Nuclear Digital Twins at EDF – quick overview

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Go Digital - Implementing Digital Innovation in a Nuclear Environment 2020

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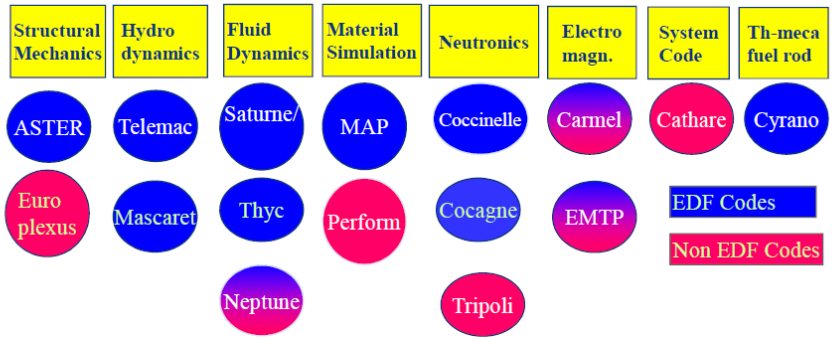
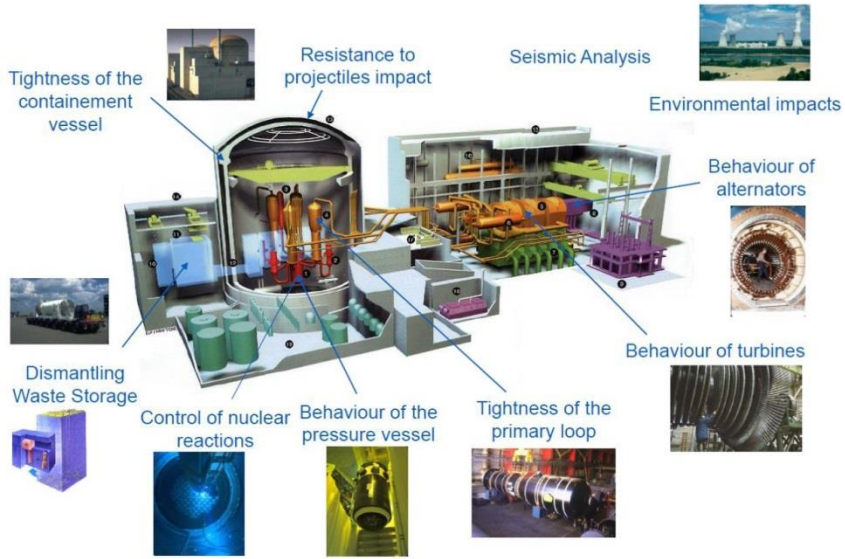
Advanced simulation legacy – the starting point

- EDF R&D have developed for 30 years its advanced simulation capacity, methodology and in-house software



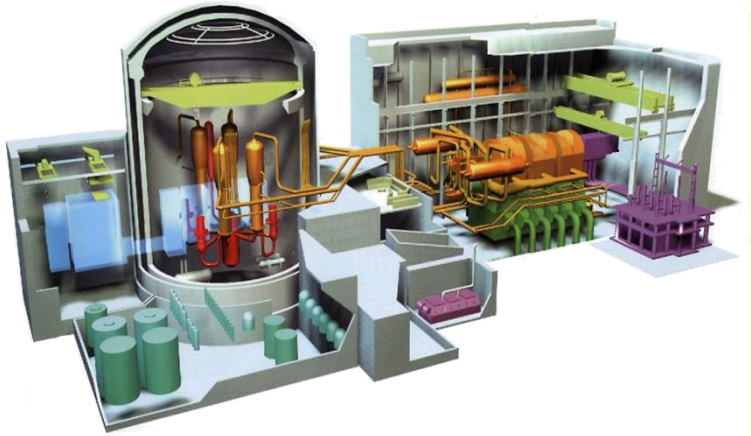
+ Interoperability (SALOME)+

+ Network of Partners (Nuclear Industry, European Projects, Int'l)



Priority given to DT for maintenance and operation

- The *Nuclear of the Future Initiative* at EDF R&D France proposed the development of Digital Twins for nuclear based on a four-level approach
- Some digital twins on each level already exist or are under development

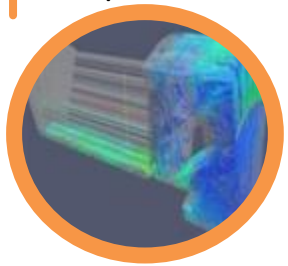


Process/multi-Systems

Island/building

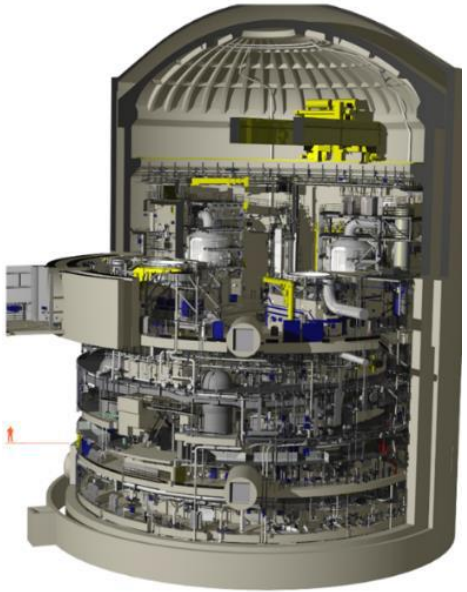
System

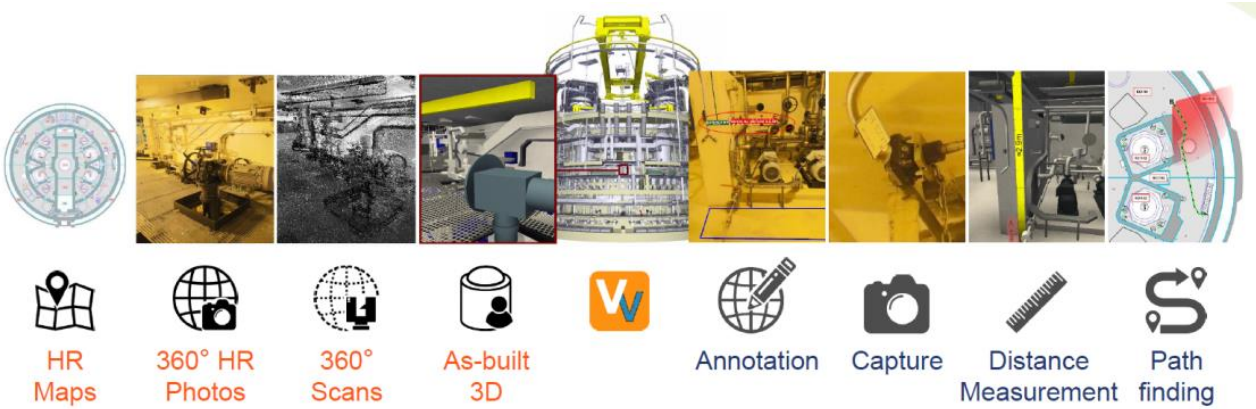
Component



Digital twin of the reactor building

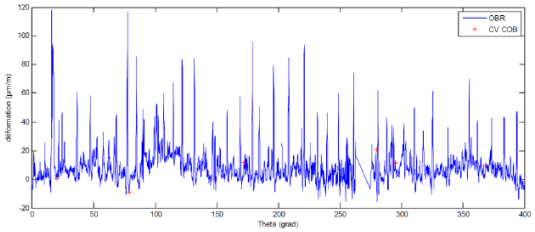
- Based on high resolution 360 photos and scan, Artificial Intelligence to recognize the key components and powered by immersive technologies (VR and AR)
- Helps for the outage preparation and people's training
- 7 reactor buildings of the French fleet have already their own digital twin



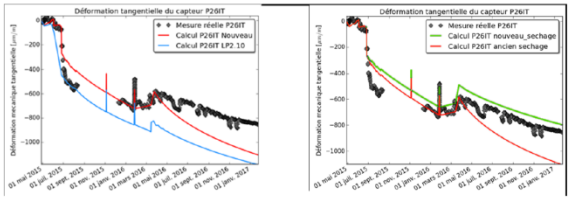


VERCORS – digital twin of the reactor containment

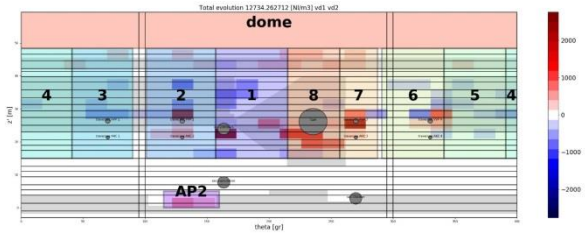
- First digital twin developed by EDF based on advanced FEM simulation
- Virtual replica of a 1:3 scale mock-up of a double-wall reactor containment built at EDF R&D in France equipped with more than 700 sensors and 2km optical fibre connected to the DT
- Initially used to forecast, in an accelerated way given the scale, the leakage rate of the containment against the age (9x faster compared to the real asset) and the localisation of the concrete cracking paths
- Successfully supported the safety cases for the 10-years outages
- Enabled optimisation of the polymer coating for reparations

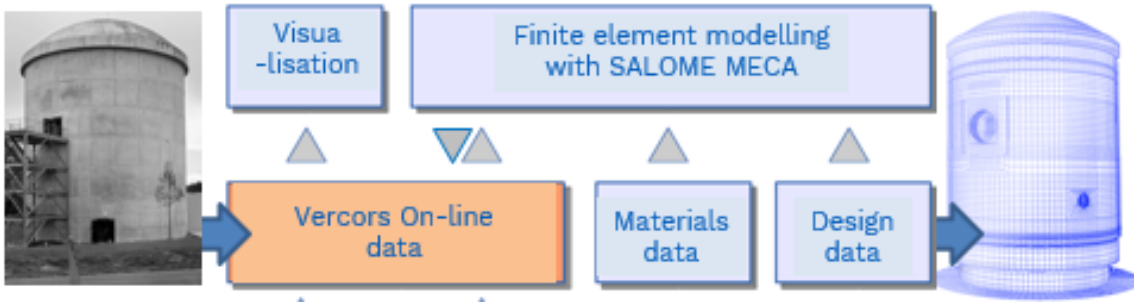


On line monitoring of containment strains



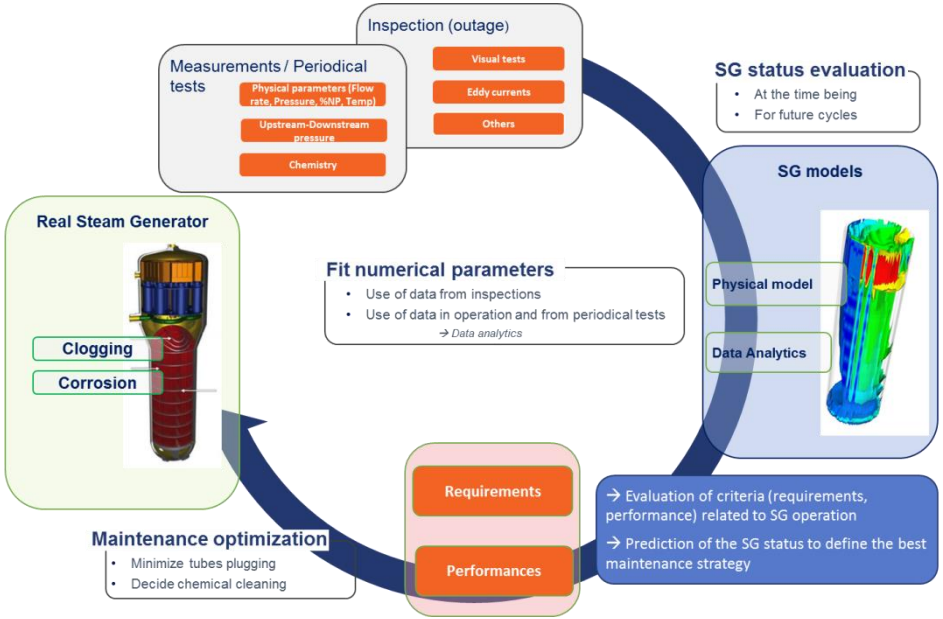
Model's parameters fitting





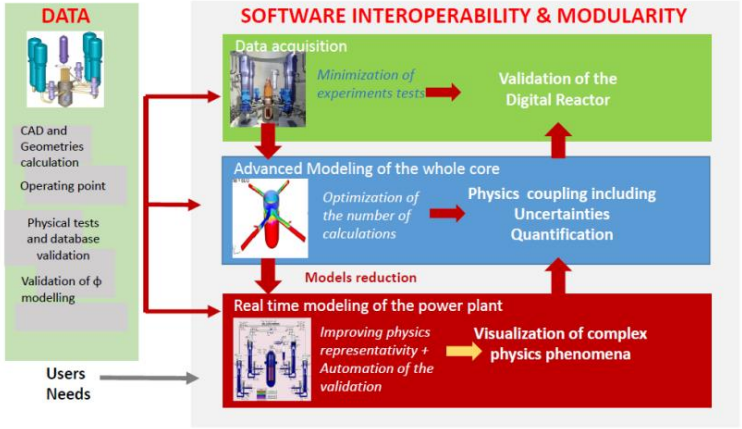
Ongoing projects : Steam Generator Digital Twin

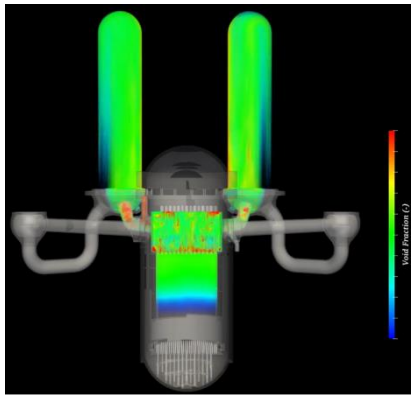
- Critical component of the PWRs with very expensive replacement cost
- The new *Steam Generator Digital Twin platform* (under development at EDF R&D) will enable the operating history and behaviour of each steam generator in the fleet to be monitored.
- Each SG DT will be fed by the data collected during operation and by the controls carried out during unit outages.
- Will be used to run simulations to test scenarios and forecast the future condition of the asset in order to schedule an optimised maintenance



Ongoing projects : PWR Digital Reactor

- Collaborative project led by EDF in France and gathering 9 partners (EDF, Framatome, CEA, Corys, ESI, Aneo, Axone, Boost and Cran) to run from 2020 to 2023
- Co-funded by the French government
- Three objectives for this DT:
  - Operators training when used as simulator
  - Improve the design of new reactors
  - Prepare safety cases by anticipating the behaviour of the reactor in various situations of operation





Scientific, technical and economical challenges

Integration	•Build a multi-physics (interoperability) and multi-scale (interchangeability) platform where all relevant physics codes should be able to plug in seamlessly.
Standards	•Be able to come together with a common standard for both new and legacy codes.
Interfaces	•Build adapted "real-time" or "operational-time" connections with the real asset allowing data flow with the good quality and appropriate format
Uncertainty	•Develop the right methodology for propagating uncertainties when doing multi-physics.
User experience	•Use advanced, ergonomic, visualization techniques (metaphors, AR, VR…) as supporting tools.
Quality	• Verification &Validation of the whole platform when using strongly coupled physics.
Skills	•Develop the SQEP with appropriate digital skills, get them engaged and make accepted the digital assets
Financial	•Identify a sustainable financial model to support the development, the operation and the maintenance of the digital assets
Security	•Put in place and manage the appropriate cyber-security and access to the digital twins

Thank You

