Karlsruhe Institute of Technology

# A Time-Dependent Fuel Cycle developed for Multi-Timescale Systems-Codes to study technology integration in advanced Fusion Power Plants

31st SYMPOSIUM ON FUSION TECHNOLOGY


T. Pomella Lobo[1*], F. Franza[1], I. A. Maione[1], L. V. Boccaccini[1]

[1] Institute for Neutron Physics and Reactor Technology (INR), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany


**Videoconference** (PIN: 0000)
https://conf.dfn.de/webapp/conference/979154332


## Abstract

Systems-Codes (SCs) are fundamental tools in Fusion Energy research that allow for parameter space exploration during conceptual design phases of power plants. They may also be used to discover relevant dependencies through parametric studies, which are especially important to evaluate technology integration in reactors. However, current state-of-the-art SCs do not to address this concern on a power plant level, in part due to the inherent difference in timescale in which each plant system predominantly operates. Thus, a novel Multi-Timescale SC approach is currently under study.

This work introduces the new methodology adopted, being developed at the Karlsruhe Institute of Technology (KIT). As example, it shows the implementation of a power plant's Fuel Cycle (FC) in the form of a new SC module, considered essential to explore fuel scenarios in the power plant's lifetime timescale. Future coupling of this module to a SC will allow one to study system inter-dependencies that affect the fuel balance at this timescale. The simulator was designed using Simulink®, with a library of generic FC components developed using a Residence-Times mathematical model. This aimed at reducing the module's required computational power, to comply with SCs requirements. The module was verified by building and running a Demonstration Powerplant (DEMO) FC model and comparing the results with other studies in literature. The model was deemed versatile and sufficiently quick for future application in a SC framework.



**Keywords:** DEMO, Fuel Cycle, Systems-Codes, Nuclear Fusion Technology

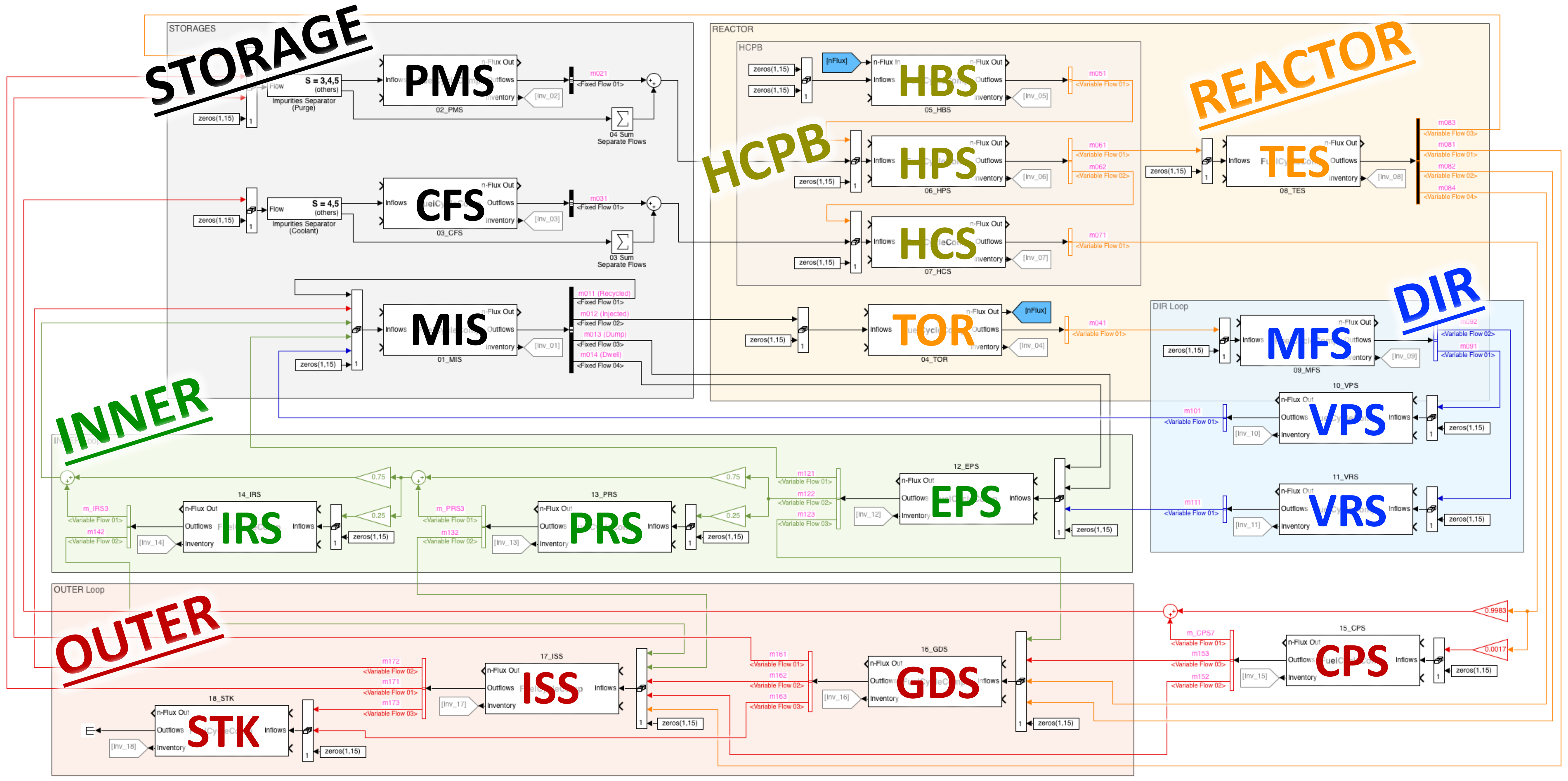


***Contact:** t.pomella-lobo@kit.edu


## Objective

- Develop time-dependent Fuel Cycle simulator for the MIRA Systems-Code.
- Coupling of simulator with other MIRA modules allows for technology integration studies.
- Current coupling:
  - Torus Exhaust module (to compute dwell-time, based on Battes-2015).

## DEMO Fuel Cycle Simulink time-dependent model (TD)



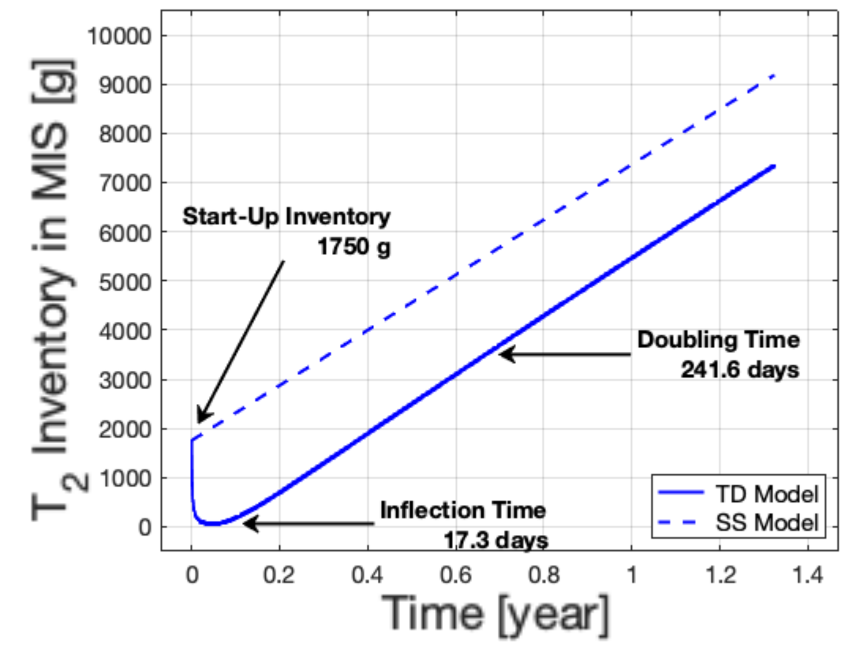

- Simulates inventories dynamics for: $T_2$, $D_2$, $H_2$, $He^3$, $He^4$, $N_2$, Xe, Ar.
- Generic components with simplified approach: Residence-Times model.
- Residence-Times (τ) computed by a pre-run Steady-State model (SS), that only models flat-top and whose outputs were verified against literature.

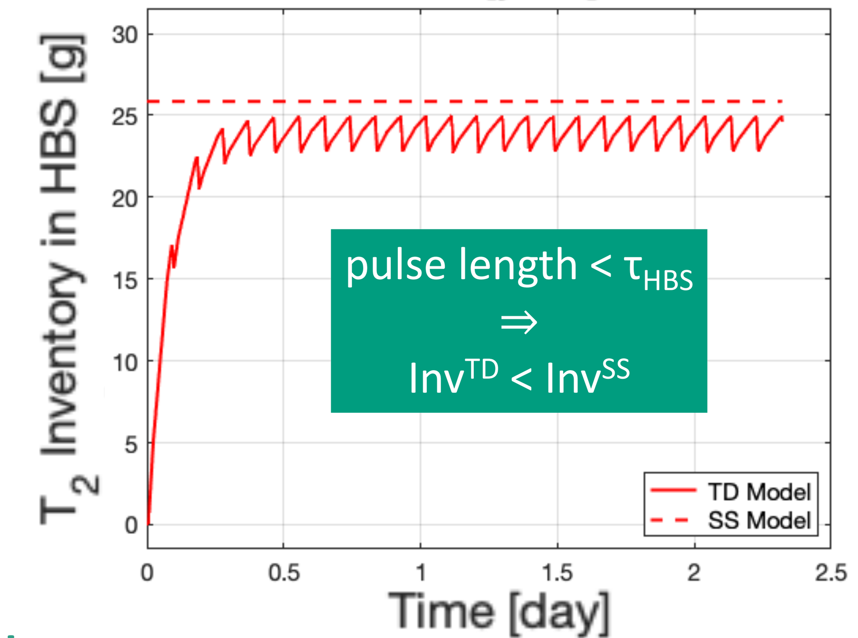
## $T_2$ Results (scenarios simulated with TD model)

(1) steady-state: retrieves SS model inventories within 1% deviation (*not displayed*)

(2) pulsed, dwell-time computed by Exhaust module, no maintenance:

| FC Section | System | | TD response (g or g/year) | SS response (g or g/year) | Deviation (%) (SS-TD)/TD |
|---|---|---|---|---|---|
| Storage | MIS | Matter Injection | 5593.1 | 5616.5 | 0.4 |
| | PMS | Purge Make-up | 0 | 0 | - |
| | CFS | Coolant Filling | 0 | 0 | - |
| Reactor | TOR | Torus | 0.51 | 0.51 | $-2.38 \times 10^{-3}$ |
| | HBS | HCPB Breeding | 24.96 | 25.85 | 3.56 |
| | HPS | HCPB Purging | 0.13 | 0.14 | 4.35 |
| | HCS | HCPB Cooling | $1.00 \times 10^{-2}$ | $1.01 \times 10^{-2}$ | 5.66 |
| | TES | Tritium Extraction | 450.24 | 484.06 | 7.51 |
| DIR | MFS | Metal Foil | 15.04 | 15.04 | $-1.96 \times 10^{-4}$ |
| | VPS | Vacuum Permeate | 9.05 | 9.05 | $-4.40 \times 10^{-4}$ |
| | VRS | Vacuum Retentate | 4.76 | 4.76 | $-5.65 \times 10^{-4}$ |
| Inner | EPS | Exhaust Processing | 20.00 | 20.00 | $-5.26 \times 10^{-3}$ |
| | PRS | Protium Removal | 158.55 | 165.05 | 4.10 |
| | IRS | Isotope Rebalancing | 145.81 | 152.67 | 4.70 |
| Outer | CPS | Coolant Purification | 9.20 | 9.91 | 7.68 |
| | GDS | General Detritiation | 730.02 | 790.19 | 8.24 |
| | ISS | Isotope Separation | 771.77 | 833.33 | 7.98 |
| | STK | Stack | 7.2 | 8.5 | 19.1 |




## Conclusions & Outlook

- Pulsed scenarios in TD result in lower inventories than in SS, due to ratios between the pulse length and residence-times.
- Thus, SS simulations output conservative inventory estimates in comparison to TD.
- Future simulations foresee more complex pulsed scenarios with:
  - addition of maintenance periods;
  - HCPB-Coolant flow variation during pulse; …