ITER POSTDOCTORAL FELLOWSHIPS 2026 – RESEARCH TOPICS

Topic 1) Agentic AI for the Exploitation of Fusion Simulations and Experiments

Description

Plasma modelling serves as the critical link between theoretical prediction and experimental validation, but the drive for high-fidelity simulations has created a significant operational bottleneck. While the Integrated Modelling and Analysis Suite (IMAS) provides the standard data model necessary to couple diverse solvers, the orchestration of these codes remains complex. Interfaces are often fragile, making the preparation of consistent input decks error prone. This challenge is foundational, affecting even single-code simulations which must be mastered before multi-code workflows can be attempted. Consequently, physicists are forced to become HPC specialists, diverting effort from physics research to concentrate instead on framework development. Here, simple parameter errors in the inputs to a high-fidelity analysis chain can translate into substantial delays, ineffective resource utilization, and ultimately opportunity costs as key insights are missed.

To address this, this project proposes an Agentic AI system to orchestrate physics codes via natural language. Moving beyond simple text generation, this autonomous operator will formulate strategies, submit HPC jobs, and monitor simulation states. By grounding the AI in the IMAS Data Dictionary and utilizing runtime introspection of physics codes, the system enforces deep semantic consistency. It proactively resolves compatibility issues, such as verifying solver validity ranges, before committing computational resources. Furthermore, by connecting to experimental databases, the agent can autonomously formulate validation cases to test hypotheses against real-world data.

The work plan proceeds in three development phases. First, the project will develop standardized Python wrappers for core solvers to convert opaque inputs into query-able objects, allowing an AI agent to inspect valid parameters and data exchange interfaces at runtime. Second, a Retrieval-Augmented Generation (RAG) system will be constructed to ingest documentation and validation databases, capturing the "soft" knowledge of code usage and limitations. Finally, interfaces to a multi-scale Coupling Library (MUSCLE3) will be defined to enable agents to connect diverse physics solvers. Here, successful workflows and usage patterns persist in a central knowledge graph to create a reusable foundation for autonomous workflow construction and execution.

Qualifications/ Expertise Required

- Expertise in autonomous agents, multi-step planning, and LLM
- Advanced Python proficiency in introspection, meta-programming, or library design
- Experience with knowledge representation or semantic data structures

Topic 2) Study of SPI mitigated disruptions to define the optimum injection sequence for the ITER DMS

Description

The ITER disruption mitigation system (DMS) is a relatively complex system with 27 shattered pellet injectors (SPI) to mitigate plasma disruptions. Depending on the predicted disruption characteristics, the Advanced Protection System (APS) will request a sequence of SPI actuations to minimize the disruption impact on the machine. Given the number of possible combinations of SPI actuations, a model should identify automatically which sequence needs to be triggered for a given plasma status and mitigation request.

The first part of this postdoctoral program will be dedicated to understanding how to express the optimal disruption mitigation strategy for different plasma states (pre-thermal quench, post-thermal quench, hot vertical displacement events, runaway electron beams) for a wide range of plasma current and plasma stored energy. This task will be performed within the ITER DMS Task Force by collecting and analyzing present ITER SPI simulation data, as well as key experimental results from SPI experiments in current devices. Additionally, a metric for non-optimal mitigation should be defined such that each mitigation back-up sequence strategy can be ranked and included in case plant availability is degraded during the pulse.

The second part will focus on the development of software, based on the knowledge obtained in the first part, to determine the required DMS pellet compositions and to generate all required DMS disruption sequences for all the plasma states according to the pulse schedule. This list of main and backup sequences is to be sent to the Advanced Protection System which will actuate the DMS in real-time if a disruption has been detected.

Qualifications/ Expertise Required

- Experience of plasma disruption physics and disruption mitigation.
- Good programming skills (C++ preferred, Python possible)

Topic 3) Coupled free-boundary core-edge-SOL transport modelling of ITER scenarios with optimum Heating and Current Drive

Description

ITER scenarios have been previously studied using several scientific software, such as DINA and CORSICA, focused mostly on the operation of PF coil and power supply systems and avoidance of operational limits (e.g. Greenwald density limit). However, these studies were insufficient to check the non-linear evolution of all the dynamic plasma quantities relevant to the various operational /physics constraints. Recently in IO, the ITER High Fidelity Plasma Simulator (HFPS) has been developed by combining a free-boundary equilibrium evolution code, DINA, and a core-edge-SOL coupled transport and source modelling code, JINTRAC now coupled to the Heating and Current Drive (H&CD) workflow. This improved integrated modelling capability provides ability to consistently evolve all the relevant plasma quantities during stationary and transient plasma phases. For example, the plasma shape and internal inductance, which influence vertical instability, need to be evolved considering peripheral fuel and impurity gas puffing which vary the plasma density and edge localized mode stability while power fluxes to the divertor need to remain under design limits. Similarly, the application of auxiliary heating power to minimize core impurity accumulation and to mitigate sudden changes of alpha heating power will affect the evolution of the internal inductance and plasma beta which in turn affect plasma position and vertical stability. To ensure the latter changes to plasma shape are required which, in turn affect H&CD application. The primary goal of this proposal is to obtain ITER plasma scenarios, with emphasis in transient phases, which will complete the new ITER baseline scenarios included in the ITER Research Plan. This study can also contribute to the verification of ITER Plasma Control System (PCS) and other ITER components and systems.

Qualifications/ Expertise Required

- Good knowledge on tokamak plasma physics and free-boundary plasma equilibrium modelling including magnetic control.
- Experience in integrated plasma scenario modelling and knowledge on plasma transient processes and control optimization would be advantageous.

Topic 4) MHD simulations of Tungsten transport in small ELM regimes

Description

Tungsten transport due to collisions and turbulence is in the ITER core plasma is very well known and a solid basis exists for the pedestal plasma of high confinement regimes (H-modes). In ITER, the pinch velocity due to collisions is predicted to be in the favourable outward direction in the H-mode pedestal. However, the influence of MHD activity on the transport of tungsten in the pedestal is less well known. Previous simulations have shown that ELMs, MHD instabilities driven by the H-mode edge pedestal, can significantly change the transport of tungsten across the pedestal. Also, the application of 3D magnetic field perturbations (RMPs), foreseen to control

ELMs in ITER, leads to an enhanced transport of tungsten across the pedestal. As an alternative to ELM control by RMPs, naturally ELM free and small ELM regimes are evaluated as viable option for ITER operation. This includes the Quasi-Continuous Exhaust regime (QCE), the QH-mode, the X-point Radiator Regime (XPR) etc.

The scientific objective of this project is to investigate the transport of tungsten impurities in the H-mode pedestal region in the QCE regime. This involves large-scale 3D non-linear MHD simulations of the small ELM regimes using the JOREK code.

The tungsten transport due to ExB flows driven by the MHD instability and due to collisions of tungsten with the main plasma ions will then be evaluated. The Tungsten is modelled as discrete kinetic particles, evolving in the evolving 3D electric and magnetic fields. The first application will be based on existing tokamak plasmas in which the QCE is well established both experimentally and in MHD simulations. The next step will aim to establish MHD simulations of the QCE regime in ITER, followed by the evaluation of tungsten in this regime. Time permitting, the challenging goal of this project is to fully integrate the impurities (tungsten, Neon), the associated radiation and its source by sputtering in the MHD simulations.

Qualifications/ Expertise Required

- Experience in numerical modelling, preferably of tokamak plasmas.
- Knowledge of basic plasma physics, MHD equilibrium, stability in tokamaks would be an advantage.

Topic 5) Quasi-symmetric (QS) error field correction in ITER

Description

Small non-axisymmetric (3D) fields are inevitable in ITER, arising from intrinsic manufacturing errors or the extrinsic application of control fields for instabilities such as Edge Localized Modes (ELMs). These 3D perturbations must be rigorously compensated, as failure to do so can lead to significant confinement degradation or disruptive magnetohydrodynamic (MHD) events, including locked modes. While Resonant Error Field Correction (REFC) is a well-established protocol for ITER, the optimization of non-resonant fields has never been systematically investigated, despite their potential to exert broad impacts on plasma performance through neoclassical transport. A promising avenue to address this gap is the minimization of radial guiding center orbit drifts, a concept analogous to quasi-symmetric (QS) optimization in stellarators. Recent applications using the General Perturbed Equilibrium Code (GPEC) demonstrate that this Quasi-Symmetric Error Field Correction (QSEFC) can effectively minimize both the resonant fields driving magnetic islands and the non-resonant fields driving neoclassical 3D transport simultaneously.

The primary objective of this project is to apply this novel QSEFC scheme to ITER and, ultimately, to develop a comprehensive Error Field Correction (EFC) strategy that addresses both resonant and non-resonant fields. The candidate is expected to utilize linear codes to investigate the robustness of QSEFC across diverse operational scenarios, assess its efficiency in resonant error reduction compared to standard REFC, and determine the optimal integration of QSEFC and REFC strategies. These correction schemes will be systematically tested against a variety of error sources, including CS/PF/TF misalignments, Test Blanket Module (TBM) perturbations, and residual low-n fields following ELM control by 3-D fields. Furthermore, the candidate is expected to explore additional MHD models or nonlinear codes to verify the linear predictions of the QSEFC scheme. This research will culminate in the validation of fast reduced models essential for ITER's pre-shot planning and uncertainty quantification, producing actionable recommendations for coil prioritization, 3D coil current optimization, and operational feasibility under varying experimental conditions. Validation of the approach in present tokamak experiments will be pursued in parallel with the evaluations for ITER.

Qualifications/ Expertise Required

- Experience in MHD modeling
- Understanding of ideal and non-ideal effects of magnetic perturbations in toroidal magnetic confinement
- Numerical simulation and programming
- Ability to collaborate with experimental and modeling teams

Topic 6) Advancing modelling framework for tritium inventory management in ITER

Description

The ability to accurately monitor the in-vessel tritium (T) inventory is essential for the satisfactory demonstration of ITER's safety case. Throughout the early phases of the ITER Research Plan, starting with hydrogen (H) and deuterium (D) plasmas and progressing to T operation, experiments will investigate fuel exchange with plasma-facing surfaces, inventory buildup, and strategies for recovery. These measurements will be complemented by modelling of H transport in plasma-facing materials, providing essential input for the definition of ITER's T recovery strategy.

A modelling framework based on the FESTIM code has recently been established to simulate the evolution of the H inventory across multiple one-dimensional material bins representing different regions of the plasma-facing surfaces. The tool incorporates surface fluxes derived from plasma boundary simulations and sets material properties in agreement with predictions of erosion and migration codes. In the new Baseline, ITER uses exclusively tungsten (W) armour on the main wall and introduces thin boron coatings to mitigate plasma operation risks associated with the lack of oxygen gettering by W.

The objective of this postdoctoral research is to advance the numerical framework for hydrogenic inventory and recovery predictions in ITER. The work will focus initially on simulating the transition from D to H operations planned during the Start of Research Operations (SRO) phase, to propose the best sequence of ion cyclotron wall conditioning, glow discharge conditioning, and tokamak plasma scenarios for controlled D removal. These simulations will provide critical input for the assessment of the planned ITER diagnostic capabilities for isotopic content, including discharge spectroscopy, residual gas analysis of partial pressures, cryopump inventory measurements, and laser induced desorption. Following this SRO analysis, the process will be repeated for the 1-month T operations phase planned in the first part (FPO-1) of the DT-1 campaign, where for the first time T accounting and removal procedures will be employed. It will inform on the T inventory build-up during this phase and the potential for removal in the subsequent months of D operations and, possibly, baking. Finally, the work will guide the initial strategy for T inventory management during the D-T phases of FPO-2 and explore methods to reconcile modelled inventories with future experimental measurements.

Qualifications/ Expertise Required

- Strong programming skills (Python or similar) for code development, numerical simulations and data processing.
- Proficiency in numerical methods, data analysis, and experience with high-performance computing environments.
- Experience in modelling H isotope transport in plasma-facing materials (using FESTIM or similar), preferably in fusion-relevant conditions.
- Understanding of gas balance and isotope exchange experiments, including relevant diagnostic methods is an advantage and knowledge of plasma-material interaction processes, including erosion, migration, and deposition phenomena are an asset.
- Ability to produce high-quality research outputs, including technical reports and peer-reviewed publications, and to communicate effectively within an international research environment.

Topic 7) Integrated Plasma Scenario Modelling

Description

Being able to rapidly perform integrated modelling of ITER plasma scenarios is important to be able to agilely address questions that arise in connection with the ITER Research Plan. The ASTRA code adopted a particularly flexible approach by using different solvers and equations depending upon the physics being modelled and has been used extensively to address questions in relation to core plasma physics, heating, fuelling and current drive for ITER over many years.

The goal of this project is to capture the knowledge associated with the employment of the ASTRA code to model ITER scenarios and transfer it to the IMAS High Fidelity Plasma Simulator (HFPS). This may require extending the HFPS to introduce new capabilities or solvers and to include different physics models present in ASTRA such as those describing core plasma physics, edge-core integration, heating, current drive and fueling. Validation exercises associated with the refined HFPS will be carried out to establish the domains of applicability for the different capabilities and are expected to be performed in partnership with the ITER Members' experimental programmes.

The resulting state-of-the-art HFPS will then be used to undertake physics studies for various stages of the ITER Research Plan and to address questions associated with the machine configuration, e.g. heating and fueling systems, and diagnostic design support and performance assessments.

Where computational expense limits the feasible scope of assessments, reduced or surrogate models will be derived from their high physics fidelity counterparts enabling more extensive physics studies to be performed for a larger range of plasma conditions.

At the completion of the project, the fellow is expected to be an expert HFPS user, fully able to flexibly address questions related to the ITER Research Plan that were previously addressed with ASTRA.

Qualifications/ Expertise Required

- Experience in numerical modelling, preferably of tokamak plasmas.
- Knowledge of plasma physics, equilibrium and transport in tokamaks would be an advantage.

Topic 8) Fuelling, density transport and control with the PDS with benchmarks and validation on current-day devices

Description

This work falls within the activities of the ITER Pulse Design Simulator (PDS) currently under development using the standard of the ITER Integrated Modelling and Analysis Suite (IMAS). The goal of the PDS is to configure an optimal pulse schedule (PS) for all the scenarios of the ITER Research Plan. It is the primary tool for scenario designers to prepare pulses that meet performances requirements within physics, machine and plant operational limits.

The initial version of the PDS includes self-consistent coupling between a free-boundary equilibrium code (NICE) and a transport solver (TORAX or METIS), including Heating and Current Drive (H&CD) sources provided by the H&CD workflow. However, actuator models for fuelling, to be used together with density transport and control algorithms are still missing in the PDS: this is the topic of this postdoctoral proposal.

TORAX currently uses the QuaLiKiz-Neural Network (QLK-NN) for turbulent transport, allowing discharges from current-day devices to be simulated, including the simultaneous transport of heat and particles.

The goals of this postdoctoral position are:

- To study existing surrogate models for plasma fuelling, choose the most appropriate and integrate them into the PDS to simulate the plasma response to gas puffing and pellet injection. Open-Source models are favoured.
- To implement density controllers into the PDS to simulate the outcome of a density request provided through specific density waveforms. To the largest extent possible these controllers should be taken from the Plasma Control System Simulation Platform (PCSSP); more basic controllers are also to be developed for test purposes.
- To activate density transport in the transport models currently implemented in the PDS and to check the evolution of the density and its deviation from the pulse schedule, accounting for actuator response times.
- To apply the PDS to specific scenarios of the ITER Research Plan to both thoroughly test the evolving PDS and assist Science Division in the general area of scenario development.

To actively propose and participate in validation activities against experiments past and present on current research tokamaks or against simulations performed with alternative simulation frameworks.

Qualifications/ Expertise Required

- Expertise in transport modelling of fusion plasmas, with experience in any of the following: fuelling models (gas puffing, pellet injection), plasma response, density transport and density control.

- Experience in Integrated Modelling, code development and programming (familiarity with IMAS an asset).
- Knowledge of Python (Fortran is a plus).
- Proximity to plasma operation on current-day devices an asset.

Topic 9) ITER scenario modelling with the PDS including tungsten transport with benchmarks and validation on current-day devices

Description

This work falls within the activities of the ITER Pulse Design Simulator (PDS) currently under development using the standard of the ITER Integrated Modelling and Analysis Suite (IMAS). The goal of the PDS is to configure an optimal pulse schedule (PS) for all the scenarios of the ITER Research Plan. It is the primary tool for scenario designers to prepare pulses that meet performances requirements within physics, machine and plant operational limits.

The initial version of the PDS includes self-consistent coupling between a free-boundary equilibrium code (NICE) and a transport solver (TORAX or METIS), including Heating and Current Drive (H&CD) sources provided by the H&CD workflow. TORAX can currently use QuaLiKiz-Neural Network (QLK-NN) or TGLF for turbulent transport. In parallel, the short-term implementation of FACIT in TORAX will enable prediction of impurity transport, particularly adapted for tungsten (W). The ITER PDS thus allows the simulation of discharges from present devices, including the simultaneous transport of heat and particles, including W, for the purposes of validation and benchmarking its application to ITER.

The goal of this postdoctoral position is twofold: the PDS will be applied to scenarios of the ITER Research Plan to model some of the most challenging scenario development aspects in synergy with the ITER Science Division (e.g. W radiation versus Electron Cyclotron Heating (ECH) to avoid radiative collapses, transient W influxes in long pulses, high beta and isotope transport, etc.). Based on the main challenges identified, the candidate will actively propose (as needed) and take part in on-going benchmark activities such as: 1) scenarios with ECH to mitigate W accumulation through combined temperature-screening and increased core turbulence 2) Study of baseline and hybrid scenarios including isotope effects; 3) Long pulse scenarios including resilience to W particulate entry; 4) ITER DT baseline 15 MA / 5.3T scenario modelling. The benchmark cases will include various levels of integration, up to self-consistent heat and particle transport, including W and its impact on radiation.

Such activities allow conclusions to be draw on the relevance of the PDS workflow and its embedded models for various ITER operational conditions. For example, one purpose is to establish the domain of validity of the QLK-NN electrostatic model given that it is trained on a reduced dataset of plasma conditions, neglecting both electromagnetic modes — such as Kinetic Ballooning Modes (KBM) — which play a significant role for core transport and become dominant in high-beta ITER 15 MA scenarios, and resistive modes which may result in steep edge temperature profiles. The integration of the recently developed TGLF-NN into the PDS can be foreseen if deemed relevant. Emphasis will be on W transport studies in ITER L-mode and H-mode plasmas, with a special care for the W accumulation in the limiter and early current ramp-up phase, with and without ECH. Integrated modelling aspects will be analysed by discussing the PDS coupling strategy, namely the compromise between performance and modularity and between accuracy and rapidity.

Qualifications/ Expertise Required

- Expertise in transport modelling, H&CD physics, plasma turbulence.
- Experience in Integrated Modelling, code development and programming (familiarity with IMAS an asset).
- Knowledge of Python language (Fortran is a plus).
- Proximity to plasma operation on current-day devices an asset.

Topic 10) Optimal path for ITER fast terminations

Description

Terminating a tokamak discharge is a complex affair, and by far not just a case of ramping down the plasma current. During a discharge termination the Plasma Control System (PCS) must reduce both the magnetic (i.e. plasma current) and kinetic energy (i.e. plasma density and temperature) of the tokamak discharge in a controlled way. This means it must achieve the termination while avoiding various operation limits and considering other constraints, such as actuator capacities or control capabilities. Under certain conditions a so-called emergency termination needs to be executed, differing from a predefined termination in the sense that the PCS must perform this function within a certain critical time, or without the availability of certain actuators or sensors. During this dynamic phase of a tokamak discharge, optimization of all control activities orchestrated by the PCS is key and this is known to be a challenging task. It is likely to be even more difficult on a device the size of ITER.

Tokamak termination scenarios can be optimized by carrying out simulations and/or experiments. However, no termination is alike, and the PCS should be able to optimize against any destabilizing events. From the mathematical point of view, the problem of terminating the plasma discharge may be viewed as equivalent to finding the optimal path between two points in a multi-dimensional space, under time varying constraints. In fact, density limits (linked strongly to pumping exhaust rates) and magnetic quantities such as shape, vertical stability and plasma inductance, restrict the available operation space. Exceeding these limits can generate undesired disruptions and this is to be absolutely avoided on ITER where stored energies are significant.

The aim of this postdoctoral proposal is twofold. Simulations inside the PCS design simulation platform (PCSSP) are first to be performed to explore the optimal way to terminate an ITER pulse under various emergency cases, on different timescales. This will allow us both to understand the termination process and define its operational space. It will require the ability to run integrated simulations in which the PCS simultaneously controls many quantities. Secondly, once a sufficient data set is generated, the problem must be formulated from the mathematical point of view and an algorithm provided to produce optimal solutions under different proposed metrics. As a first step, this algorithm should be able to generate a static optimal path calculated at the beginning of the fast termination phase. A more advanced version would also investigate the possibility to re-configure the optimal path while it is being traversed. These theoretical studies will need to be validated through integrated simulations inside PCSSP.

Qualifications/ Expertise Required

- Knowledge of control theory, optimal control. Knowledge of tokamak scenario design and plasma physics an advantage.

Topic 11) Physics basis for runaway electron beam benign termination on ITER

Description

Runaway electrons (RE) in tokamaks such as ITER remain a critical concern due to the significantly enhanced avalanche multiplication at high plasma current, far exceeding that observed in present-day devices. In the event of RE avoidance failure, ITER plans to rely on RE impact mitigation strategies, amongst which the benign termination scheme, accessed through the injection of hydrogenic isotopes and the subsequent recombination of the RE companion plasma, stands out as a promising option.

While this technique has been experimentally demonstrated in several machines, including JET, TCV, ASDEX Upgrade and DIII-D, and while its experimental accessibility in terms of neutral pressure is increasingly well established, the underlying physical mechanisms that lead to the substantial reduction of RE loads on plasma-facing components (PFC) remain insufficiently understood. Present fluid-based simulations of RE terminations in ITER do not clearly reproduce the transition between benign and non-benign regimes, leaving key aspects of the physics conjectural. Consequently, major uncertainties persist regarding the applicability, robustness and operational margins of this scheme in ITER.

The main objective of this postdoctoral project is to elucidate the physical pathways by which hydrogenic

isotope injection leads to reduced RE impact on the PFCs (whether through broadening of the energy deposition footprint or modifications to RE beam distribution function) and by which means the MHD activity is impacted by recombination. To this end, the candidate will employ the recently developed MHD–RE kinetic-hybrid framework within the JOREK code to simulate RE termination scenarios with a focus on capturing the transition between benign and non-benign outcomes in ITER-relevant conditions. For that purpose, benign and non-benign terminations from present tokamak experiments will be simulated and validated first with the JOREK code and then subsequently applied to ITER scenarios.

Qualifications/ Expertise Required

- Expertise in non-linear MHD modelling, RE and atomic physics, as well as proficiency in FORTRAN and Python programming
- Experience with high-performance computing, will be essential.

Topic 12) SOLPS-ITER simulations in support of ITER Start of Research Operation (SRO) and reduced model generation for the ITER Pulse Design Simulator

Description

This postdoctoral project is focused on producing a database of SOLPS-ITER simulations exploring wide range of scenarios foreseen during the Start of Research Operation (SRO) phase of ITER Research Plan. This database will eventually become the analogue for SRO of the main Q = 10 simulation set originally produced with SOLPS-4.3. It will benefit from a number of major improvements in model fidelity which have now been incorporated into the latest version of SOLP-ITER, including wide-grid (WG) simulation capability and the inclusion of full drifts and currents.

Once constituted, this new set of simulations will be used to develop/deliver boundary models, for example based on the SOLPS Neural Network (SOLPS-NN) approach recently developed in the community, for use as Muscle3 actors in the ITER Pulse Design Simulator (PDS) and eventually in the ITER High Fidelity Plasma Simulator (HFPS). The code runs will also constitute a rich database of simulations, stored in the ITER Integrated Modelling Analysis Suite (IMAS), for use in plasma-wall interaction (PWI) studies (e.g. material migration, tungsten sources, fuel retention), both inside the ITER Organization (IO) and by the IO's many external collaborators. The successful candidate will be expected to support a variety of these PWI investigations as required.

Qualifications/ Expertise Required

- Demonstrable experience in the use of the SOLPS-ITER code. Expertise in simulating with drifts and currents and/or the new wide-grid option are assets.
- Knowledge of Python/Matlab essential (Fortran is a plus).
- Experience/basic understanding of neural networks is considered an asset.

Topic 13) Developing a Digital Twin for Fusion Energy: A Foundational World Model Approach

Description

This project proposes the development of a Fusion World Model (FWM), a generative AI system capable of learning the complex, non-linear dynamics of Tokamak plasmas to support the operation of future devices like ITER. While our ultimate goal is a foundational FWM for ITER, we will leverage the available open-source repositories of tokamak experimental data (such as that from the MAST tokamak) for inital training. Such datasets are uniquely suited for this task since they contain thousands of plasma pulses spanning many years of operation and comprising hundreds of terabytes of multi-modal data, including high-resolution wide-angle camera footage synchronized with scalar diagnostics. By training on this type of resource, we aim to build a system that can "dream" valid plasma scenarios, enabling robust pulse planning, real-time control, diagnostic health monitoring, and the discovery of new physics.

The operation of current Fusion devices relies heavily on analytical models and pre-programmed sequences. We envision a paradigm shift where a FWM learns the "physics of the machine" directly from experimental data and simulations. Just as a human world model allows you to navigate a dark room by predicting the outcome of your steps before you take them, a FWM allows the control system to predict the future state of the plasma given

current actuator inputs. This capability unlocks "Dreaming": the ability to simulate millions of potential pulse trajectories in a latent space. This is not just about control; it is about robust pulse planning. Much like planning your route through a busy subway station, the FWM allows us to foresee potential collisions or delays (instabilities) and chart a safe path through the high-dimensional operational space.
This system would provide proactive operational boundaries, mitigating the risk of damage to critical components. As the machine learns what scenarios induce disruptions or bring the machine close to its operational limits, such as approaching force limits on coils or density limits that trigger unstable MHD activity in the plasma, it can adapt so that future cases do not get themselves into these situations. Furthermore, it allows us to optimize machine utilization by knowing where to "shine the light" next, illuminating areas of the operational space where new physics may be hiding. We can rapidly iterate on natural language pulse objectives, formulating derisked, robust plans that may be passed to agentic AI for validation via integrated simulation before a single experiment is run.

Qualifications/ Expertise Required

- Expertise in autonomous agents, multi-step planning, and LLM
- Advanced Python proficiency, specifically in introspection, meta-programming, or library design
- Experience with knowledge representation or semantic data structures
- Experience with Retrieval-Augmented Generation (RAG) systems
- Experience designing automated workflows for HPC systems
- Background in interfacing with or wrapping legacy C++ and Fortran code
- Experience developing multi-modal systems that combine computer vision with natural language processing.

Topic 14) Integrated Diagnostics and Data Fusion for Dust, Erosion, and Tritium Assessment in ITER

Description

Accurate assessment of dust production, erosion, and tritium retention in ITER is critical for operational safety, regulatory compliance, and machine protection. The transition to tungsten-based plasma-facing components introduces new challenges: dust production rates are expected to be much lower than in previous beryllium scenarios, and measurement sensitivity must be recalibrated accordingly. Existing diagnostics (Dust Monitor, Erosion Monitor, Samples, Tritium Monitor, IVVS, ART tools) each provide local, system-specific data with inherent limitations in coverage, sensitivity, and uncertainty.

This postdoctoral position will focus on developing a holistic methodology for integrating and calibrating data from all available diagnostics, with the aim to:

- Develop methodologies to estimate dust accumulation and production rates expected under tungsten plasma-facing component scenarios, using existing results or producing new results from modelling, and based on the existing diagnostic baseline.
- Formulate strategies for assessing erosion patterns on the first wall and divertor, including approaches for calibrating local measurements to enable reliable global extrapolation.
- Assess and validate existing models for dust transport and tritium retention, and develop new ones when needed, integrating manual calibration concepts and benchmarking against published experimental data from fusion research.
- Design and implement a Dust, Erosion, and Tritium Evaluation and Correlation Tool (DETECT) for data fusion, uncertainty quantification, and operational decision support.
- Collaborate with teams working on existing fusion devices to identify effective diagnostic strategies, calibration techniques, and modelling approaches that can be adapted for ITER operations.

The researcher will collaborate with diagnostics, remote handling, and safety teams to define calibration procedures, integrate manual and automated sampling strategies, and recommend operational improvements.

The work will directly support the safety knowledge acquisition program, contribute to regulatory documentation, and enhance ITER's readiness for SRO, DT-1 phases.

Qualifications/ Expertise Required

- Experience in experimental or computational research in complex technical environments, ideally involving diagnostics, measurement systems, or data analysis.
- Ability to produce high-quality research outputs, technical reports, and peer-reviewed publications.

Topic 15) Support for the design and verification of the 55.EV - In-vessel Optical/IR/MW calibration system

Description

The primary function of the 55.EV In-Vessel Optical/IR/MW Calibration System is to provide calibration equipment and inspection tools for ITER diagnostic systems. In-vessel calibration will be performed using the Agile Robot Transporter (ART), a remote-handling arm designed for in-vessel operations. ART enables the deployment and manipulation of tools inside the vacuum vessel (VV) through interchangeable end-effectors. The 55.EV team will design specialized end-effectors to address the calibration requirements of ITER Optical, Visible Spectroscopy, Infrared (IR), Electron Cyclotron Emission (ECE), and Microwave (MW) diagnostics.

The postdoctoral researcher will contribute to the design and engineering activities of the 55.EV system, including:

- Consolidating calibration requirements from diagnostic client systems.
- Optimizing the calibration strategy by considering diagnostic requests, installation schedules, and required calibration positions and timing.
- Analyzing needs to define the most efficient set of equipment (e.g., light/IR sources, detectors, cameras) that satisfies both technical requirements and operational constraints.
- Supporting the integration of equipment into ART end-effectors.
- Assisting in the preparation of documentation for system milestones.

Qualifications/ Expertise Required

- Knowledge of fusion plasma with a clear understanding of the fundamental principles underlying Optical, Visible Spectroscopy, Infrared (IR), Electron Cyclotron Emission (ECE), and Microwave (MW) diagnostics.
- Comprehensive understanding of standard calibration methodologies and requirements for Optical, Visible Spectroscopy, IR, ECE, and MW diagnostics in fusion devices.
- Hands-on experience in the calibration of diagnostic systems, including Optical, Visible Spectroscopy, IR, ECE, and MW diagnostics for fusion applications.
- Experience and familiarity with remote handling (RH) tools and technologies will also be appreciated.

Topic 16) Automated component handling

Description

The Remote Handling Project in ITER has been developing handling equipment and tools to carry out the initial assembly of the in-vessel components in the ITER Tokamak. One of the main assembly systems is called the Blanket Assembly Transporter (BAT), and it is used to install the ITER blanket modules inside the vacuum vessel (VV).

The BAT is a long reach bespoke robotic arm and the blanket modules weigh between 1.4 and 4 tons. The Blanket modules need to be picked up and installed in precise locations on the vacuum vessel walls as an automated operation. There are many variations in shape, size, and location of the modules that make this a very challenging task.

The BAT will use a vision system to achieve accurate positioning within the VV and a six degree of freedom force-moment sensor to manage forces through the engagement of components and transferring of loads between the robot and the VV wall.

A sophisticated control algorithm needs to be developed to interpret the force-moment measurements and adapt

the motions of the BAT in order to install/remove modules as an automated function. The algorithm will have to deal with multiple contact points during the operation and resolve the correct motion to reliably complete the task without damaging the equipment or environment.
The development work will take place using an industrial robot with 2 ton capacity and mock-ups of the components and VV. The objective is to develop the methodology and control algorithms that successfully perform the tasks and can then be ported to the BAT.
An additional aspect is the modelling of the deflections of the BAT through the process of the load transfer operation in order to be able to remotely monitor that the performance of the system remains within operational limits.

Qualifications/ Expertise Required

- Experience in robotic system design/analysis & control theory
- Experience in MATLAB/SIMULINK, Python, C/C++
- Experience in 3D CAD & robot simulator and programming as advantage

Topic 17) Neutron Transport Modeling for ITER Neutron Diagnostic Calibration / Neutronics

Description

ITER neutron diagnostics are essential for machine performance, protection, control and licensing, as they measure fusion power and first-wall neutron fluence. At ITER's target of 500 MW fusion power, a 10% measurement uncertainty translates to 50 MW – making precise diagnostic calibration critical. Because full experimental calibration is impractical for ITER's scale and complexity, it must be complemented by detailed neutron transport simulations for careful planning of the DD and DT calibration campaigns and accurate estimation of the calibration parameters.
The postdoctoral researcher will contribute to the optimization of the neutron calibration procedures, focusing on engineering for the final design of the In-Vessel Neutron Calibration Campaigns. One of the objectives is the development of high-fidelity models for the Neutron diagnostics. The researcher will quantify uncertainties and systematic errors associated with neutronic modelling, employing existing or novel methods such as sensitivity analysis and uncertainty quantification to improve confidence in the calibration factors. He will participate in developing the detailed design of the IVNC end-effector in preparation for the manufacturing of this component. Finally, the researcher will address nuclear safety aspects of the in-vessel calibration procedure, ensuring compliance with ITER's nuclear safety requirements.
The position requires producing high-quality engineering outputs and collaborating effectively with ITER partners and the broader fusion community.

Qualifications/ Expertise Required

- Advanced knowledge of neutron and gamma-ray transport theory and Monte Carlo methods (e.g., MCNP, OpenMC, TRIPOLI, or similar codes).
- Must be eligible to a MCNP license
- Experience in developing high-fidelity neutronic models for complex systems.
- Proficiency in sensitivity analysis and uncertainty quantification techniques.
- Strong programming skills (Python, Matlab, or similar) for data processing and code development
- Familiarity with neutron diagnostics and their calibration is an asset
- Ability to produce high-quality research outputs, technical reports, and peer-reviewed publications.