikanta Sahu
Gyrokinetic transport driven by Ubiquitous Modes in LTX-like Tokamak with "flat" temperature	Sagar Choudhary
Compact Fusion Pilot Plant: Drivers for Nuclear Analysis Requirements	Shishir P. Deshpande

ANTYA UPDATES AND NEWS

1. New Packages/ Applications Installed

=> New modules have been installed in ANTYA

To check the list of available modules
$ module avail –l

ANTYA HPC USERS' STATISTICS— NOVEMBER 2024

Total Successful Jobs~ 638

♦ **Top Users** (Cumulative Resources)

- **CPU Cores** — Amit Singh
- **GPU Cards** — Abhishek Agraj
- **Walltime** — Amit Singh
- **Jobs** — Sagar Choudhary

Acknowledgement

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