Reversibility and retrievability

Governance and Technical approach

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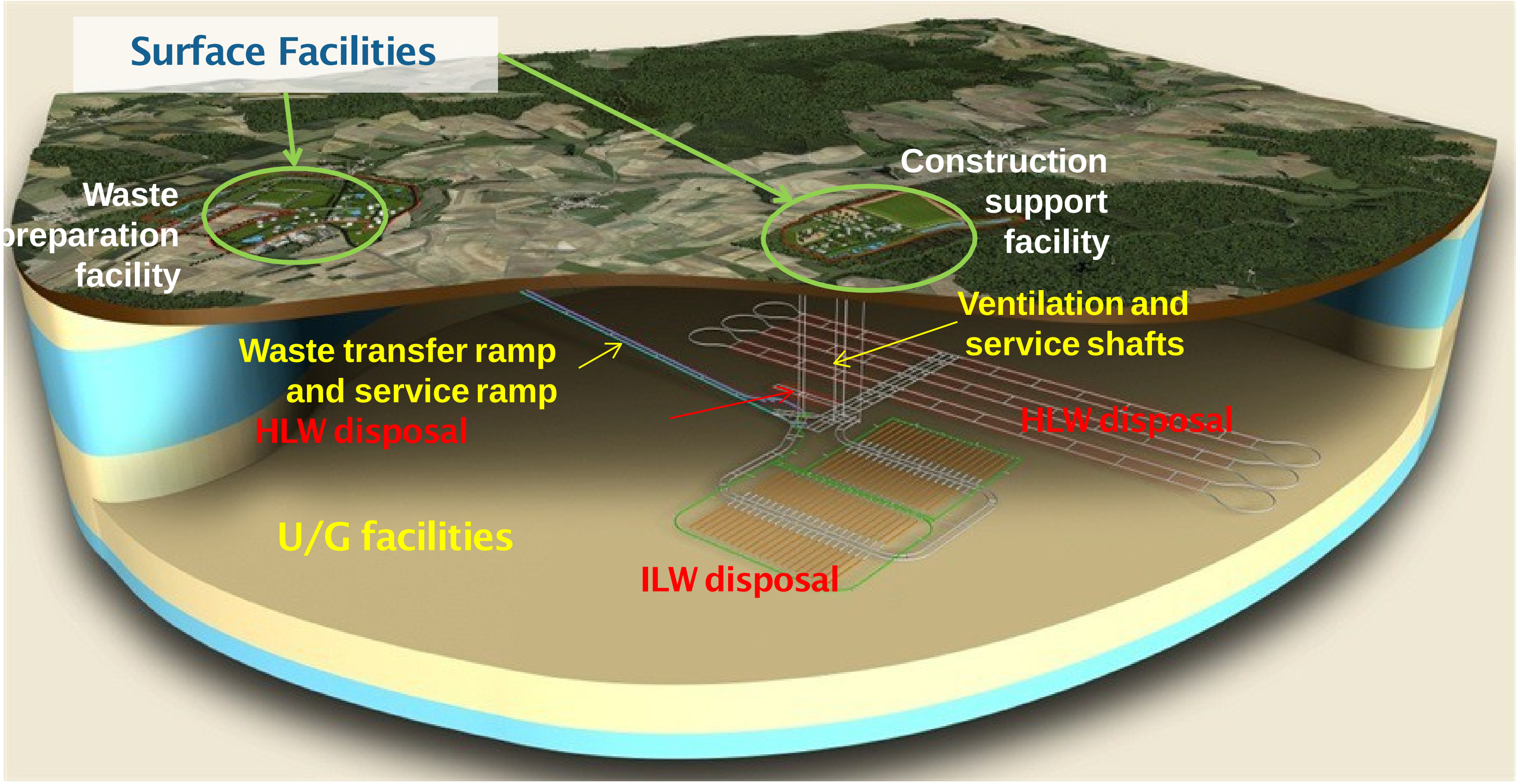
Cigéo at the end of 120 years of operations

The underground facility is hosted 500 m deep in thick argillite (hard clay) formation



The history of reversibility in France

- **Law of December 31, 1991: request for the study of a repository, reversible or irreversible**
- **1992-1998: search for sites for the implementation of an underground laboratory**
  - Emergence of reversibility as an important issue for public acceptance and political decision-making (1998 CNE report on reversibility)
- **June 28, 2006: Law for the Sustainable Management of Radioactive Materials and Waste**
  - The disposal must be reversible and the reversibility period will not be less than 100 years
  - A future law will define the conditions of reversibility
- **2006-2012:**
  - Exchanges with local stakeholders to know their expectations
  - Exchanges with the scientific community (Symposium Nancy, 2009); AEN Reversibility & Retrievability Project, 2007-2011; Reims Conference, 2010)
  - Emergence of two notions of different levels: Reversibility of decisions and recoverability of waste
- **2012-2016: Public debate Cigéo / preparation of the law**
  - Andra's declination of the concept of reversibility in the form of "tools“
  - Vote of the law of July 25, 2016

Public debate input for a new vision on reversibility

2013-2014 Public Debate in France followed by Andra's proposals

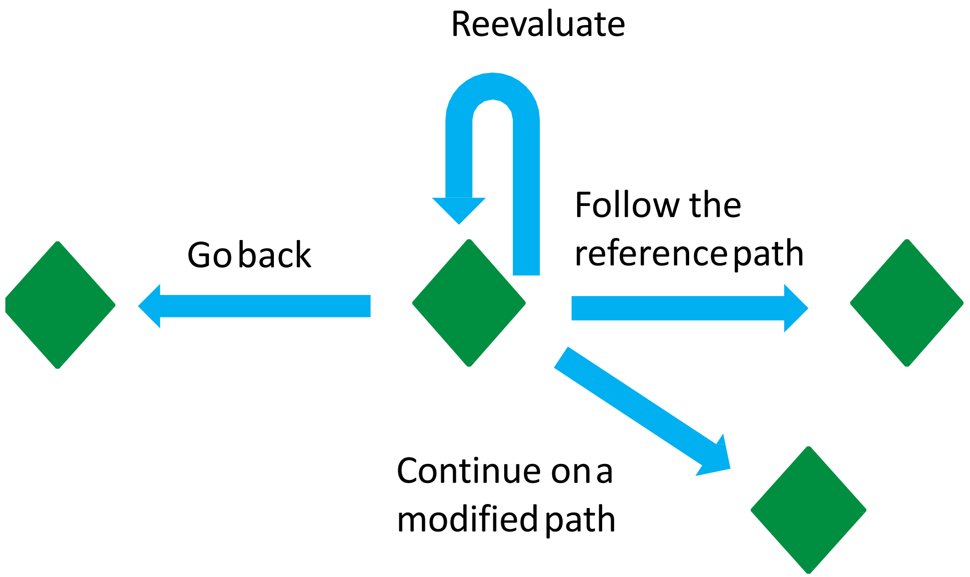
- Take a decision which commits the society for **120 years (4 generations!)** is not reasonable
- It is therefore necessary to make the **decision progressive** in order to make it possible

➪ *The concept of reversibility is moving towards a Governance approach, for which technologies provides tools*

- In such a context it becomes possible
  - To allow a learning phase
  - To give way to technical progress
  - To enable the next generation to redirect choices made before or to go back: *every generation decides for itself, leaving open the option for the following*

Meeting the expectations regarding reversibility

- Reversible disposal may be defined as a progressive process, where freedom of choice is left at each step: “Reversibility is the capacity, for successive generations, either to continue the construction and then the exploitation of the successive phases of a disposal, or to re-evaluate the choices previously defined and to modify the management solutions "



So that:

- Allows a gradual and controlled implementation of the repository
- Alternative waste management options may be chosen if relevant
- In case of undesired repository evolution, corrective actions may be implemented
- If waste becomes a resource, it may be retrieved.

PARS : a powerful tool to describe the phenomenological evolution of disposal /environment

Objective

Description of the evolution of phenomenological processes which affects in space and time radioactive waste disposal and its environment

Constraints

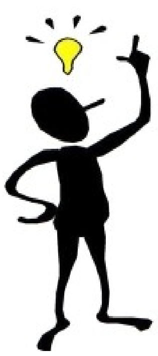
- Many components / materials / interfaces / (coupled) processes
- Management of :
  - 6 orders of magnitude in time
  - 7 orders of magnitude in space

How to do ?

Needs to set up a specific approach / methodology

Tool to fullfil objective

Phenomenological Analysis of Repository Situations (PARS)



From phenomenological assessment to safety assessment

Phenomenological assessment	Preliminary assessment	Safety assessment
	• All components • Quantification THMC processes which have an influence on hydraulic and release/transfer of radionuclides ❑ Influence of T, 2-phase-flow,EDZ, chemical degradation, geodynamic evolution, …	• Quantification/verification of the safety function affected to a component to ensure safety • “Weight” of component and/or physical process on the global performance of the system • Quantification of radiological/toxical impact in the global system *(hydraulic and transfer migration)*
Basic and sound detailed quantification *(space/time)* THMCR evolution of disposal and geological environment (+ uncertainties)	Evolution of disposal and geological environment ***in terms of release and radionuclide transfer***	Quantification of safety scenario (normal and altered evolution)
PARS	**Conceptualizatio n of scenarios (models, data)**	**Safety reports**

Reversibility

Reversibility = enhancement of the possibilities given to next generations to reconsider the decisions taken previously, of the range of choices open to future generations.

In practice, the implementation of reversibility relies on a set of governance (G) and technical (T) tools:

- ***(G) Continuous improvement of knowledge (R&D; monitoring);***
- **(T) Incremental development, progressivity of construction;**
- **(T) Flexibility of operation and relating time-schedules;**
- **(T) Adaptability of installations;**
- ***(T) Retrievability of waste packages;***
- **(G) Transparency and transmission of knowledge;**
- ***(G) Involvement of society;***
- ***(G) Control by the State and reviewers under the supervision of the Parliament.***

Retrievability – One of the tools for reversibility

- Retrievability can’t be demonstrated indefinitely

↳ Retrievability can only be a tool for reversibility, not an objective and an end by itself

- **COST** linked to retrievability
  - Retrievability does not imply high costs if it is considered at the design phase and thus be intrinsic to the disposal design
  - Taking account of retrievability from the early design stages is estimated to be at the level of a few % of the total cost (2 to 10)
  - The cost for retrieving will have to be supported by the generation making the decision for; it does not need to be provisioned by the present generation

Retrievability – One of the tools for reversibility

- The waste from Cigéo's inventory is ultimate waste:
  - There is no intended use of these wastes (for the oldest, after about half a century of surface storage and research)
  - Most of this waste comes from spent fuel recovery operations - the recoverable part of it has been extracted
- Our generation plans to dispose waste in Cigéo without the intention to retrieve it later (European directive of July 19, 2011)
- Cigéo is designed to be closed (dismantling of equipments, backfilling, seals…). Closing operations naturally increase the level of the effort required to go back and remove packages
- Then, the recoverability (the ability to withdraw packages disposed in Cigéo) is not viewed as an end in itself. It only makes sense when associated with the other tools of reversibility and when it contributes to it:
  - Flexibility offered to the operator (rearrangements, modify the conditioning process before finally disposing of the waste)
  - Based on an improved knowledge, ability to redirect all or part of waste to other management facilities (the long-term safety of which should be at least equivalent to that expected from Cigéo)

Disposal concepts and retrievability (1/2)

The production of a deliverable including all elements related to retrievability is a commitment of Andra following up the 2013 Public Debate.

The main design options on which retrievability is based are :

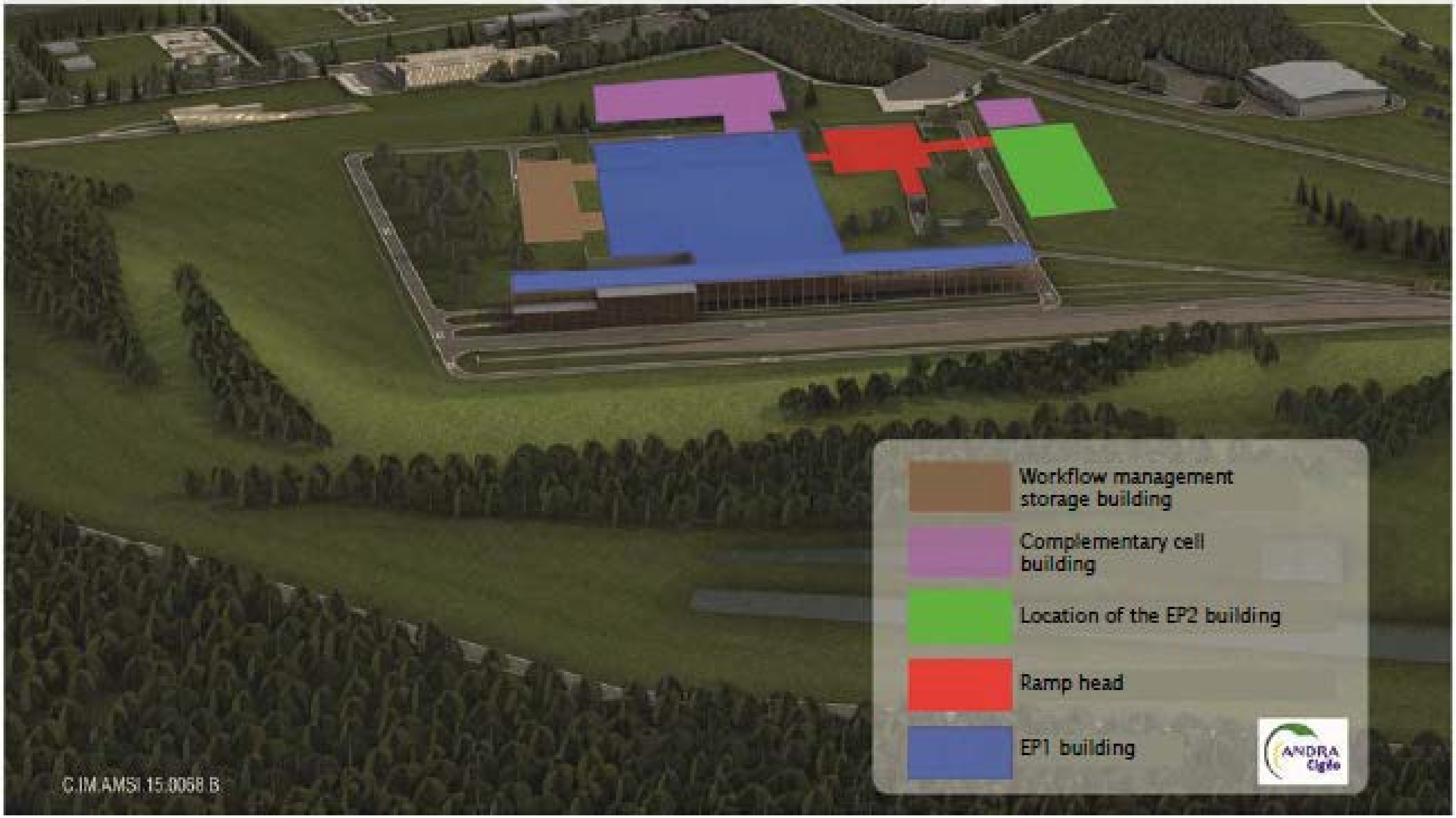
- robustness and durability (functions, constrains during operation, principles of design, dimensioning, manufacturing): containers, cells, equipment left in place in the cells
- monitoring of retrieval conditions: availability of functional clearances, monitoring conditions in the cell and of the components
- Performance of the equipment for retrieval operations: design basis (HLLLW package removal robot), in situ performance evaluation(penalizing conditions)
- Ability to deconstruct Cigéo partial closure structures: design, ability to deconstruct closure structures and to re-equip the installation

Disposal concepts and retrievability (2/2)

The main design options on which retrievability is based are (continued):

- incorporation into the design of preventive provisions
  - Reservation of space in the handling cells to install specific equipment
  - Reservation of areas on the surface for the construction of buildings possibly necessary for hypothetical scenarios of retrieval (workshops of expedition ...)
- realization of specific and necessary operations on the assumption of a possible retrieval of waste packages
  - Training of staff for dedicated operations
  - Specific controls
  - Information management (cartography, "material library" ...)
- periodic re-evaluation of retrieval conditions

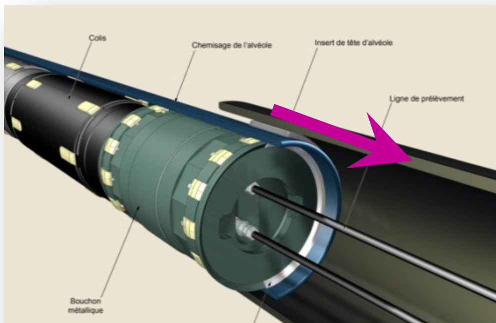
Locations of the surface facilities dedicated to retrievability



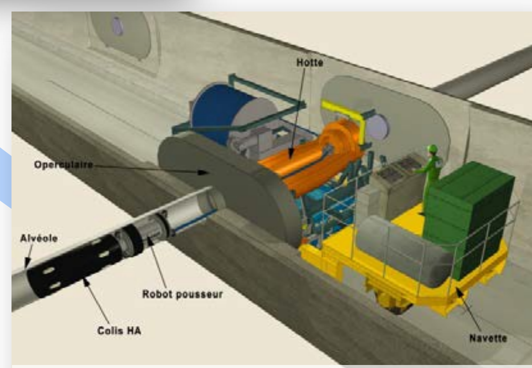
Reversibility: Retrievability

Equipments, waste packages, disposal cells designed in order to allow package retrieval

Waste package removal tests in a deformed cell



Opening of the cell



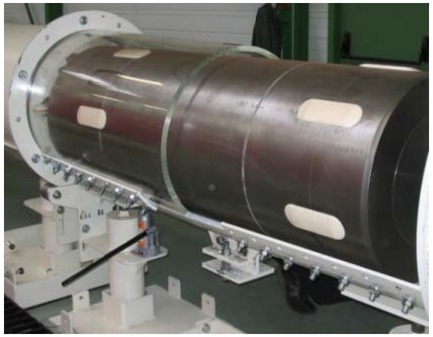
Retrieving the waste package

Transfer back to surface

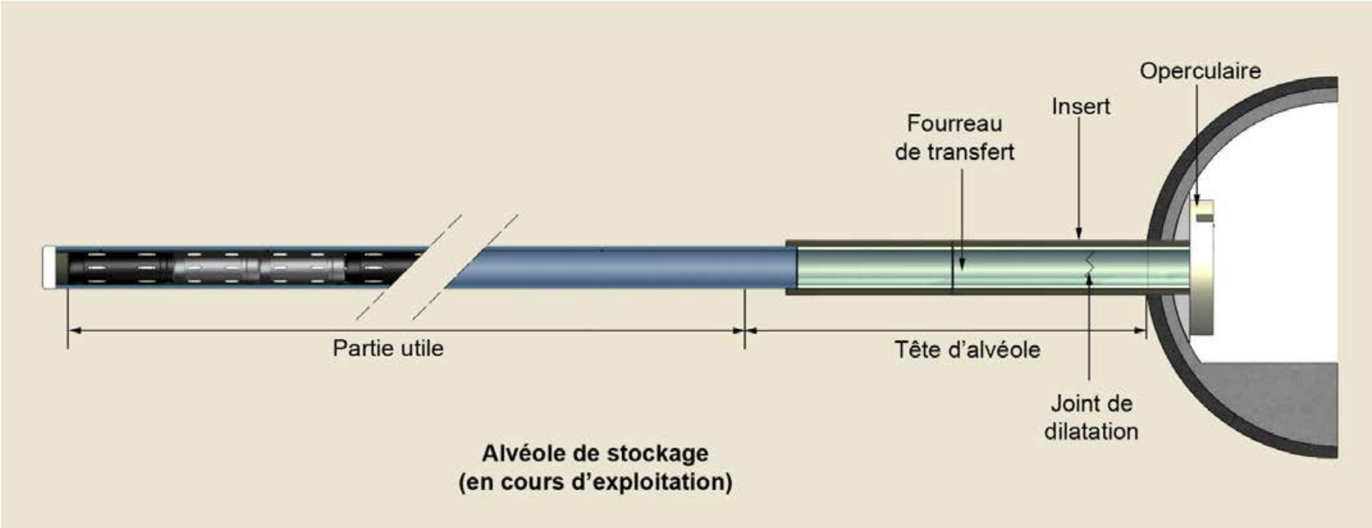
Design features supporting retrievability (HLW)

The waste packages are emplaced into disposal cells :

- ❑ The liner maintains a gap around the packages, making retrieval easy if decided
- ❑ In order to limit corrosion, specific features are studied for tight assembling of the liner and for a low change of air after waste emplacement



HL waste disposal package



Test to retrieve a waste package from a distorded disposal cell

Stability with evolving environment

- The development of the project is very progressive, as will be its construction
- This progressivity implies the concept of reversibility
  - Providing the possibility to retrieve already disposed of radioactive waste packages
  - Allowing a gradual and controlled implementation of the repository
- It also offers opportunities for
  - Adaptability, including optimization
  - Flexibility (options for SF direct disposal)
  - Testing at scale 1 (industrial pilot phase)
  - Controlling: monitoring
  - Implying next generations in the decision process, letting them a burden with already available solutions, but also with the freedom of developing their own solutions
  - Making funds available

Our challenge for 2019 is to be able to tell a story with solutions, but also with open options to make it “as evolutionary as possible”

A geological disposal under the control of society

To regularly review the operation of disposal and decide together the next steps

- ❑ **Regular appointments with all actors: residents, communities, reviewers, State …**
- ❑ **Consultation on the basis of:**
  - The results of safety reviews
  - The industrial, monitoring, socio-economic impact feedback
  - Technical developments and advanced searches
- ❑ **1st appointment proposed 10 years after commissioning**

Additional implications and conclusion

As a direct consequence of the reversibility process

- Monitoring of the disposal cells and waste packages behavior
- Long-term memory keeping

Reversibility implies additional technical requirements

- But it relies on the real operation life of the repository and on the progressivity of decisions
- Additional costs are minimized when considered at the early stage of design

Reversibility provides opportunities

- Flexibility for future policies, by taking account of the direct disposal of SF
- Integration of new technical developments during the lifetime of operations

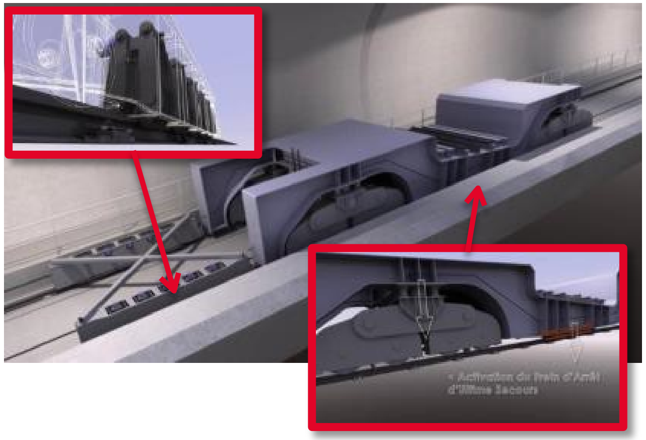
End of a contradictory debate between storage and disposal ?

Main objectives of the monitoring of Gigéo

Check that the installation remains in the nominal operating range as defined in the safety report and in the general operating rules

Salle de commande

Identify any possible operating drifts of the installation, likely to bring the installation out of this nominal operating range in the absence of corrective actions



Monitoring of Cigeo: 2 aspects

Classical monitoring of industrial (nuclear) facilities

- Nuclear/industrial processes
- Workers safety…

Specific monitoring associated with radwaste disposal specificities

- To support **retrieviability** of radwaste disposal packages
  - as tool for **reversibility** (i.e. governance of Cigéo) during operation
- To support assessment of **consistency of disposal system state (components) during operation with post closure functions**
  - To ensure that components of disposal system will fulfill their post-closure safety functions

Monitoring of Cigeo: Overall strategy

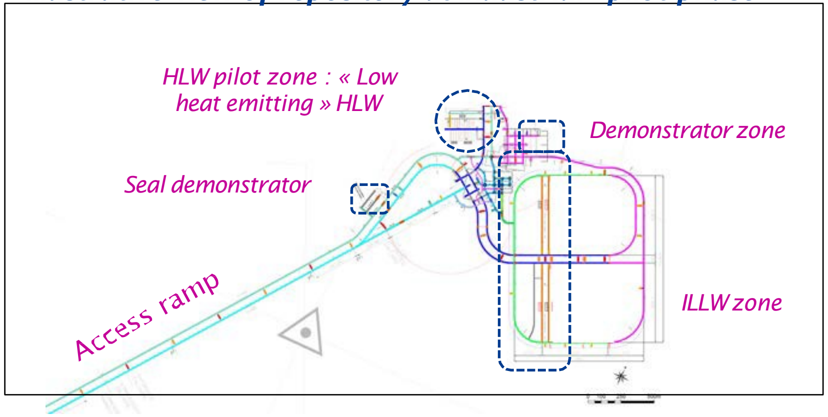
The licensing operation (around mid 2019)

- To define a preliminary monitoring plan
- To assess the capability of the monitoring system to fulfill its functions with relevant arguments on feasibility of the monitoring system: Not a demonstration at this milestone and focus on the disposal cells

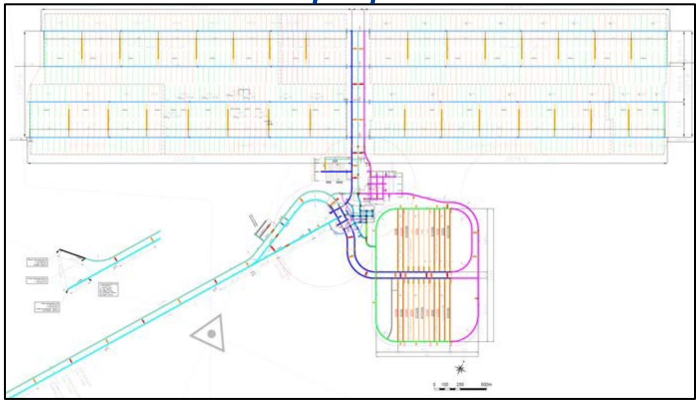
The industrial pilot phase (around 2025)

- The first step of Cigéo before authorization for progressive complete operating
- A monitoring process that measures the parameters related to the dimensioning and the behavior of the structures for a secular exploitation
- A monitoring relying on parts of the underground installation (test underground structures) subject to specific monitoring measures
- To assess the capability of monitoring system to fulfill its functions
  - ILLW zone and HLW pilot zone (with "low heat emitting" HLW): A few disposal cells : to monitor common cells and to deport part of monitoring in « witness » cells
  - Demonstrator zone: Seal and future optimizations (large diameter drift or ILLW disposal cell…)

Illustrative view of repository at industrial pilot phase



Illustrative view of disposal at closure



Monitoring of disposal cells: HLW disposal cells

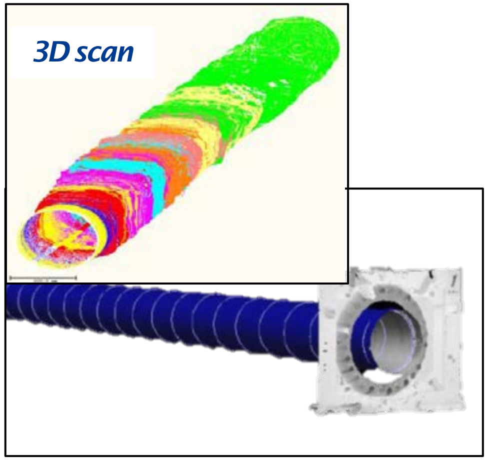
Host-rock

- To check that favorable properties of Callovo-Oxfordian are preserved
  - Temperature, pore water pressure, stress, strain in boreholes around the disposal cells and the zone

Metallic Sleeve and HLW over-pack

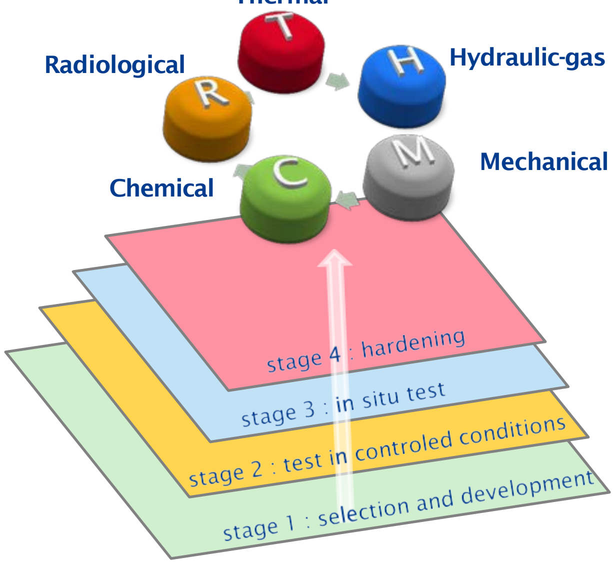
- To check the ability to retrieve waste packages
  - Sleeve strain
  - Functional clearance between sleeve and HLW over-pack
- To check that the post-closure safety function “to protect waste from water" is preserved
  - Measurement of mass loss on metallic coupons
  - Gas composition into the disposal cells (H_2, O_2…)
  - Temperature and Hygrometry
  - Liquid water flow and chemical composition of liquid water (corrosion)

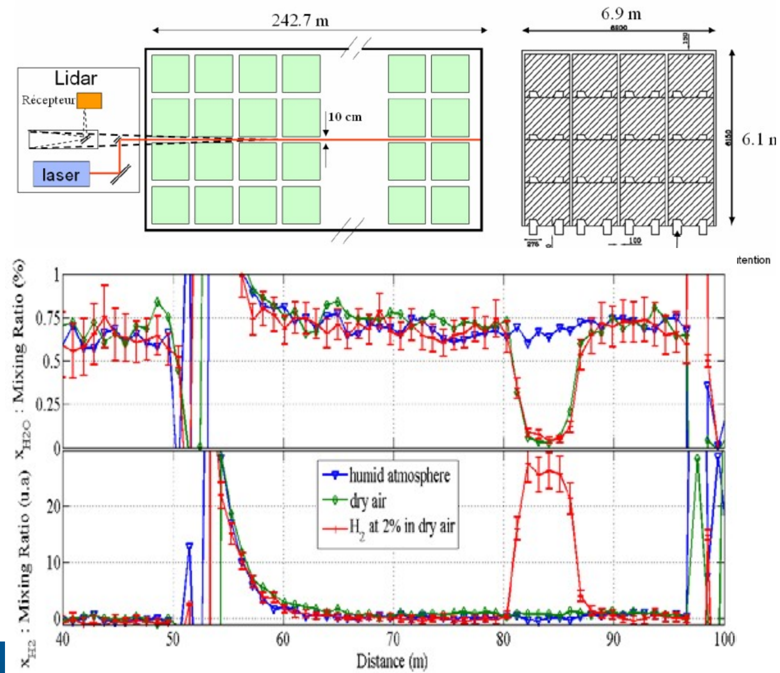
Monitoring of sleeve strain and clearance between sleeve and HLW over-pack



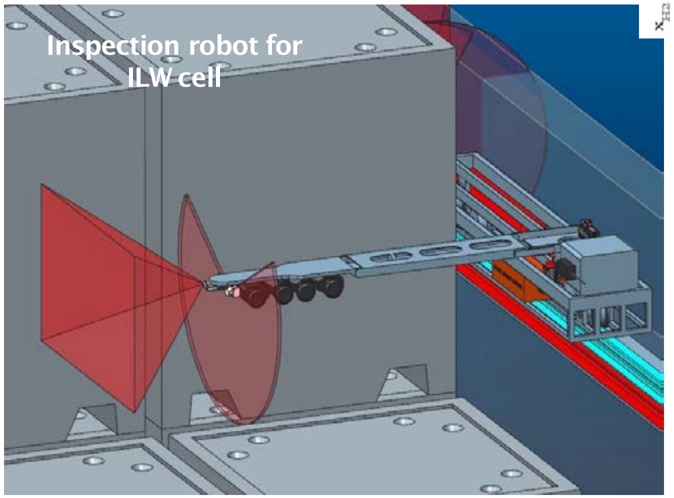
Monitoring of Gas composition within the disposal cell

RD&D for monitoring strategy development: non-intrusive and maintainable equipements





Raman Lidar
Spatial profile of H2 concentration


Inspection robot for ILW cell

Inspection robot for HLW cell

ROBOTS

Viewing of the underground infrastructures and waste packages

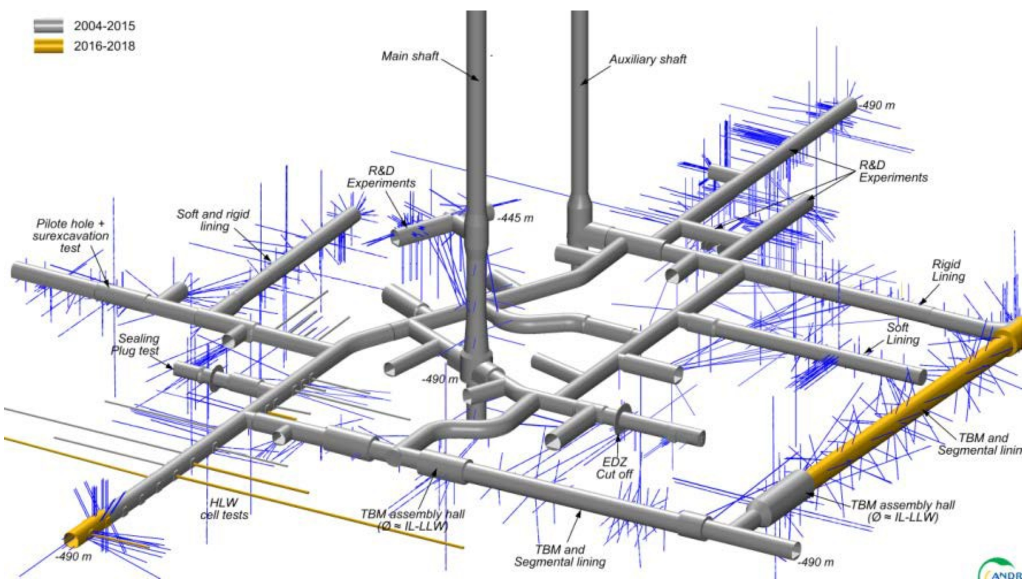
Monitoring the evolution of the geometry of the infrastructures

Measuring temperature

15 years of feedback from the URL operations

- 11005 operating sensors in june 2017
- 1,6 millions of data recorded everiday in the database
- 3 billions of data already recorded in the database

25 different technologies



Physical parameters monitored

- Température
- Water content
- Water flow
- Total pressure
- Pore pressure
- Relative humidity
- Déformation
- Creep
- Shifting
- tilt
- Conductivity
- Ph, Eh

Summary (1)

- Ethical concerns for reversibility originate in the time scale required to manage the most harmful radioactive waste and especially Cigeo's century-long service life.
- The cost of technical measures taken to ensure reversibility is factored into in the project, meaning that current generations are providing future generations with easier options for acting on the disposal process. However, should future generations decide to exercise these options, for example, to modify the repository to allow the emplacement of new types of waste or remove waste packages, they will have to take responsibility for their decisions.

Summary (2)

- The 'incremental development' of Cigeo gives future generations the possibility to accelerate or delay Cigeo's construction. It promotes the inclusion of future phases of construction and all improvements made possible throughout the project's century-long service life by scientific and technical advances and feedback.
- More particularly, optimization opportunities that have already been identified but which have not yet reached a sufficient degree of technology maturity for inclusion in the construction license application to be filed in 2019, if their licensing is granted, be integrated into subsequent stages of the project

Summary (3)

- Operational flexibility gives future generations the possibility delay or accelerate (within certain limits related to equipment performance, equipment usage rates, and operator availability) the flow of packages emplaced within Cigeo. It also makes it possible to amend the reference closure scheme to foresee or delay partial closure operations.

- The adaptability of Cigeo's facilities makes it possible to modify the project following changes in its initial design assumptions, such as its reference inventory. Cigeo's design means that it can be adapted to the disposal of spent fuel or waste that is currently intended for near-surface disposal facilities (low-level long-lived wastes).

- Retrievability gives future generations the possibility to reconsider the decision to use deep geological disposal as a way of managing all or part of the radioactive waste packages emplaced at Cigeo.