

A detailed 3D digital twin visualization of the CIGEO radioactive waste management project site. The image shows a complex industrial facility with various buildings, roads, and underground structures. A large yellow area indicates the repository location. A blue callout box is positioned in the upper right corner of the visualization.

FROM BIM TOWARDS 4D DIGITAL TWIN OF CIGEO PROJECT TO SUPPORT OPERATING PHASE ISSUES, NEEDS AND WORK IN PROGRESS AT ANDRA

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EURAD/PREDIS webinar on Digital Twins
in Radioactive Waste Management
16 February 2022



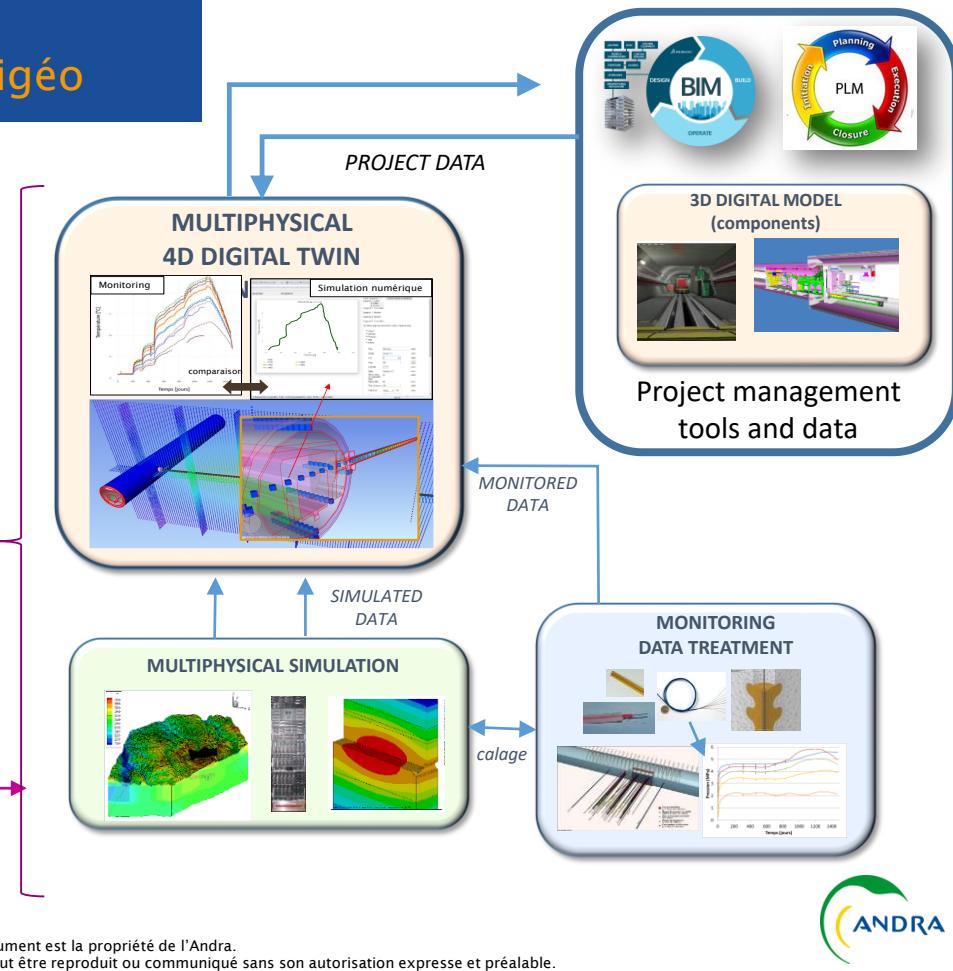
General framework

Towards full digitalization of Cigéo

A key issue of transformation in terms of multi-criteria performance (*economic, technical, safety, governance, ...*)

Ongoing **development** and **deployment** of methods and tools supporting management of **design, construction, operation, maintenance, safety and monitoring**

- A methodology combining BIM and PLM technology at the central part of project management
 - Collaborative and interoperable environment
- 3D digital model
- Many core "business applications" through **Digital Twins** :
 - Digital twin 4D (space/time) for multi-spatial, multi-physics, multi-components behavior (simulated/measured data)
 - Digital twin by Virtual/augmented reality tools for accidental situation
 - ...

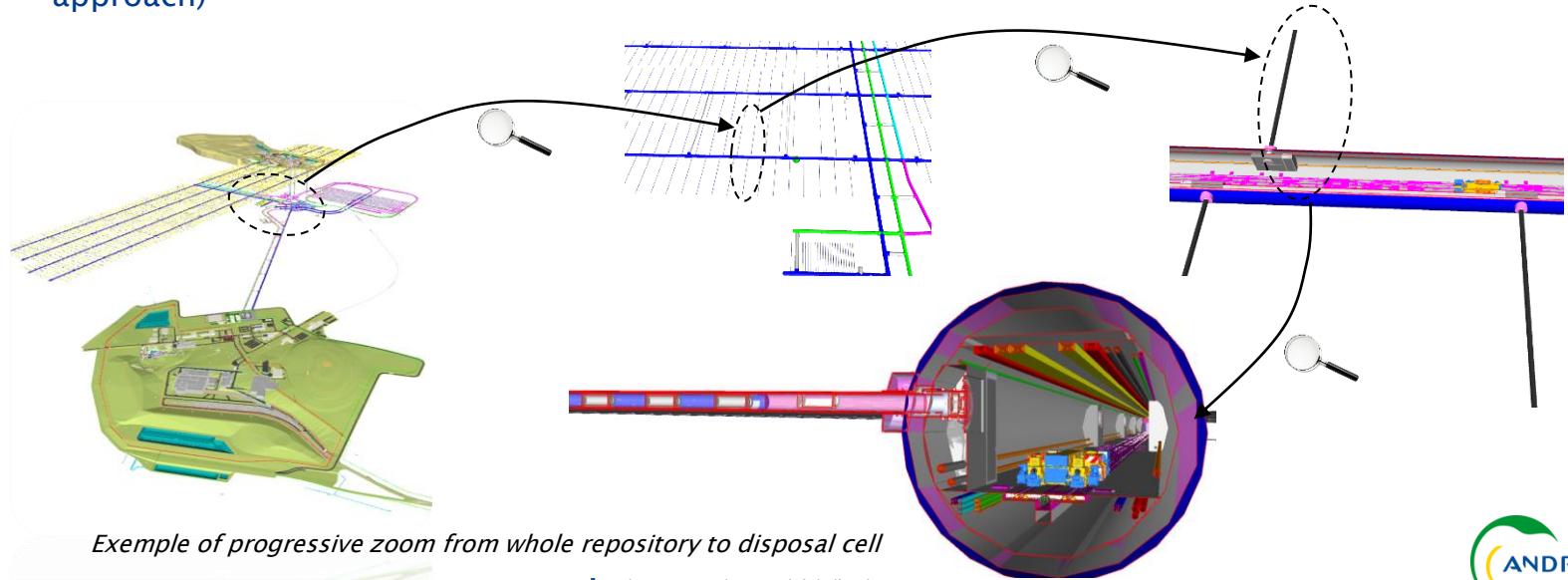


3D digital model of Cigéo (1/3)

An operational tool as central part of project management

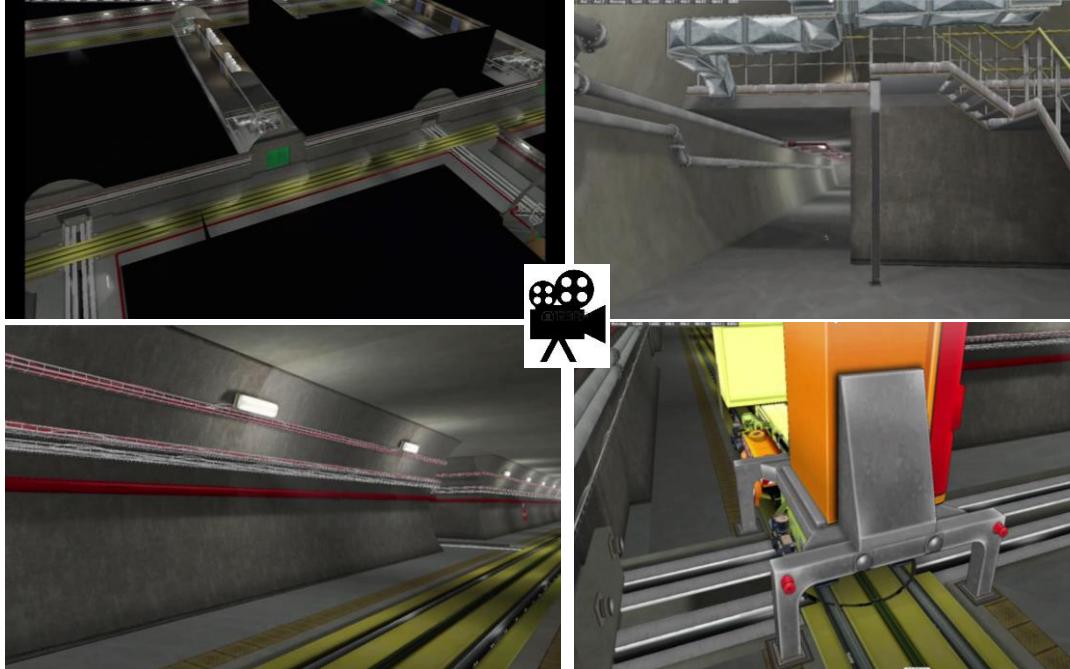
3D geometric modelling of whole project **achieved** and **operational** :

- Detail of all components of Cigeo's surface and underground installations, with global architecture at the end of Detailed Engineering Study phase
- Graphic Interface to access to all kinds of data of the project about components (data centric approach)



3D digital model of Cigéo (2/3)

An operational tool as central part of project management

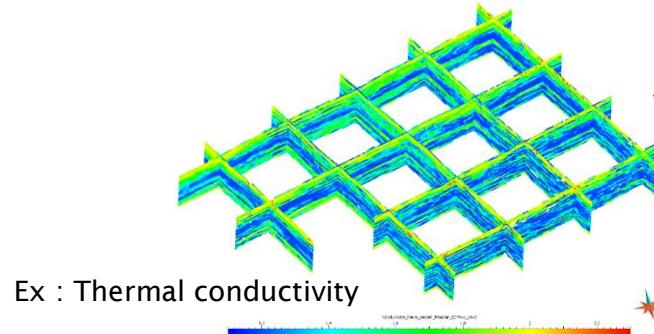
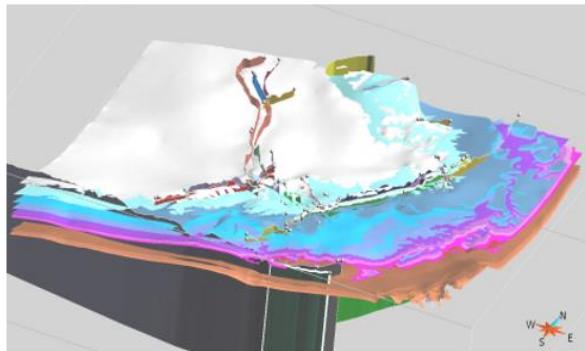


- Dynamic visualization
 - easy moving
 - many views
- Interactions with environment
- Integration of industrial process

3D digital model of Cigéo (3/3)

Integration of geological knowlege

Scientific Environment



DRD/EAP/22-0010

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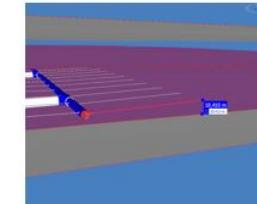
Project Environment

Geomodelling
CAD

GOCAD

3D digital model +
geometry geological layers

Intégration of local
THMC properties
(Treatment method from
3D-sismic survey)



Project application

Example of applications for
design optimization :

- Check the safety requirement of minimal thickness of host rock upper / lower disposal cells
- Improve numerical simulation taking into account natural variability

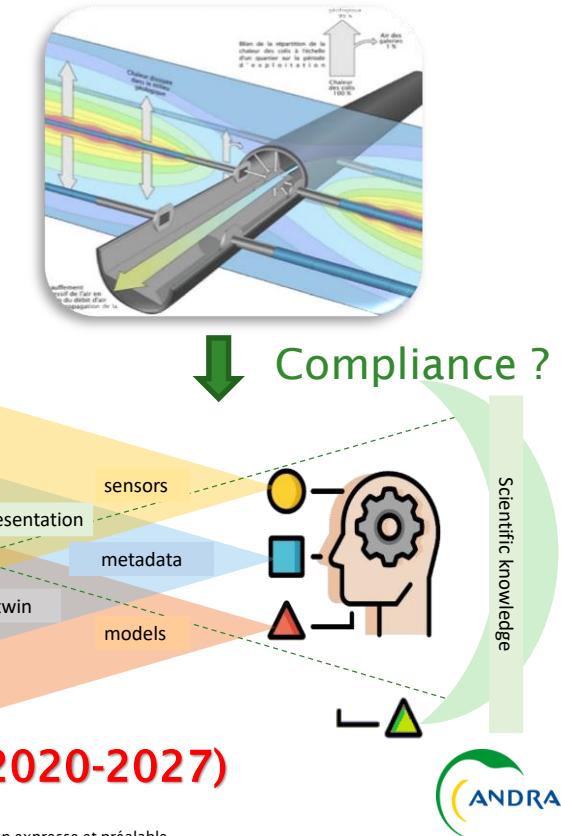


4D Multi-physical Digital Twin of Cigeo Objectives

A multi-knowledge integration tool (physical and components) of the 4D phenomenological behavior of the disposal to :

- Inform and predict in "real time" the "multi" behavior of the disposal system
 - Check that the facility and its geological environment remain within the phenomenological operating range defined within the framework of the safety assessments and the commissioning authorization
 - Contribute to ensure operational safety
 - **Decision-making tool**
 - Control of the environmental conditions for the retrievability of the packages
- Capitalize multi-physical knowledge (time/space), including post-closure

⇒ **Work in progress with stepwise approach (2020-2027)**



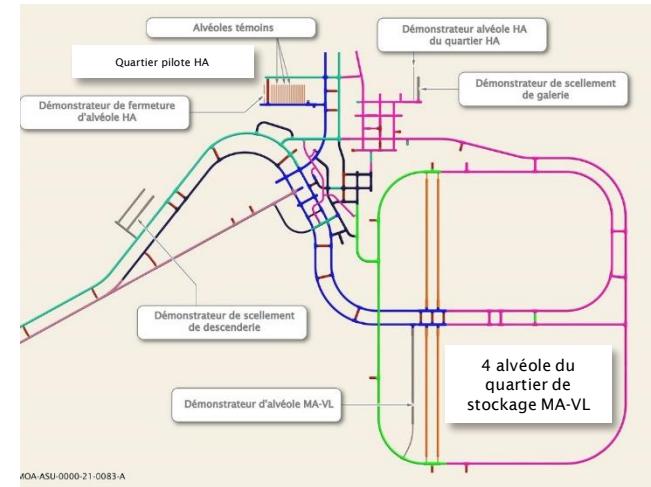
4D Multi-physical Digital Twin of Cigeo

Strategy of development (1/4)

A set of complementary and interdependent "local" digital twins, at the (components / processes) local scale, then an assembly :

- For multi-physical evolution during construction and operating phase, on disposal cell, HLW and ILW parts, galleries, seals, ramp, digital twins about :
 - "THM of host rock close to exothermic HA disposal cells"
 - "Thermo-aeraulics of the ventilated galleries "
 - "Mechanical evolution of the lining steel of the HA disposal cells"
 - "Gas Transfer in the MA-VL disposal cell"
 - "Hydrogeology of (sub)surface limestones"
 - Etc...
- For large-scale performance verification, digital twins of demonstrators:
 - "HM Behavior of Gallery Seals"
 - etc...

→ Strong link with monitoring needs



4D Multi-physical Digital Twin of Cigeo

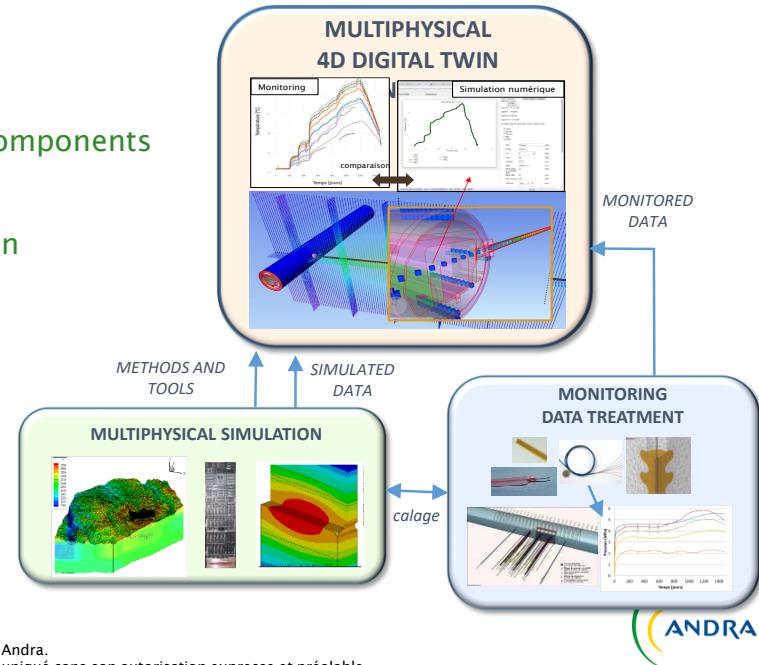
Strategy of development (2/4)

2 main kinds of development:

- Development of a unified, readable and accessible **digital ecosystem** (software platform) to process (time/space) the components of the digital model and constitute the 4D multi-physical digital twin(s) :
 - **integrator** of software components of all kinds
 - **assembler** of big data from simulation and sensors
 - **interoperable** to manage data exchanges between components
- Development of **methods /tools** for :
 - HPC multiphysics couplings for numerical simulation
 - Data management and processing

Developments by « **technological blocks** » with a modularity adapting to :

- Progressive development of Cigéo
 - Evolution of design
 - Evolution/consolidation of scientific knowledge
- Strong link with BIM/3D digital model*

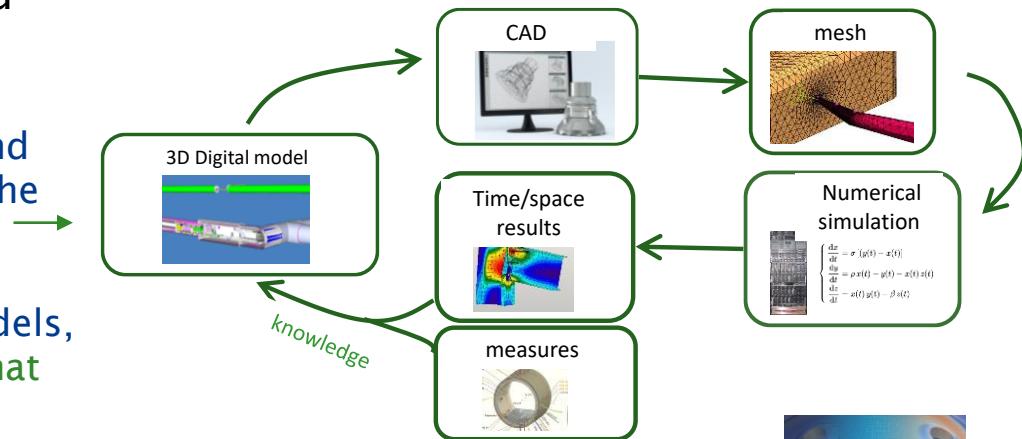


4D Multi-physical Digital Twin of Cigeo

Strategy of development (3/4)

Main works about **digital ecosystem** and management of **interoperability** :

- Benchmark of existing platforms to test and manage interfaces with different tools of the global chain
- Implementation of solvers (tools, metamodels, reduced models) with **Data Exchange Format**
- Specific works
 - Simplification of « object tree » for each (component/physical process)
 - Compliance between exhaustive list of 3D digital model vs modelled component
 - Techniques of interpolation in space/time approach
 - Implementation and projection of big amount of results on 3D digital model

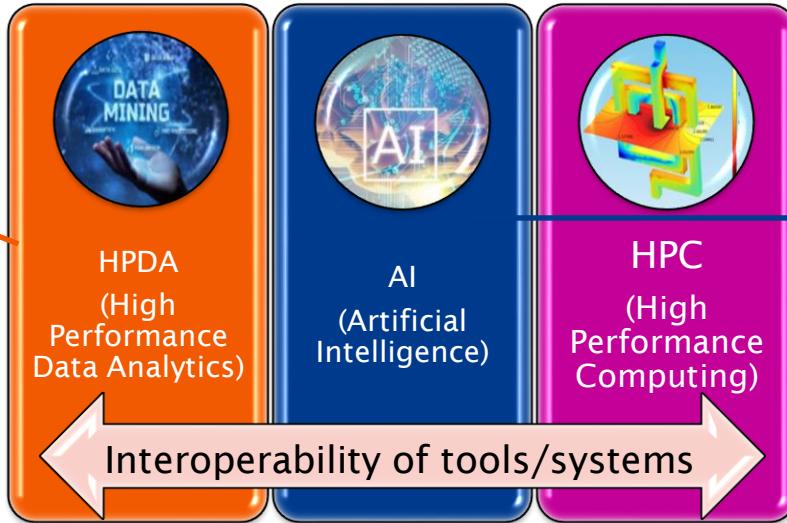


4D Multi-physical Digital Twin of Cigeo

Strategy of development (4/4)

Main R&D efforts carried out in the field of digital twin...

- Processing, transferring, storing and securing large amount of data
- Data assimilation & fusion algorithms



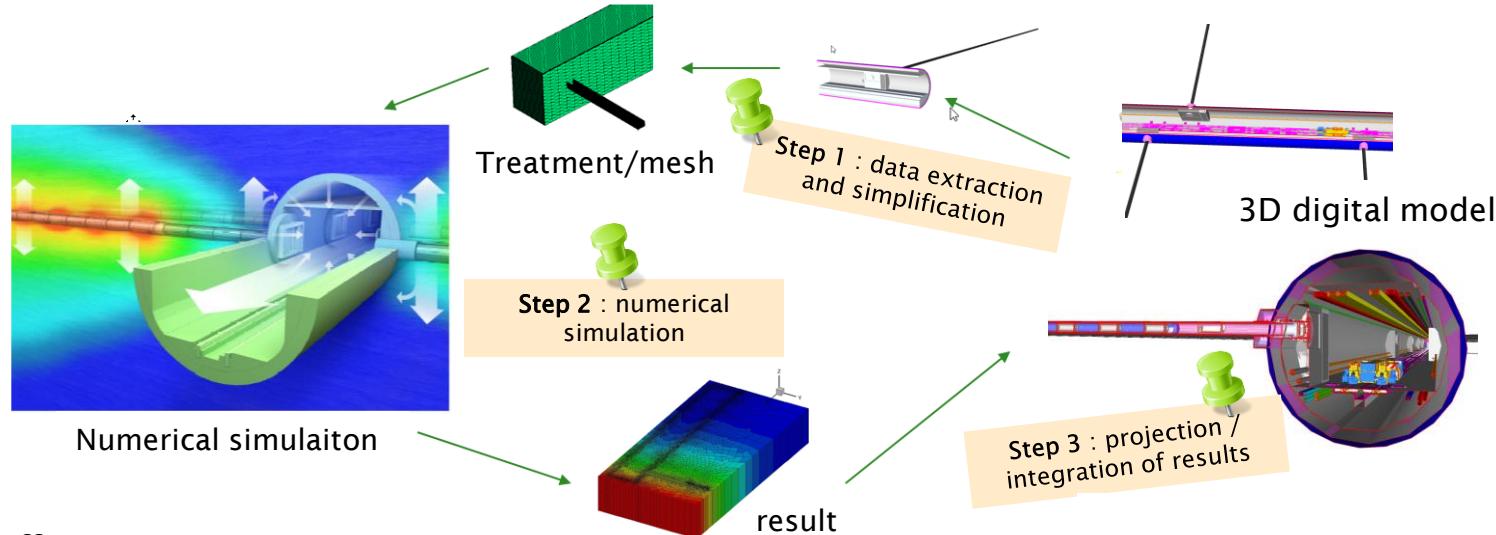
- Multi-physical and multi-media couplings
 - Efficient and robust highly // solvers,
 - Model calibration
 - Meta-modelling
 - VR/AR algorithms
-
- Machine learning algorithms for simulation and data processing
 - Geo-learning
 - Decision-making tool

... tested on 3D digital model and experiments / demonstrators in URL, in order to validate **technological blocks**



Examples of work in progress

Example 1: integration of thermal evolution of HLW disposal cell (1/3) Cycle process to test interoperability of tools

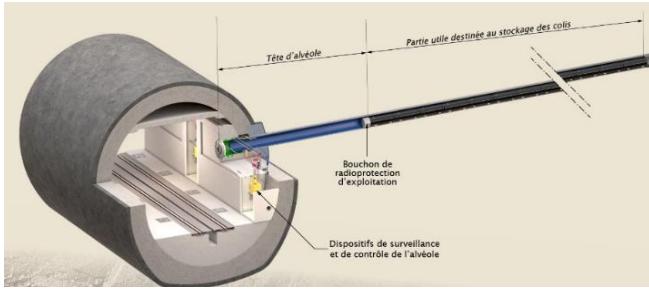


Different steps

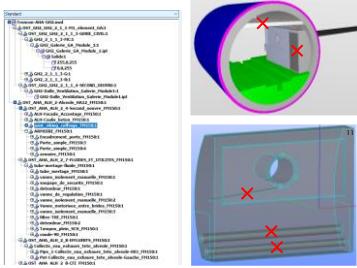
- implement a process sequencing extraction, adaptation and meshing of a geometry from the 3D digital model,
- perform a numerical simulation out of the 3D digital model
- project and integrate the results (space/time) within 3D digital model → contribution to 4D digital twin

Example 1: integration of thermal evolution of HLW disposal cell (2/3) From detailed geometry to grid

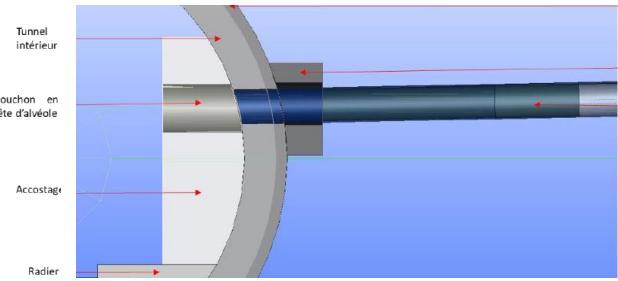
Detailed basic geometry



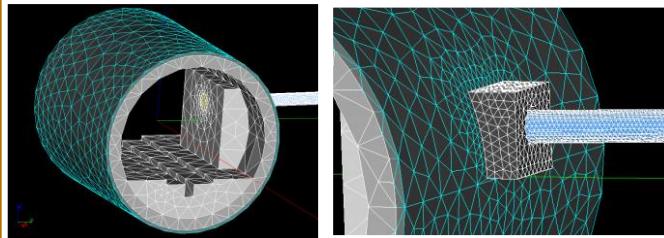
Simplifications



Simplified and « cleaned » geometry



Mesh geometry



« STEP » format
(CAD, mesh)



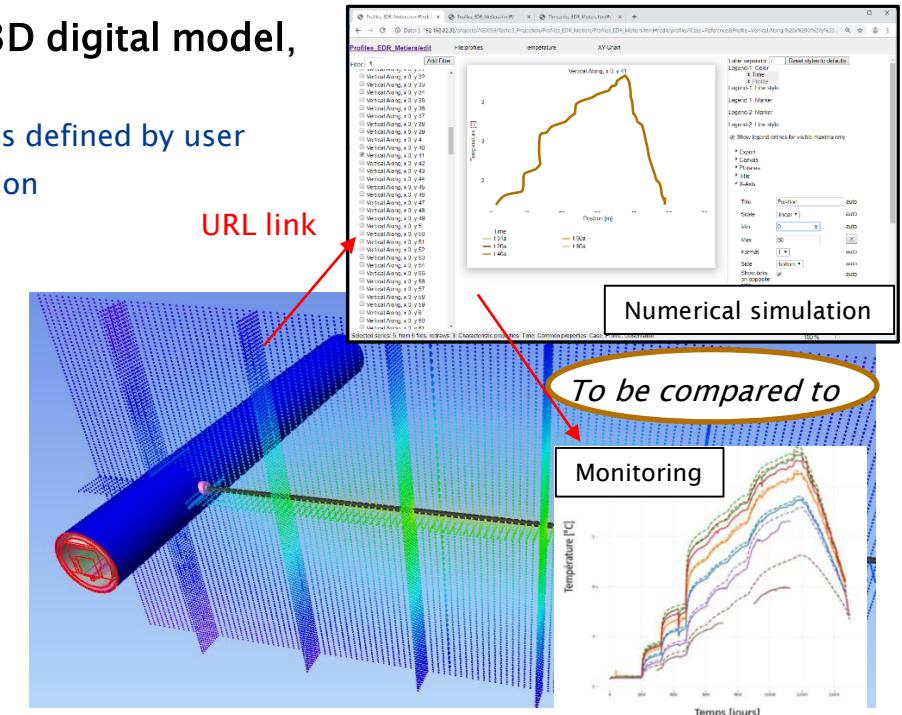
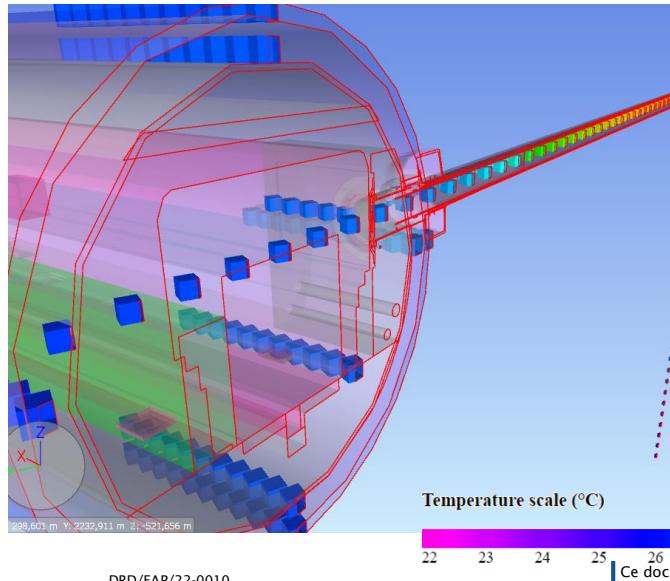
Tetrahedral mesh

Example 1: integration of thermal evolution of HLW disposal cell (3/3)

Projection of thermal results in 3D digital model

Integration of temperature plume in 3D digital model, through small « volumic » cells :

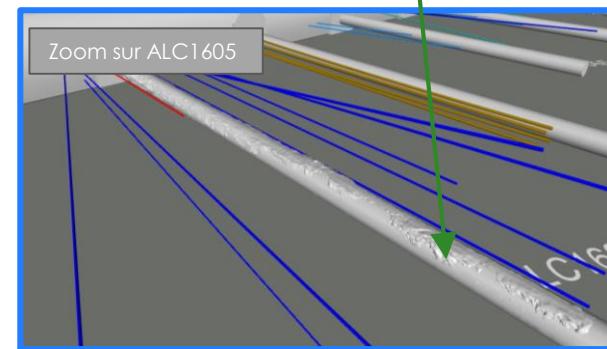
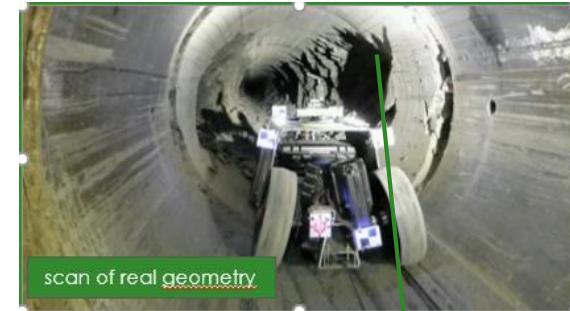
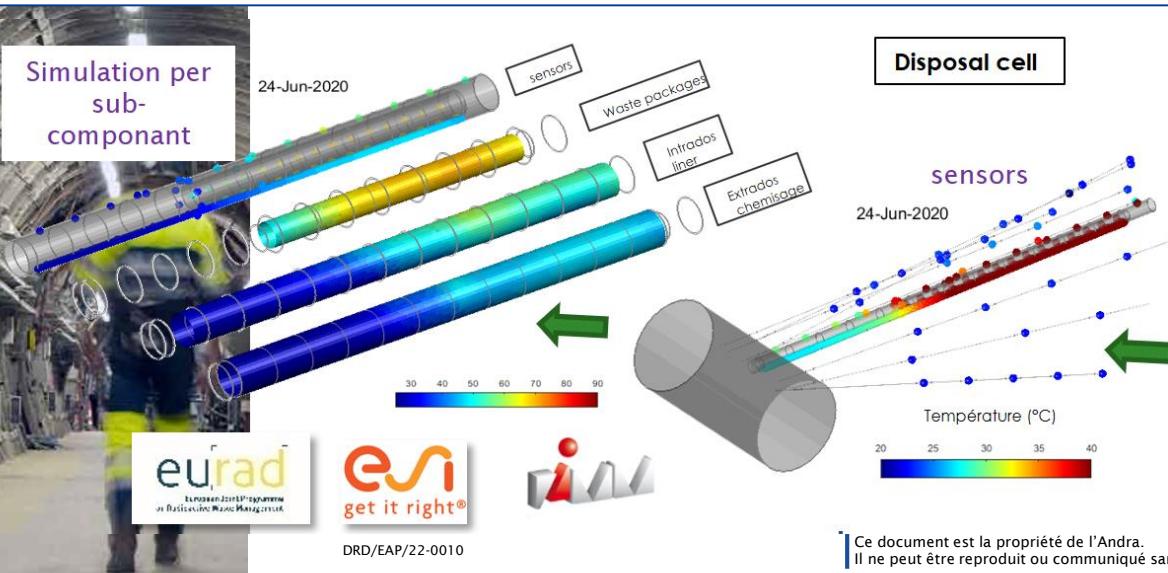
- Adjustable number, position and size of cells defined by user
- Independent from grid in numerical simulation
 - Interpolation algorithm



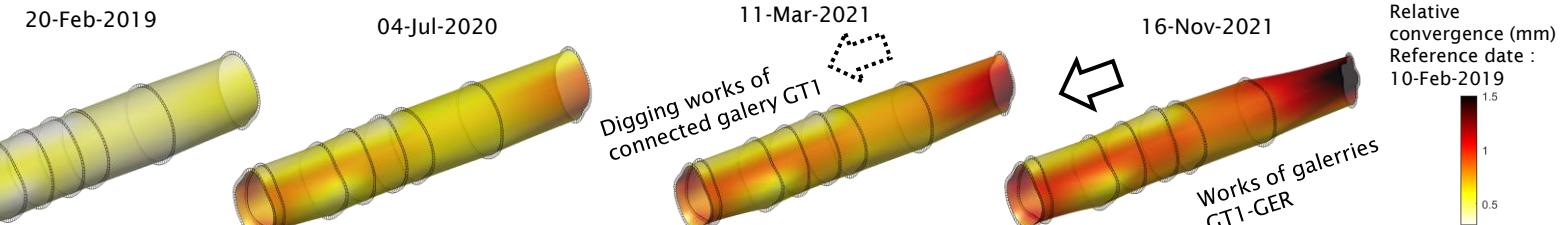
Example 2 : construction of DT of HLW disposal cell demonstrator Work in progress in WP MODATS (EURAD)

Main objectives

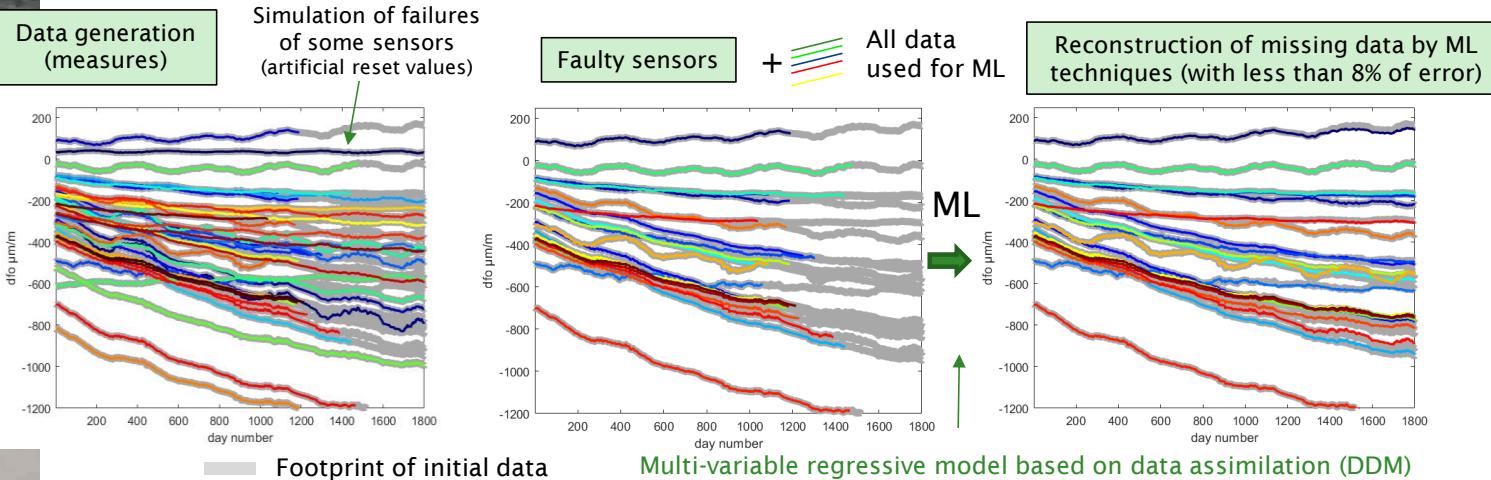
- Collect and treat informations about real geometry of components
 - 3D Scan Lidar of excavation
- Set up thermal model (grid, calibration phase, simulation)
- **Digital twin** of thermal evolution of HLW disposal cell
 - Comparison measures/simulation
- Artificial generation of drifts, failures in sensors to analyze abnormal regimes



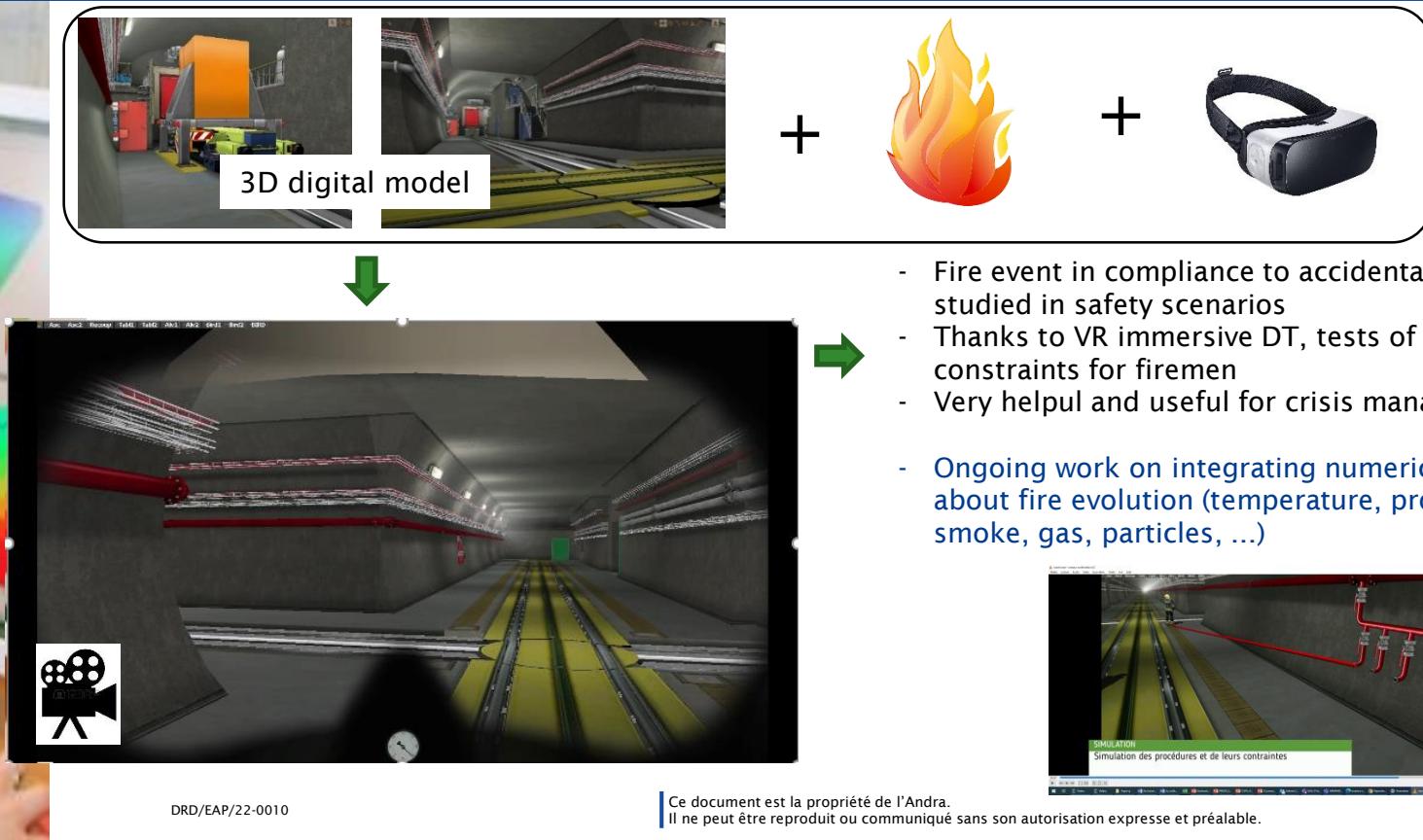
Example 3 : Machine learning techniques to reconstruct missing information in DT ORS experiment (convergence) – Data assimilation method

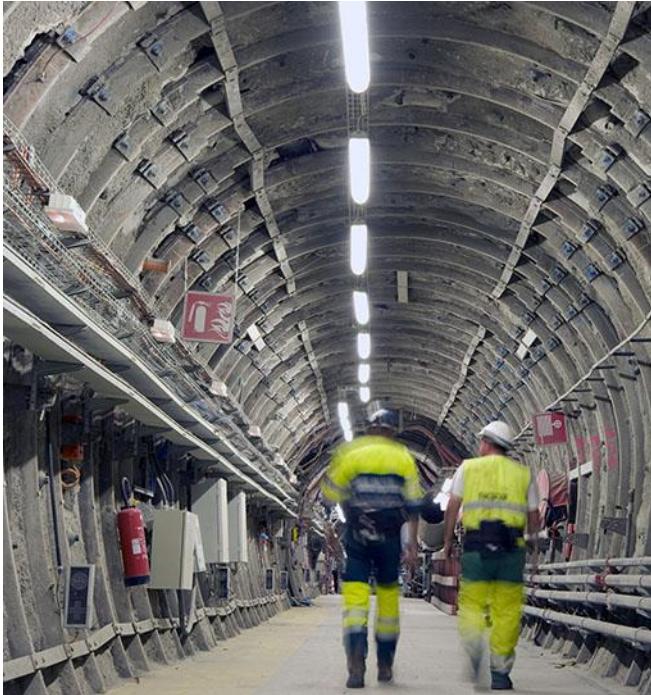


132 extensometers located over 8 rings to measure radial and ortho-radial deformations at the intrados and extrados of the gallery concrete liner.



Example 4: Cigeo Digital Twin for accidental scenario VR Immersive and dynamic approach for fire event





THANK YOU

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