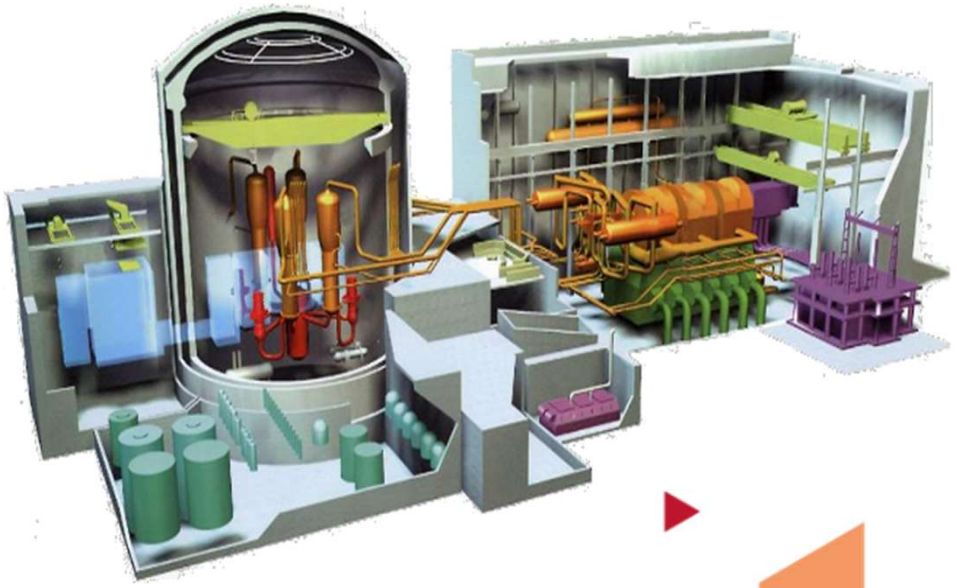
# Digital Nuclear Reactor Initiative



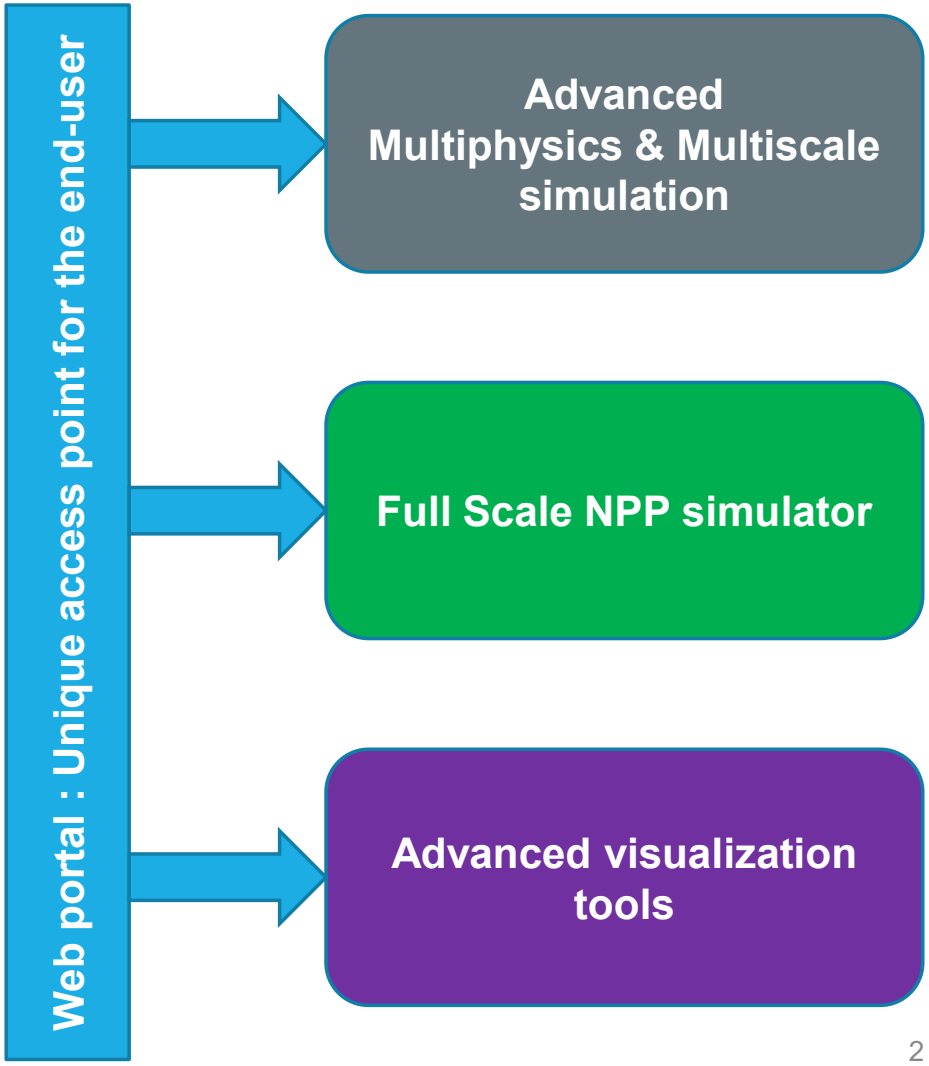
## Digital Nuclear Reactor: Goals and current state

**SNETP Virtual Forum – 04/02/2021**
**Chaï Koren - EDF R&D**

# DIGITAL NUCLEAR REACTOR INITIATIVE

- An initiative which transformed into a 4 year project (2020-2023) and combining efforts from 8 partners : *EDF*, CEA, FRAMATOME, CORYS, ESI, AXONE, BOOST, CNRS-CRAN

- Aiming at providing an advanced Digital Twin comprising:
  - An advanced Multiphysics & Multiscale simulation workbench for nuclear applications
  - A modular and easily configurable Full Scale NPP Simulator
  - Advanced & instructive visualization tools
  - A single digital portal for the three modules and associated services.

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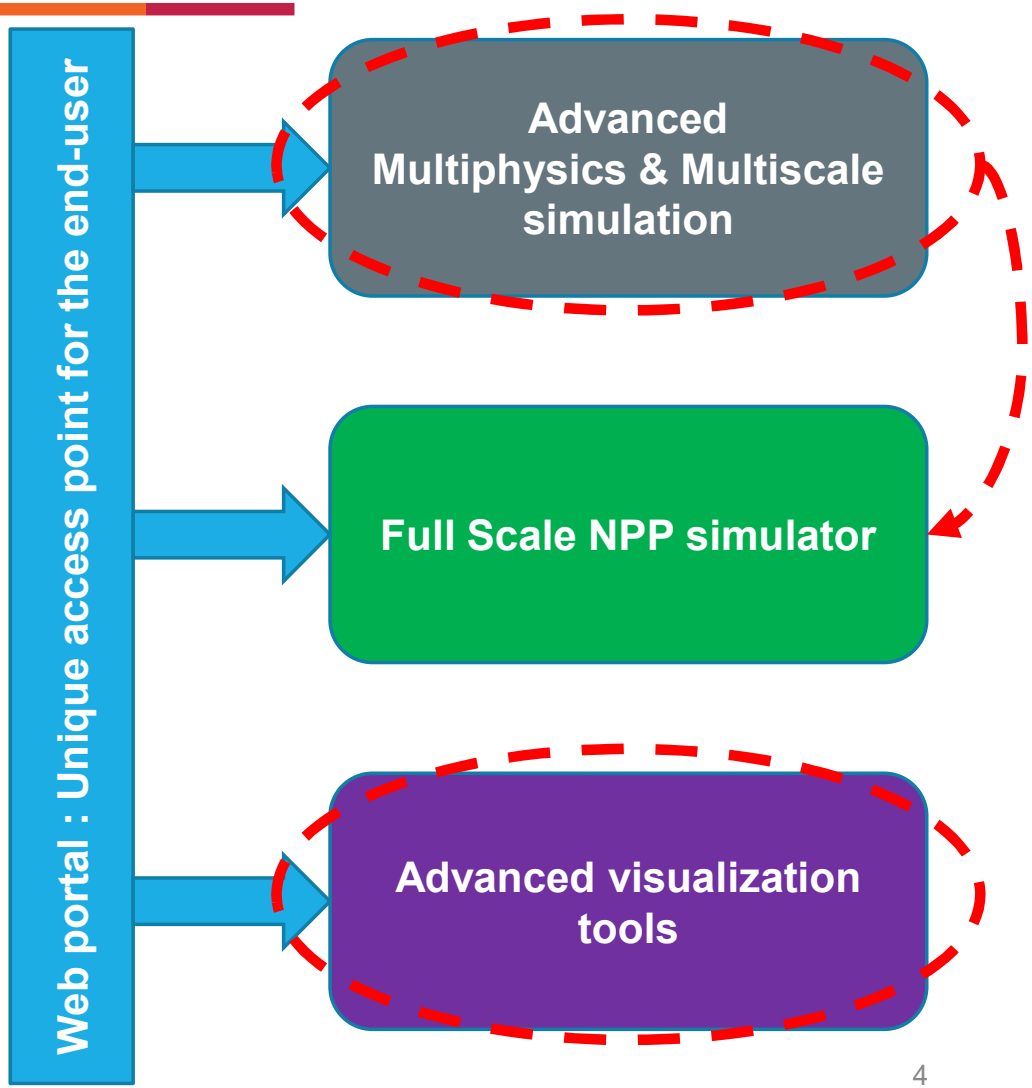


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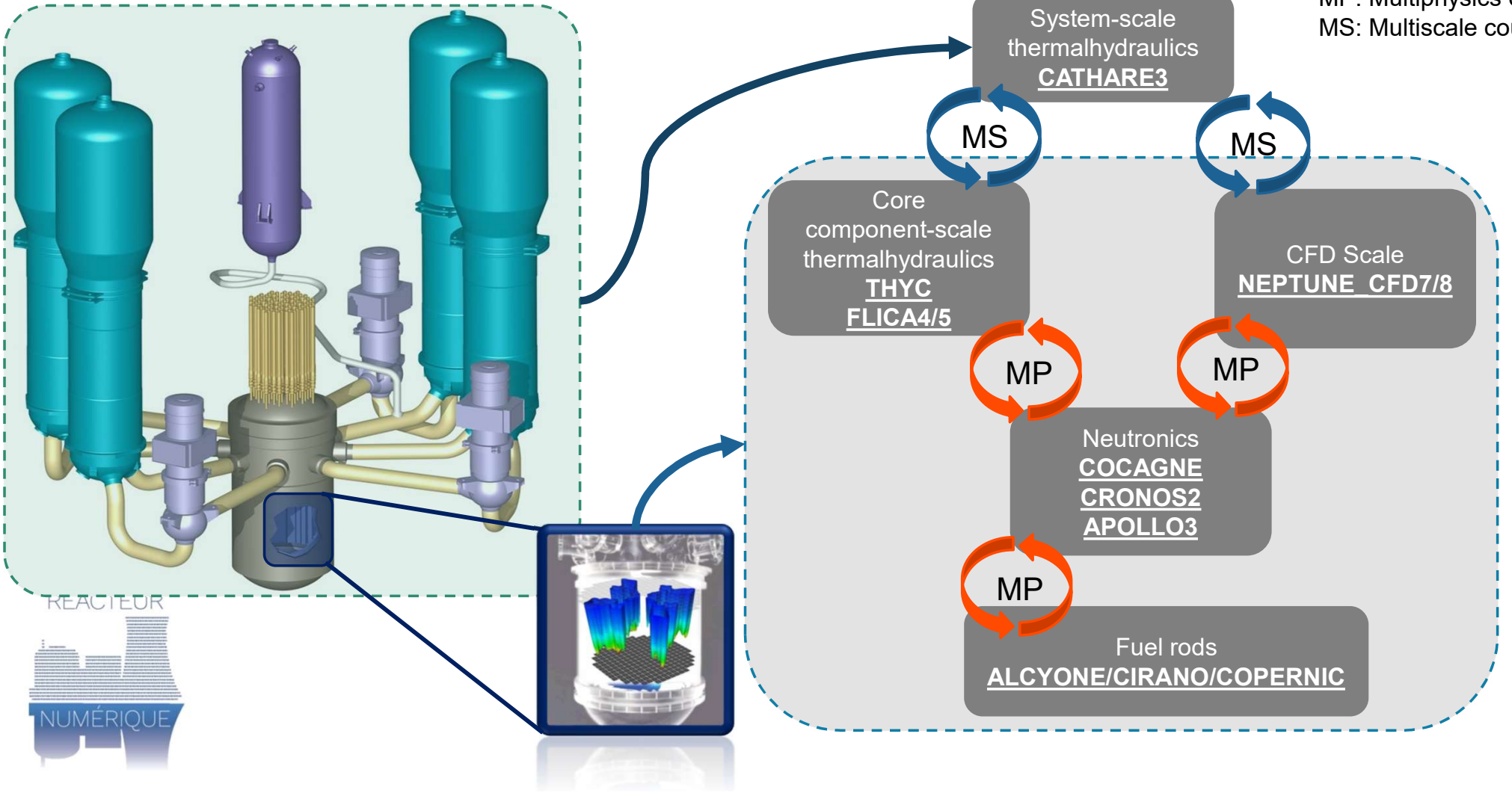
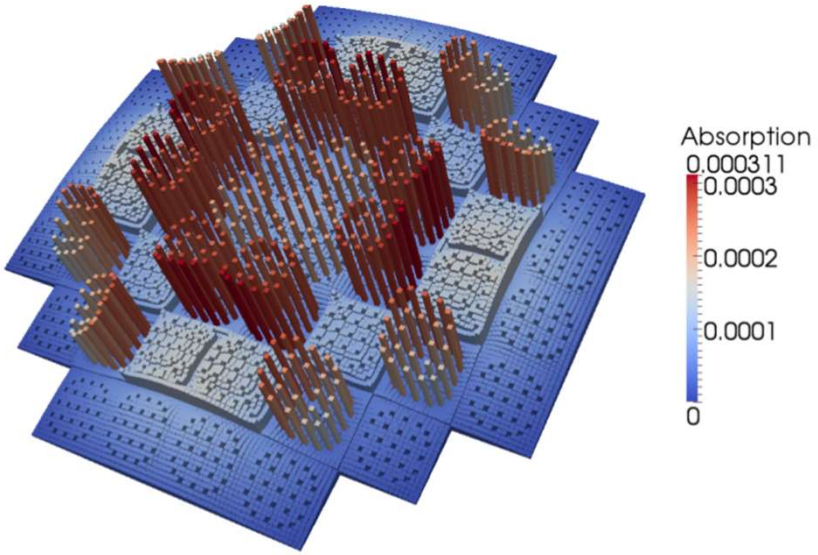
# Multiphysics & Multiscale workbench



# Multiphysics & Multiscale workbench

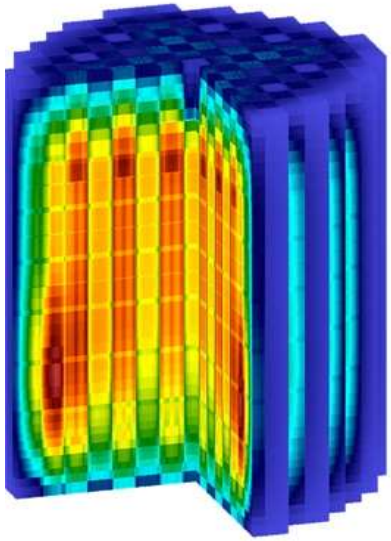



**COCAGNE**, new EDF in house Core code

- Multi-domains cross-section homogenization (including explicit Pin by Pin)
- Simplified transport ( SPn  n=1,3) and full transport Sn Cartesian flux Solvers
- Micro depletion model with ~50 isotopes using real core power.
- Up to 26 energy groups.

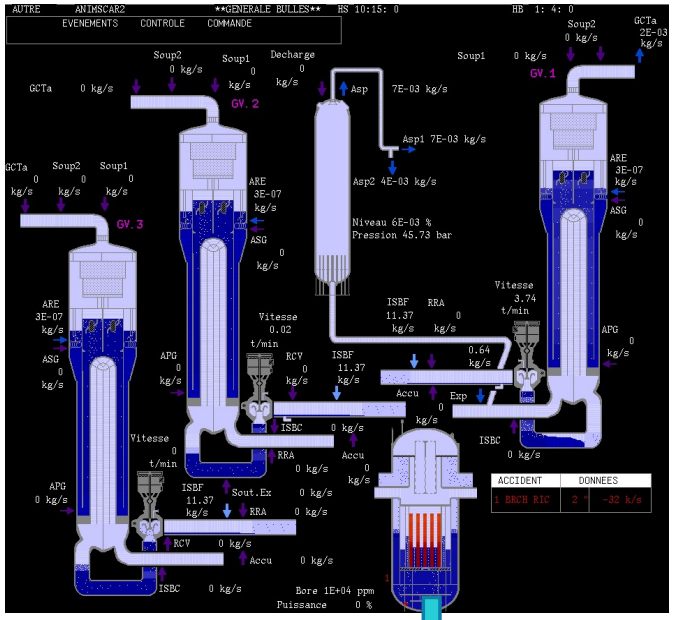
**APOLLO3**, CEA new neutronics code

- Both lattice and core calculations
- Transport solvers on unstructured meshes
- Parallelization on thousands of nodes
- Depletion chain with more than a thousand isotopes
- Allows advanced calculation such as direct calculation (on going work)

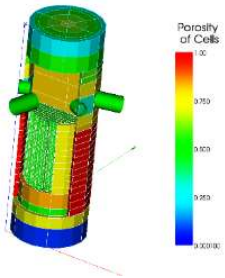


# Multiphysics & Multiscale workbench

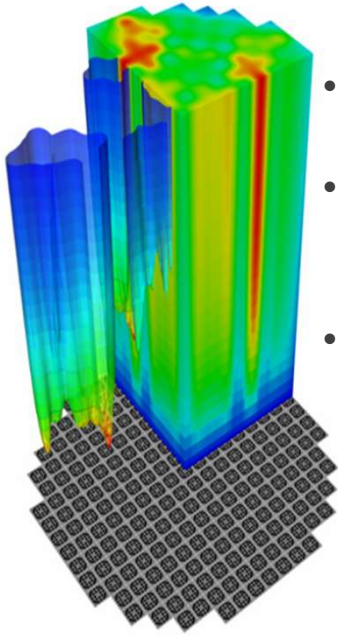
***System scale :*** **CATHARE3,** a CEA, EDF, FRAMATOME and IRSN collaboration




Two-phase thermal-hydraulic code used for reactor safety analyses…



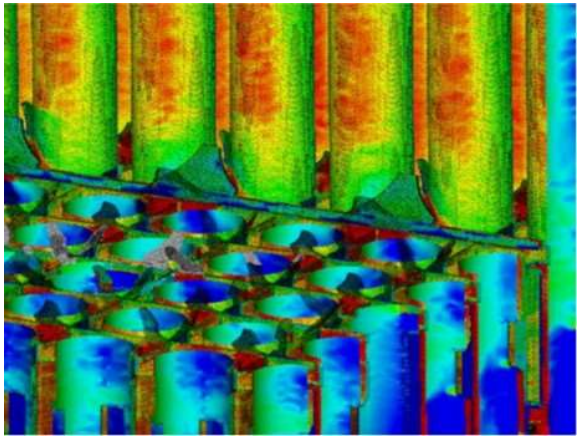

***Component scale*:**
**THYC**, EDF In-house code
**FLICA4** developed at CEA



- Single and multiphase flows
- Used for Cores, Steam Generators, Heat exchangers
- Part of the current Multi-physics Core Simulation chain of EDF

***CFD scale*: NEPTUNE_CFD,** a EDF, CEA, FRAMATOME and IRSN collaboration

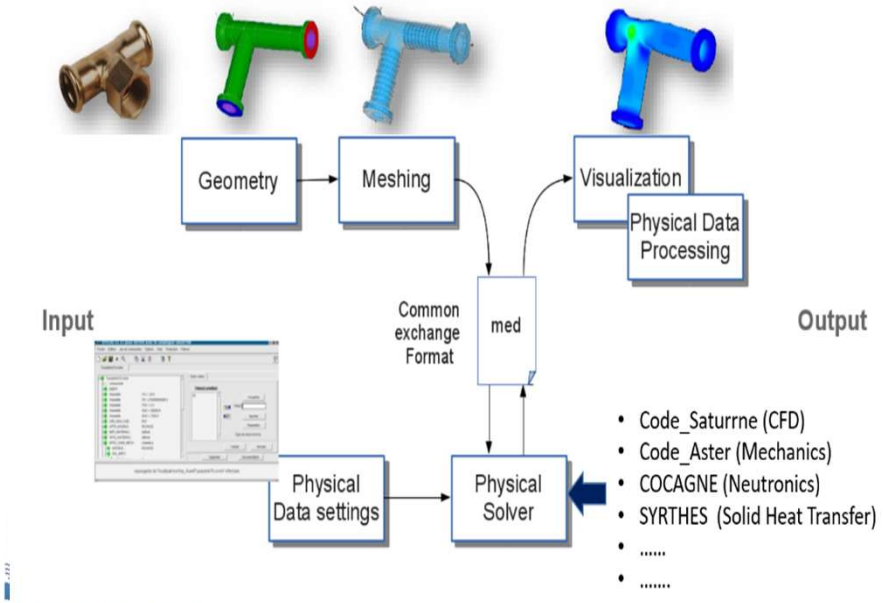
- Multiphase-flows solver : free-surface flows, boiling flows, bubbly flows…
- Dedicated models are available to simulate regime transitions of two-phase flows.



# Multiphysics & Multiscale workbench

**Based on the SALOME open-source numerical platform (EDF/CEA) :**

- ❑ Preprocessing tools : CAO modeler, Meshing
- ❑ Proven capabilities of code integration & coupling, including simulation codes approved by french regulator (ASN) as well as external codes



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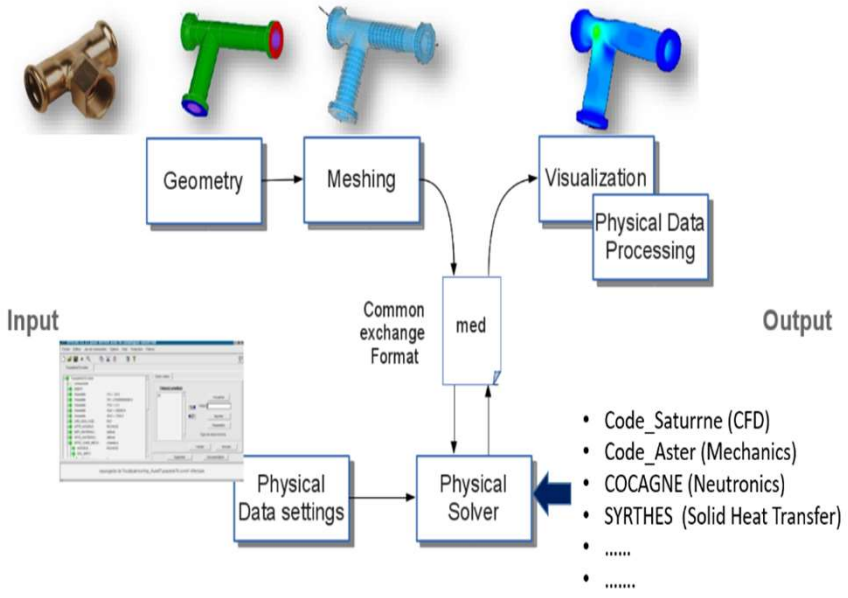
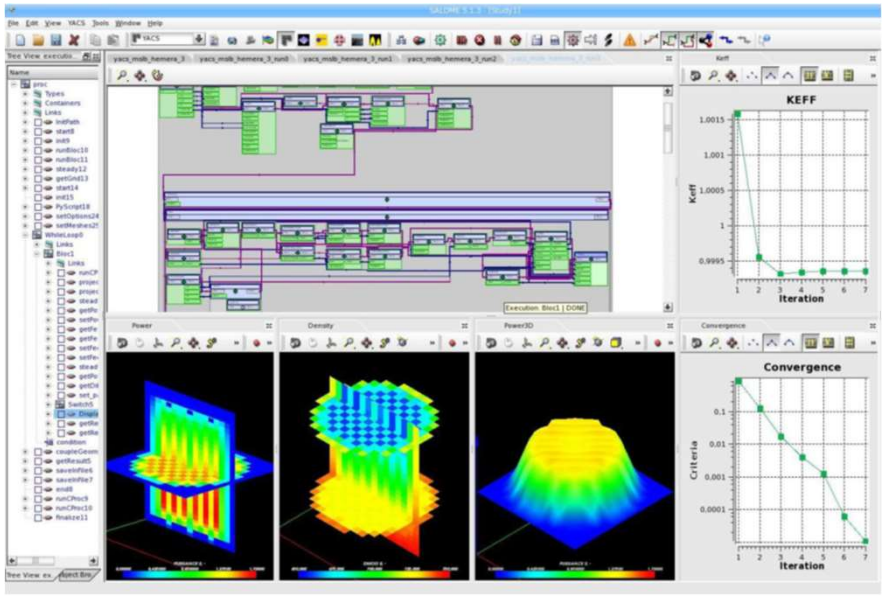
- ❑ Numerous tools : Jobs distribution, parametrical studies, data coupling, mesh interpolation, …
- ❑ Advanced postprocessing tools



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  - Capacity to write data using **MED** format or in a serialized manner
- A set of drivers can then be easily:
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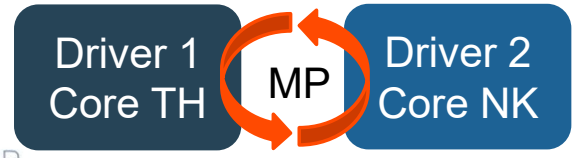
Ex 1 : Code – Code coupling

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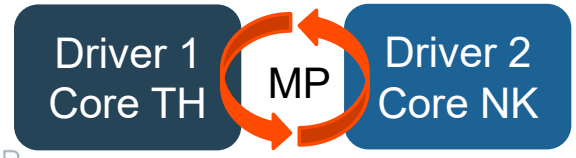
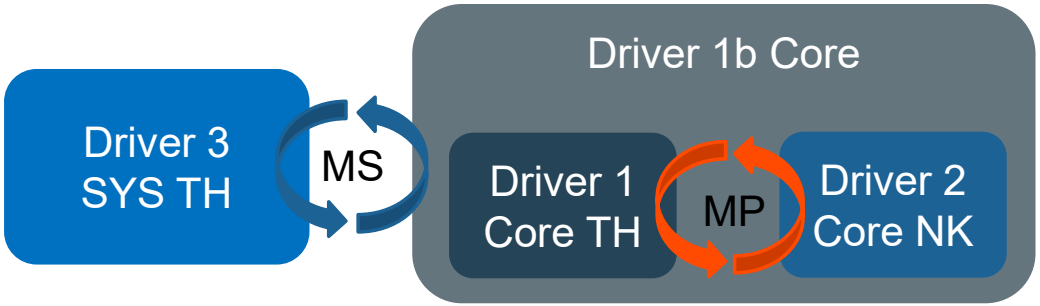



Ex 2 : Code – Macro Driver coupling

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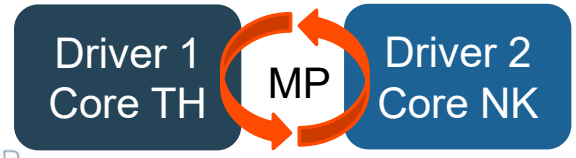


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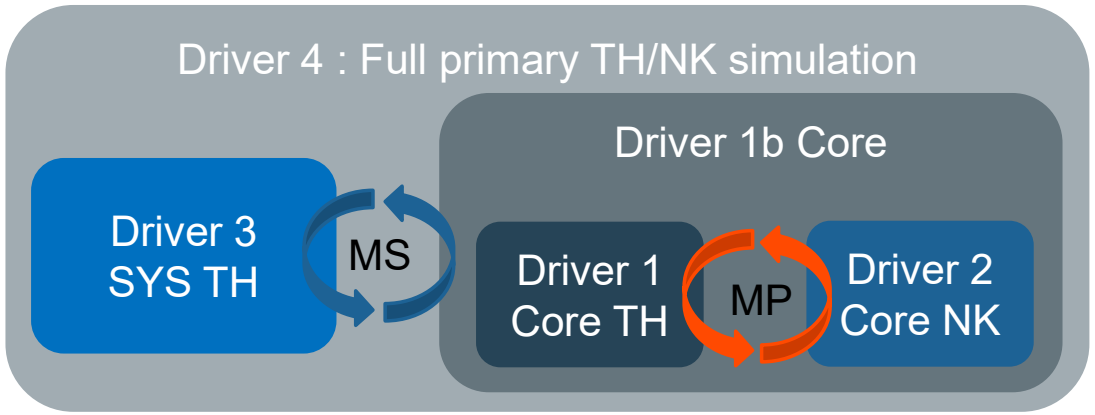


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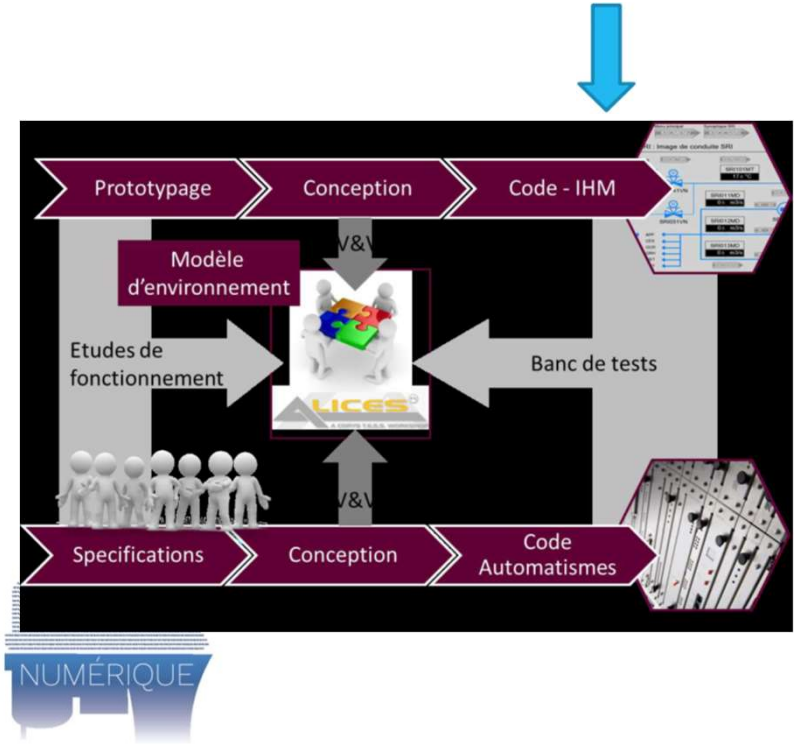
# Full Scale workbench : ALICES platform

- A digital platform which can use international standards (such as FMI) for a Plug'N'Play module integration
- A complete set of tools to handle a full-scope simulation of a nuclear reactor



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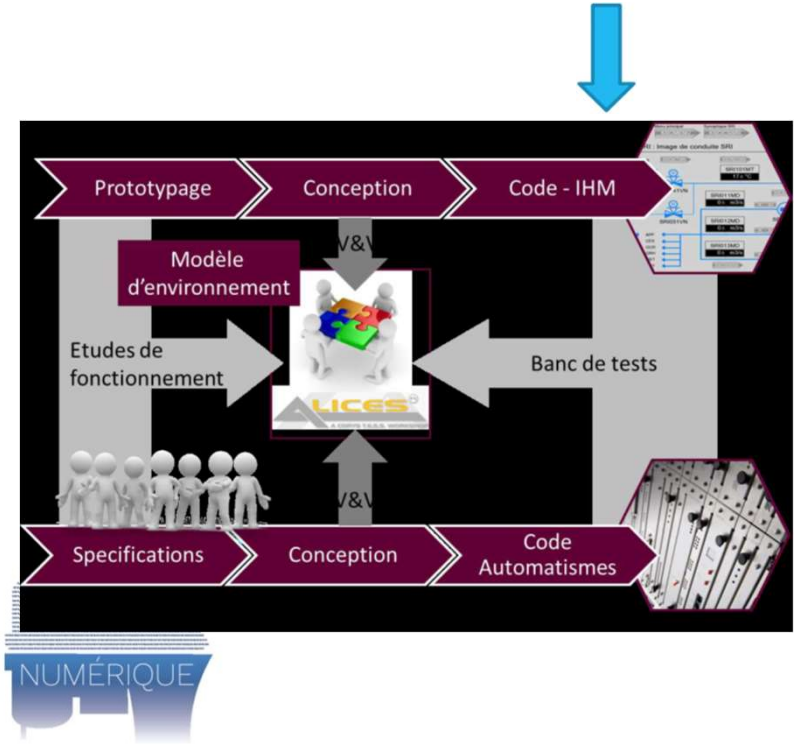


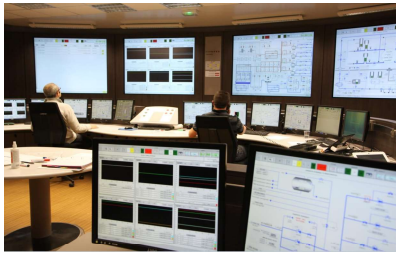

- A platform which can :
  - Act as the backbone of Control Room simulators used for opeartors training
  - Be used to simulate an entire reactor while taking into account tens of systems and sub-systems
  - Be used for design and optimization studies

# From advanced simulation to Full Scale simulators

**Advanced simulation workbench**

***Integration using FMI Standard (FMU module)***

**Full Scale NPP Simulator**



- Operators training
- Driver assistance systems
- Operations studies

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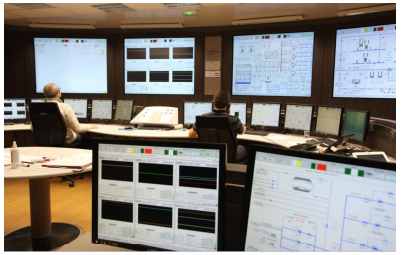
# From advanced simulation to Full Scale simulators

**Advanced simulation workbench**

***Integration using FMI Standard (FMU module)***

***Option 1 :***
Integrate a code « as is » using the FMI standard.
Possible for codes which can attain real-time simulation or faster.

**Full Scale NPP Simulator**



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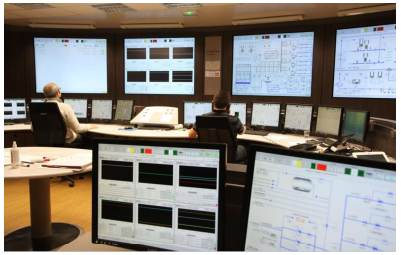
**Advanced simulation workbench**

***Integration using FMI Standard (FMU module)***

***Option 1 :***
Integrate a code « as is » using the FMI standard. Possible for codes which can attain real-time simulation or faster.

***Option 2 :***
Generate reduced order models for codes which cannot attain Real Time Simulation (CFD for example)

**Full Scale NPP Simulator**



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# Full Scale Simulator : Instructive visualization


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# Questions ?