



Avec le soutien de



Le pôle de compétitivité du nucléaire civil



Digital Nuclear Reactor

Projet Réacteur Numérique



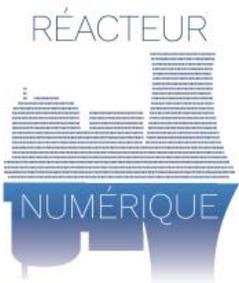
SNETP 2022 – June 2nd, 2022 – Lyon (France)

Cécile Clarenc-Macé – EDF R&D – Digital Reactor Project - Technical Coordinator and WP4 Leader



Agenda

- The project**
- Product 1: a platform for studies**
- Product 2: a full scale NPP simulator**
- « Software as a Service » platform**
- First results**



Digital Nuclear Reactor Initiative

Partners



Support



Clients

Bpifrance
Operators
Engineering
Design
office

Dates & Budget

From January 1, 2020
to December 31, 2023

Total budget : 29 M€

2 Innovative products based on a continuum of models in reactor physics

SERVICE PLATFORM FOR STUDIES

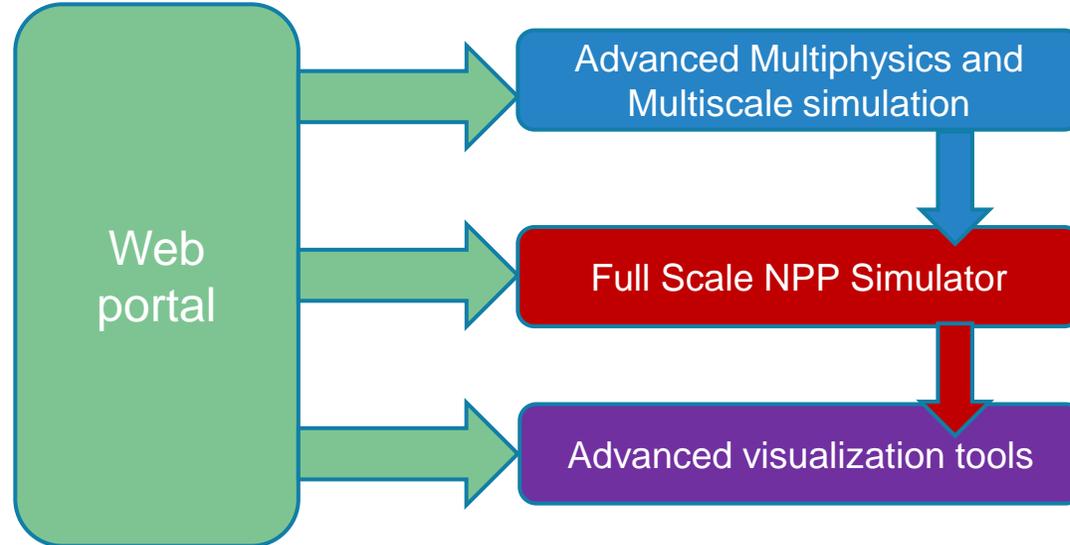
**PROVIDE MULTI-PHYSICAL AND MULTI-
SCALE SIMULATION BASED ON COUPLING
OF SPECIALIZED CODES TO DEVELOP NEW
METHODS AND EXPERTISE**

TRAINING SIMULATOR

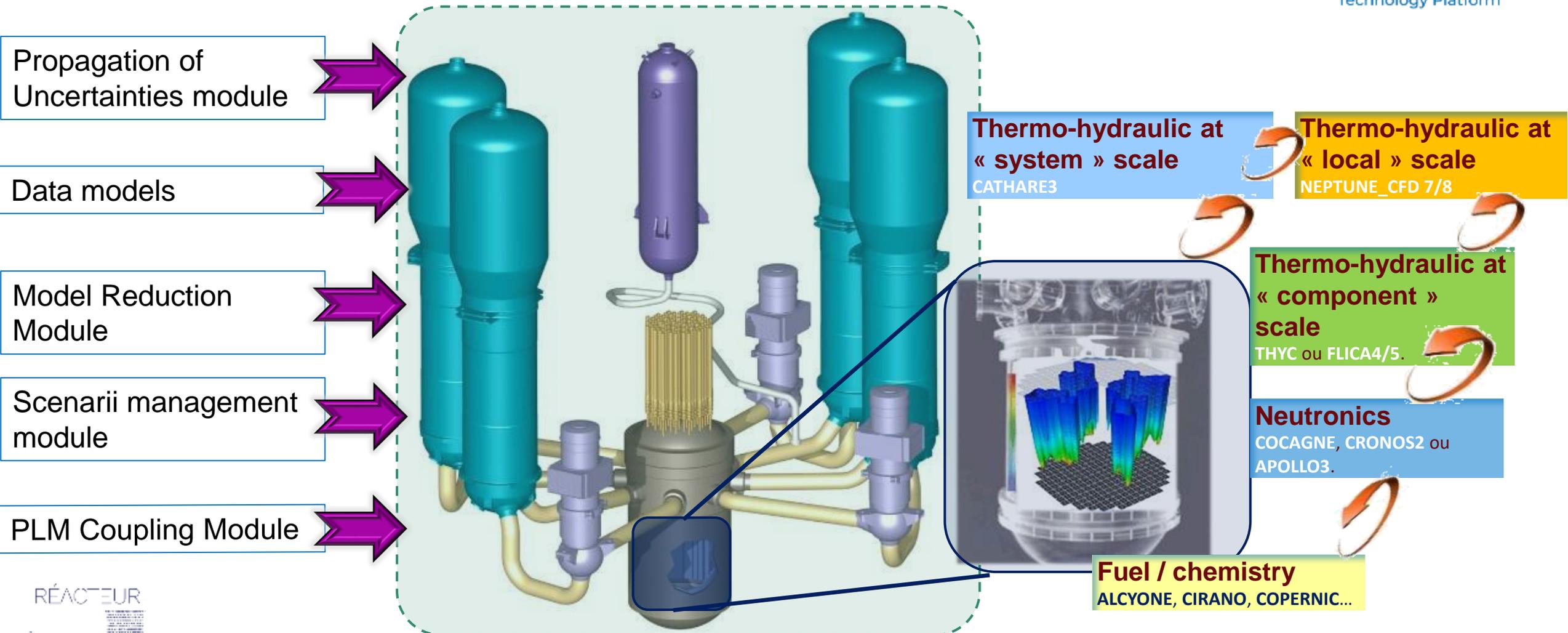
**TRAIN OPERATORS ON A DIGITAL TWIN
REPRESENTATIVE OF THE PHYSICAL STATE
OF THE NPP AND COUPLED TO PROCESS
DATA**

The digital reactor initiative

- 8 partners involved:
 - CEA, EDF, FRAMATOME, CORYS, ESI Group, AXONE, AFNET-SERVICES, CNRS-CRAN
- Development of the digital twin of a nuclear reactor comprising:
 - A multiphysics and multiscale coupling platform for advanced simulation
 - A full scale simulator
 - Advanced visualization tools
 - A single web portal offering access to all services



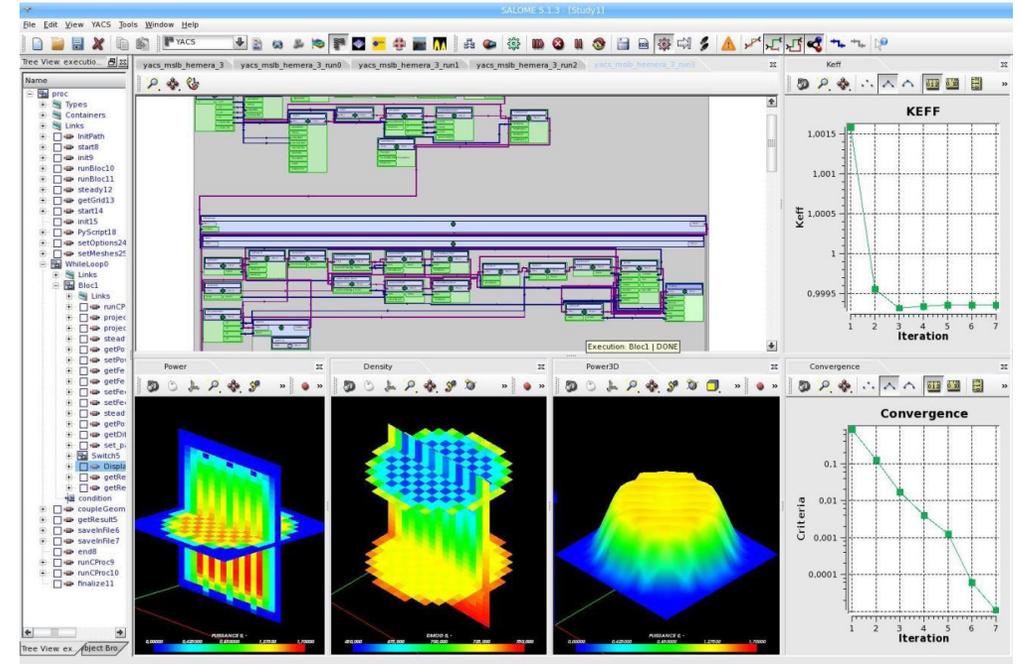
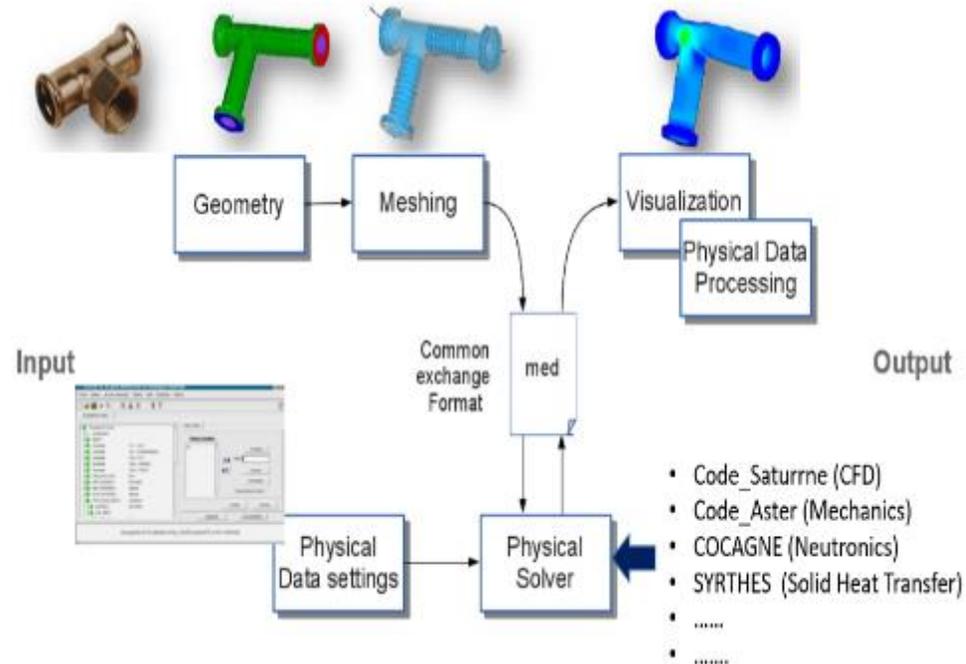
Product 1: platform for studies



Multiphysics & Multiscale workbench

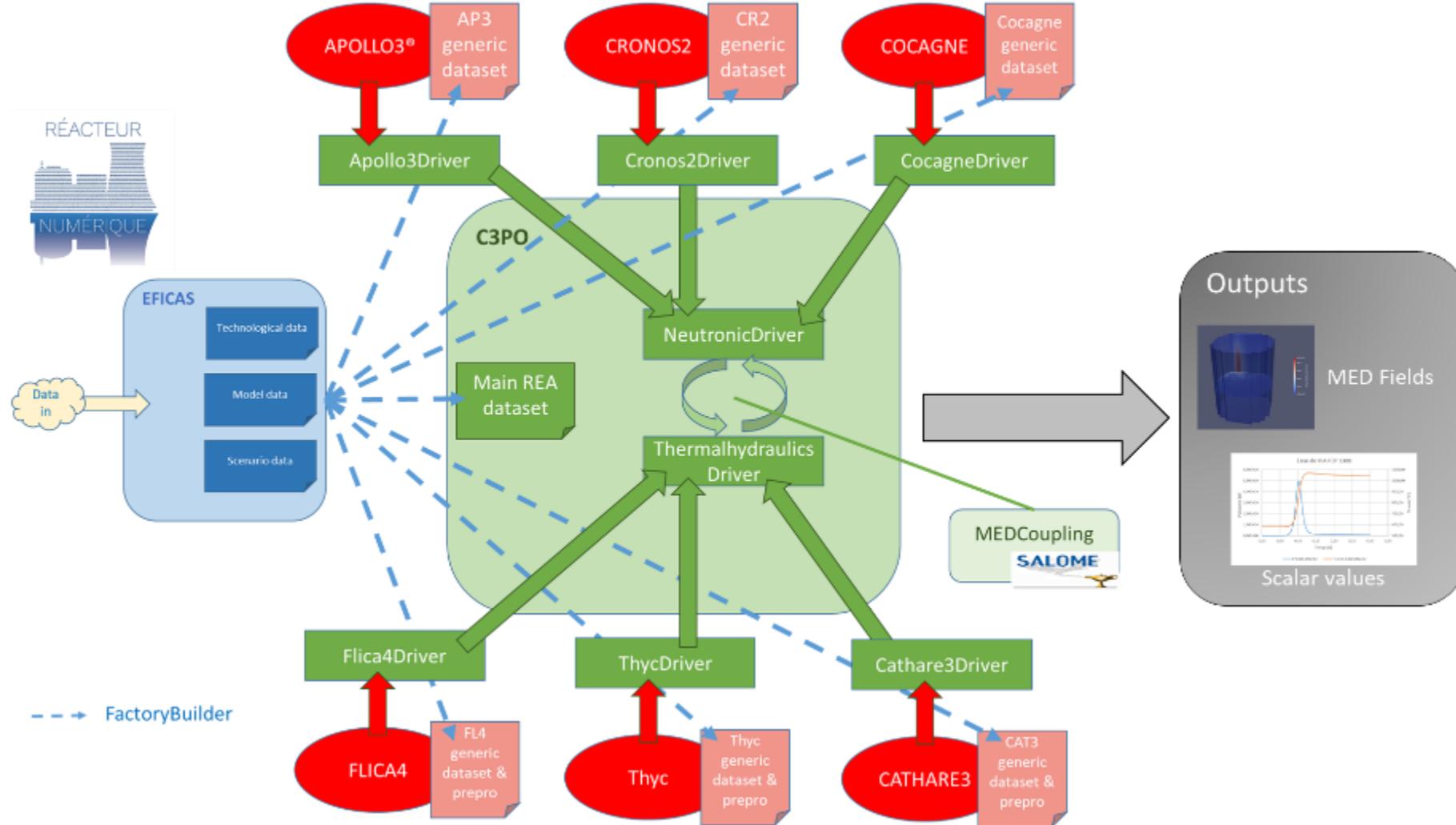
Based on the SALOME open-source numerical platform (EDF/CEA) :

- ❑ Preprocessing tools : CAO modeler, Meshing
- ❑ Proven capabilities of code integration & coupling, including simulation codes approved by French regulator (ASN) as well as external codes
- ❑ Numerous tools : Jobs distribution, parametrical studies, data coupling, mesh interpolation, ...
- ❑ Uncertainties treatment software: OpenTurns, Uranie, GUI Persalys (new!)
- ❑ Advanced postprocessing tools



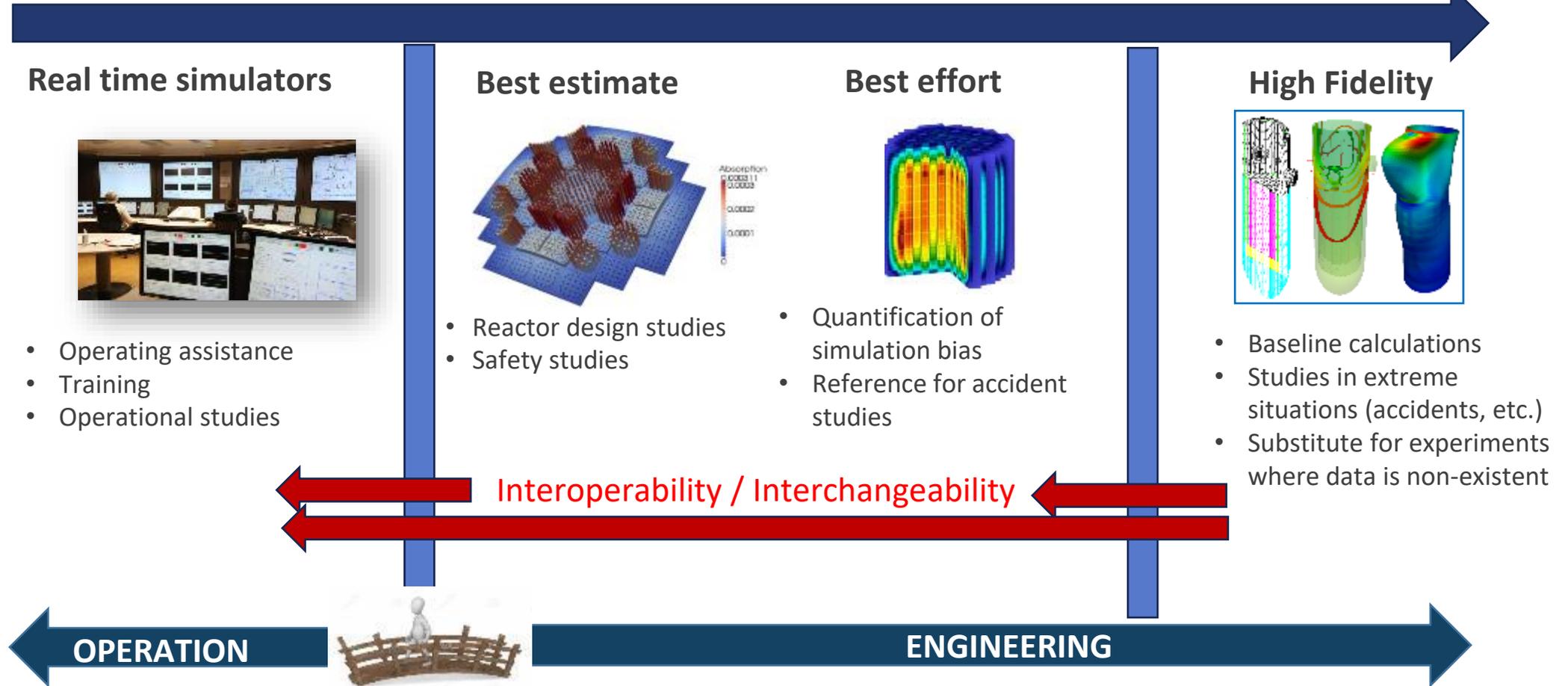
A common coupling platform

Current architecture

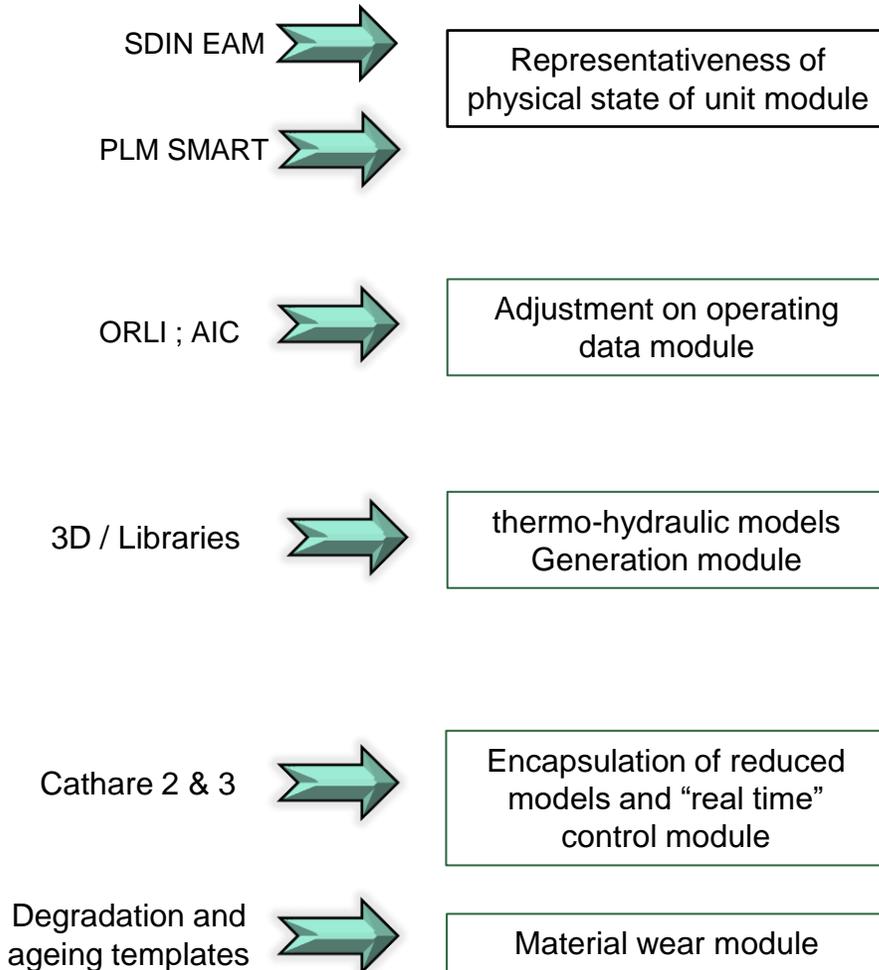


One ambition: ever more robustness and precision on a wider scope of use

Higher quality modelling



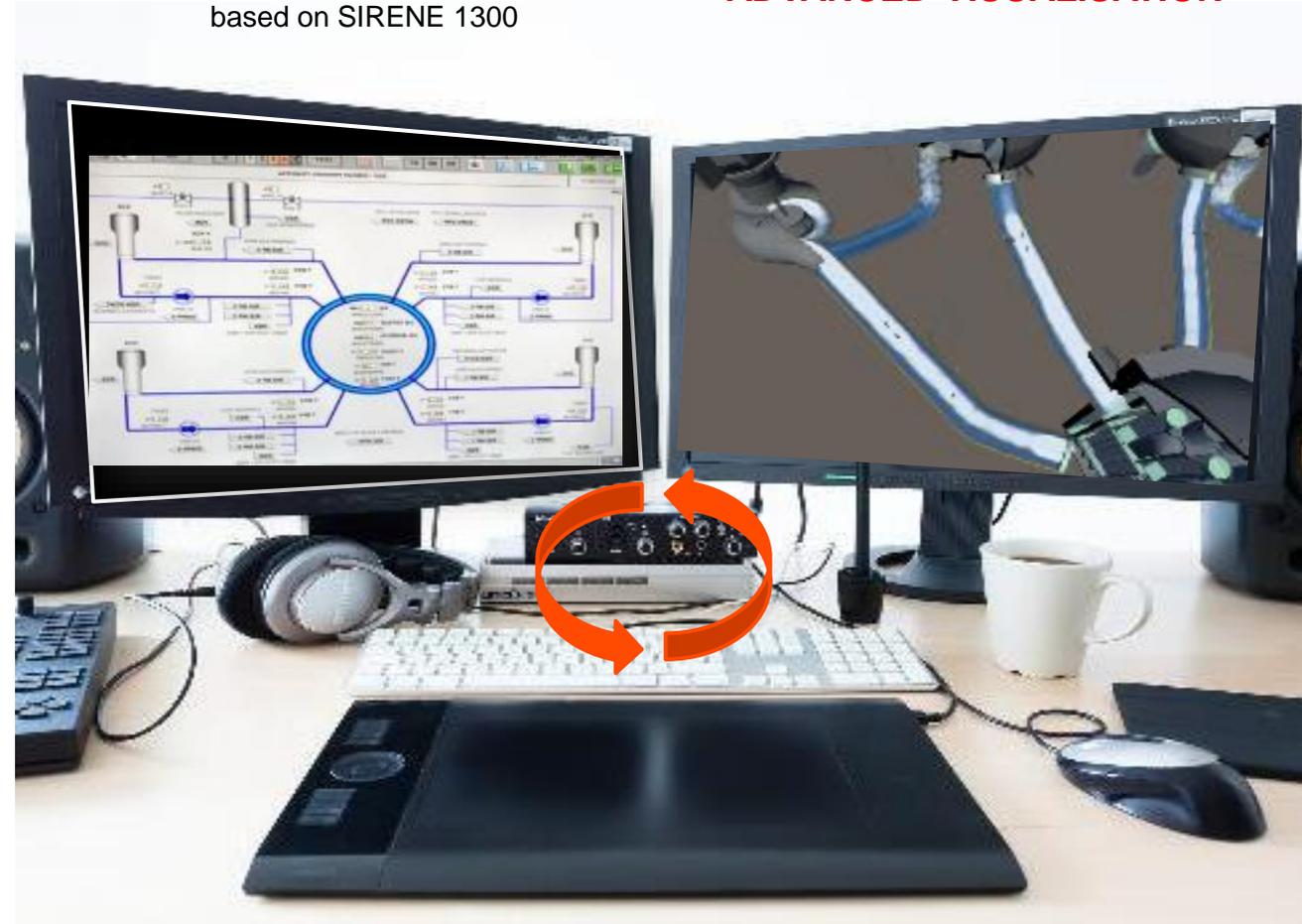
Product 2: Full Scale NPP Simulator



OPERATION BENCH

based on SIRENE 1300

ADVANCED VISUALISATION



Requirements Monitoring
(STE)

Operator guidance &
procedure validation

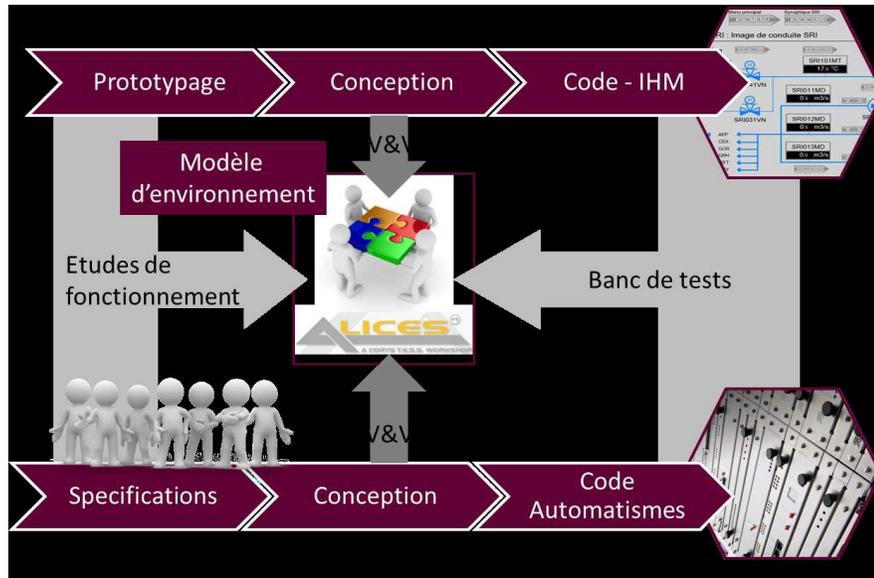
Full Scale workbench backbone

Based on ALICES platform (Corys):

- ❑ A digital platform which can use international standards (such as FMI) for a Plug'N'Play model integration
- ❑ A complete set of tools to handle a full-scope simulation of a nuclear reactor
- ❑ Used as backbone of operators' training simulators
- ❑ Used also for design and optimization studies

Connected to advanced visualization tools based on Unity:

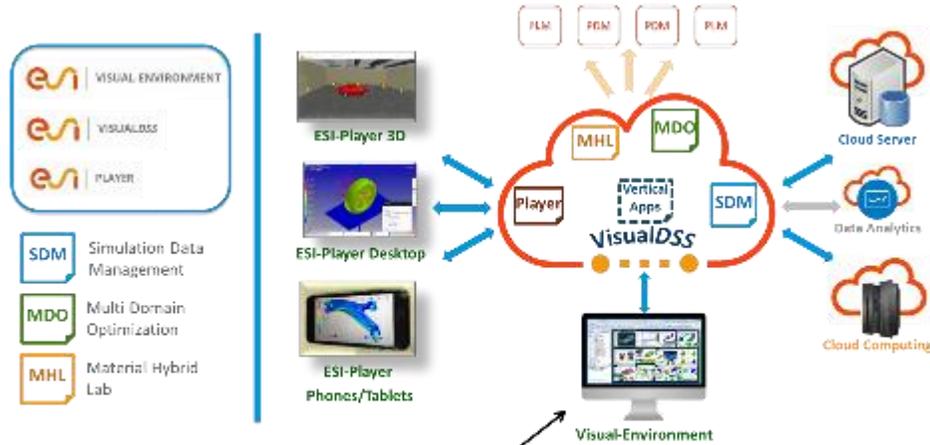
- ❑ Idea: use of metaphors, techniques used a lot in games and movies industries.
- ❑ EDF has some experience in this domain with MINERVE application and plans to upgrade it using up-to-date technology.



Project aims' for both training and engineering:

- ❑ Ease the update of simulator's configuration along with maintenance operations
- ❑ « digital twin »: Simulator is mirroring the actual NPP state using data assimilation
- ❑ Include ageing modeling
- ❑ Include smart functions like « operation rules monitoring »

SaaS Platform for end-users

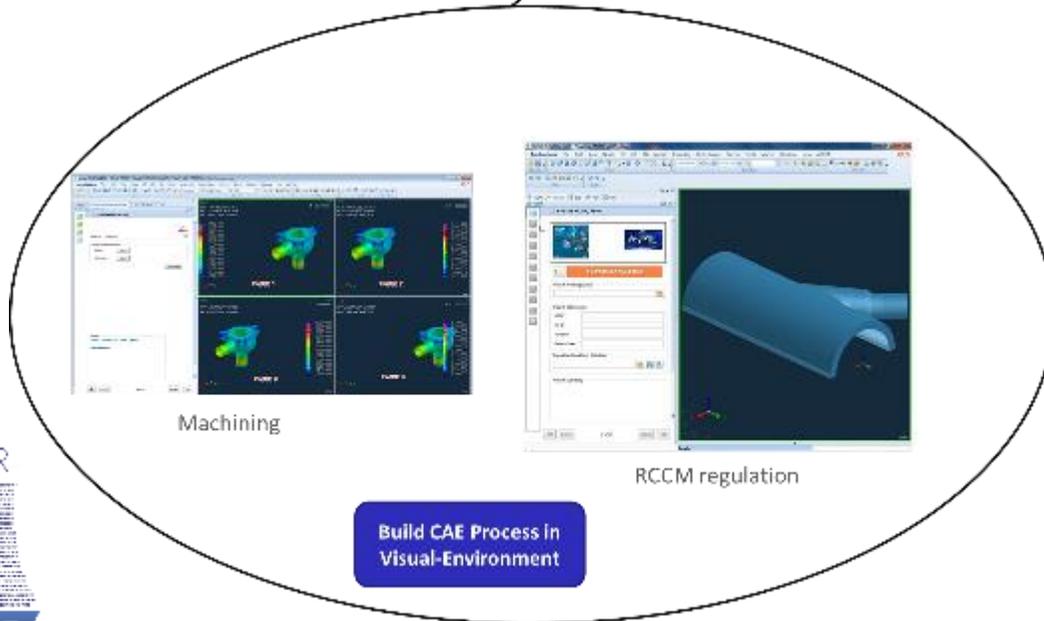


Based on Visual DSS platform (ESI Group):

- Multi-Domain Computer Model Management
- CAE Process Automation
- Project Workflow Management
- Simulation Content Management
- Systems Integration Framework
- Reporting and Decision Support

Project aims' for this platform:

- Allow personalization with new simulation workflows
- Ease the access to various simulation software
- Unify entry data collection



First results : demonstrators

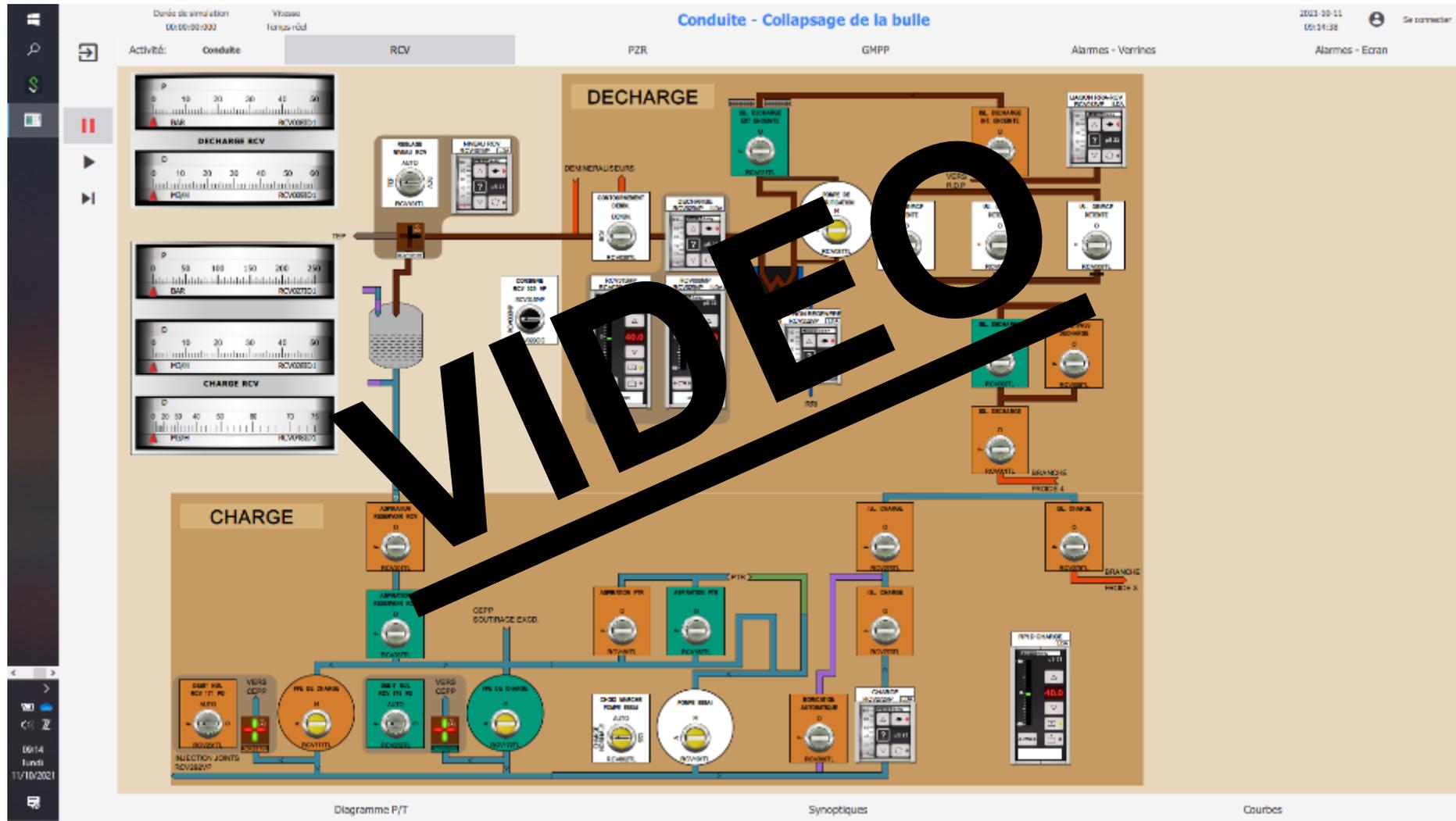
- ❑ Platform for studies:
 - ❑ Two use cases in progress: Rod Ejection Accident and Islanding
 - ❑ Interchangeability and physical couplings work well 😊

- ❑ Full scale simulator:
 - ❑ Training prototype available for « Pressurizer steam bubble collapse » (see video)
 - ❑ Very good feedback from operators 😊
 - ❑ Work in progress on: model reduction, wedging with operational data,...

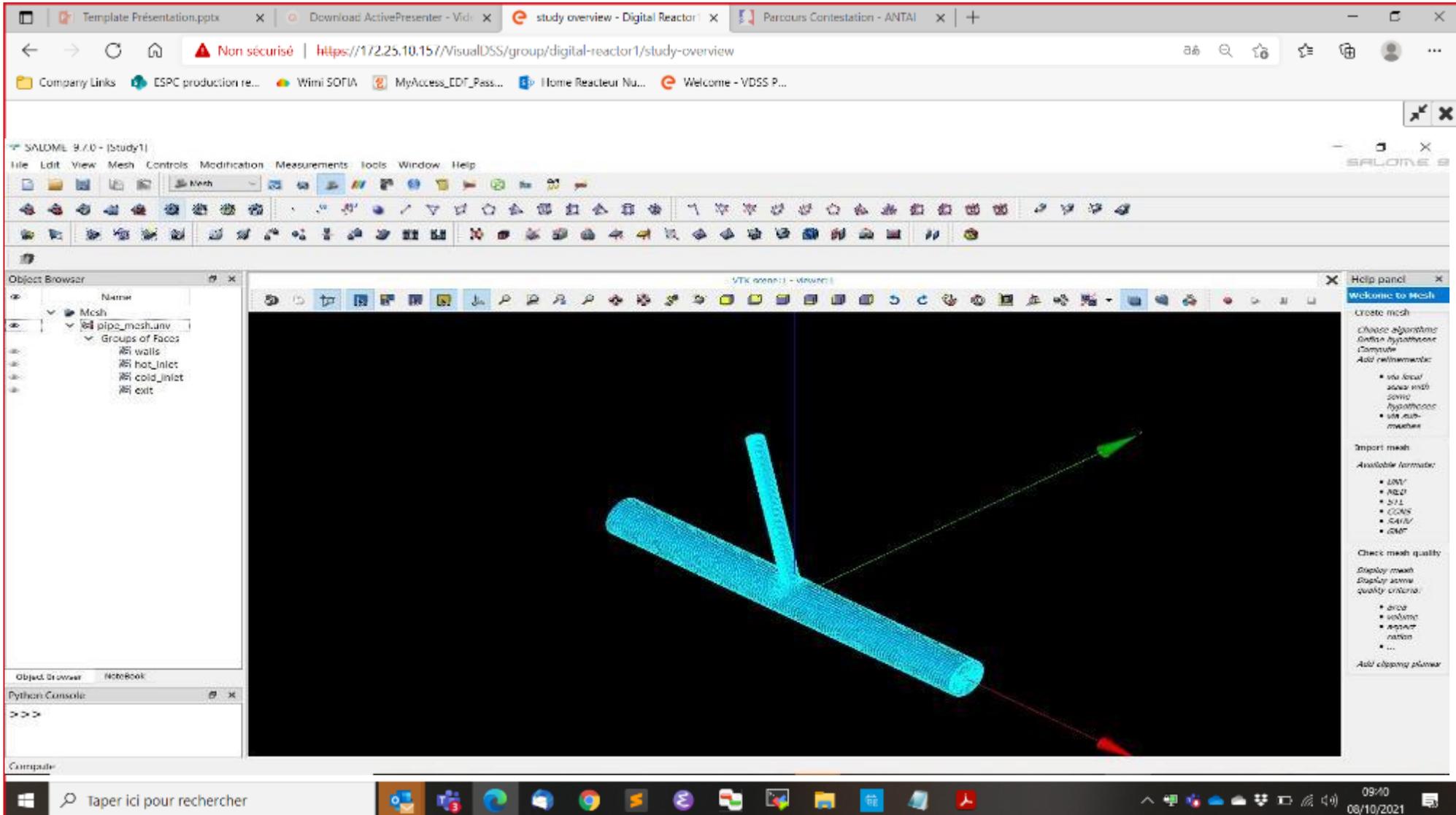
- ❑ SaaS platform:
 - ❑ First « PoC » available for parametric studies (using Salomé and code_saturne) 😊
 - ❑ Next steps: connect to Visual DSS
 - ❑ The training prototype
 - ❑ Then the platform for studies
 - ❑ And provide access to Salomé platform



Full Scale Simulator : training prototype



SaaS platform : simulation study using Salome



SaaS Platform : parametric study

Browser tabs: Template Présentation.pptx, Download ActivePresenter - Vid..., study overview - Digital Reactor, Parcours Contestation - ANTAI

Address bar: Non sécurisé | <https://172.25.10.157/VisualDSS/group/digital-reactor1/study-overview>

Company Links: ESPC production re..., Wimi SOFIA, MyAccess_EDF_Pass..., Home Reacteur Nu..., Welcome - VDSS P...

Page Title: Digital Reactor1

Search for ...

Navigation: Dashboard, **Projects**, Models, Catalog, My Files

Projects / RN_WaterMix_PR / Studies / parametric_study1_water_mix

Workflow Tasks: Pre Treatment, Simulation, Analyse

Overview

Workflow

Content Viewer

Workflow Tasks

Pre Treatment

Simulation

Analyse

RUN_9

cold_inlet_temperature 40
hot_inlet_flowrate 2
cold_inlet_flowrate 0.6

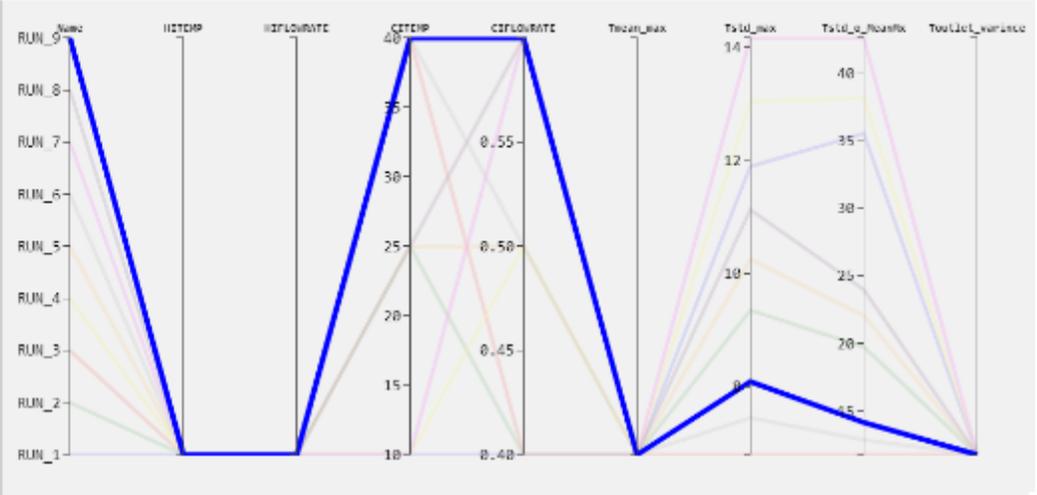
ID #1
Name qualite du melange
Description la temperature du fluide en sortie doit etre homogene

Variable	Min	Max	Units	Result	Status	Proposed Change
Toutlet_variance	-	0.01	-	0.00	✓	<Enter the comments>

ID #2
Name tenue a la fatigue
Description les variations de temperature en paroi doivent etre limitees afin de prevenir la formation de fissures

Variable	Min	Max	Units	Result	Status	Proposed Change
Tmean_max	-	80	DegC	80.00	✓	<Enter the comments>
Tstd_max	-	10	-	8.09	✓	<Enter the comments>
Tstd_o_MeanMx	-	2	-	14.14	✗	<Enter the comments>

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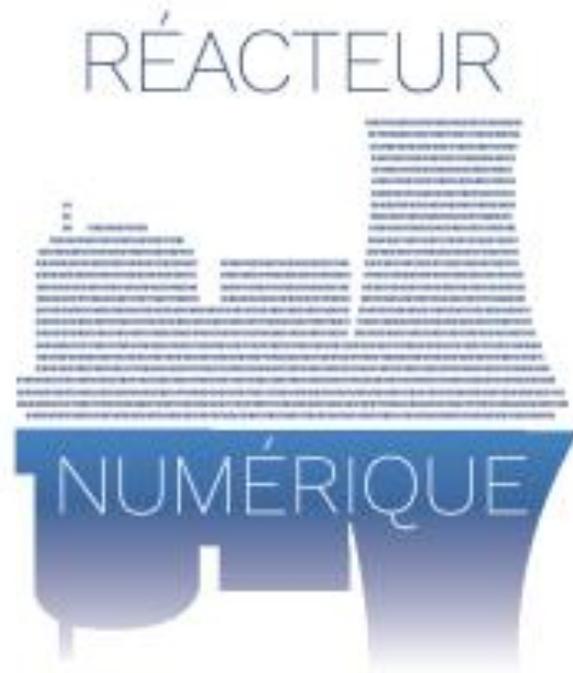
Run	HITEMP	HIFLOWRATE	CITEMP	CFLOWRATE	Tmean_max	Tstd_max	Tstd_o_MeanMx	Toutlet_variance
RUN_1	80	2	10	0.40	80.00	13.04	18.20	0.00
RUN_2	80	2	25	0.5	80.00	10.25	22.07	0.00
RUN_3	80	2	40	0.5	80.00	7.45	12.86	0.00
RUN_4	80	2	10	0.6	80.00	14.16	42.66	0.00
RUN_5	80	2	25	0.6	80.00	11.13	24.05	0.00
RUN_6	80	2	40	0.6	80.00	8.09	14.14	0.00
RUN_7	80	2	10	0.55	80.00	13.04	18.20	0.00
RUN_8	80	2	25	0.55	80.00	10.25	22.07	0.00
RUN_9	80	2	40	0.55	80.00	7.45	12.86	0.00

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Thank you for your attention