DOPAS Training Workshop 2015

Learning Unit 2 : Preparation of an in-situ or full-scale plug or sealing experiment

How to come up with a coherent demonstrator program for plugs and seals

Theoretical basis to Andra's iterative safety assessment process and the latest safety assessment round including the role of FSS and REM experiments in DOPAS project

Jacques WENDLING (Andra/DRD/EAP)
D2 2.1 15 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Summary

General history of deep underground repository in France

- The 1997-2005 period : feasibility phase
- The 2006-2015 period : the Cigéo Project

General procedure for safety assessment analysis

- The FA (Functional Analysis)
- The PARS (Phenomenological analysis of Repository Situations)
- The QSA (Qualitative Safety Analysis)

The actual loop

- Major milestones in terms of safety loops
- Actual general planning
- Main planned experiences

Conditions for use of this training material

The training materials for the DOPAS Training Workshop 2015 have been produced partly with the European Commission's financial support. The materials can be downloaded from the DOPAS WP7 webpage and used in general freely without a permission for non-commercial purposes providing the source of the material and Commission support is referred to.

The figures and pictures in each presentation originate from the organization that has produced the specific training material unless mentioned otherwise.

Some photos and materials in the presentations present prior knowledge (background information) of the consortium partners. This information requires a permission for all uses from the copyright owner.

The information presented in this training material is to be used as a whole: partial reproduction may lead to misunderstanding and/or bad conclusions.

Non-commercial use means that if this training material is used e.g. in education, training, or consulting no fee may be collected from using this material.

For other uses, please contact the DOPAS project.

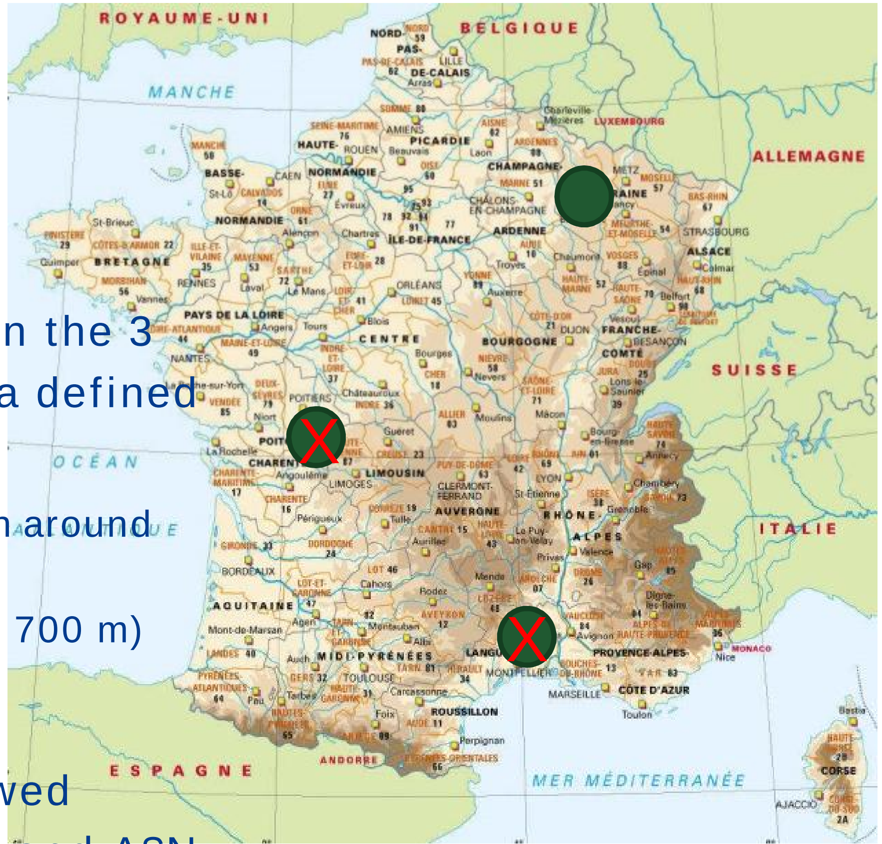
General history of deep underground repository in France

- The 1991-2005 period (the feasibility phase)
- The 2006-2012 period, the Cigéo project today

The 1991-2005 period: siting

1992-1994: Site screening for U/G research laboratories

- Consultation mission led by Member of Parliament Christian Bataille
- Site selection on the basis of voluntary sites
  - 2 types of rocks, 3 areas preselected :
    - *Granite: Vienne*
    - *Clay: Gard, Meuse/Haute-Marne*

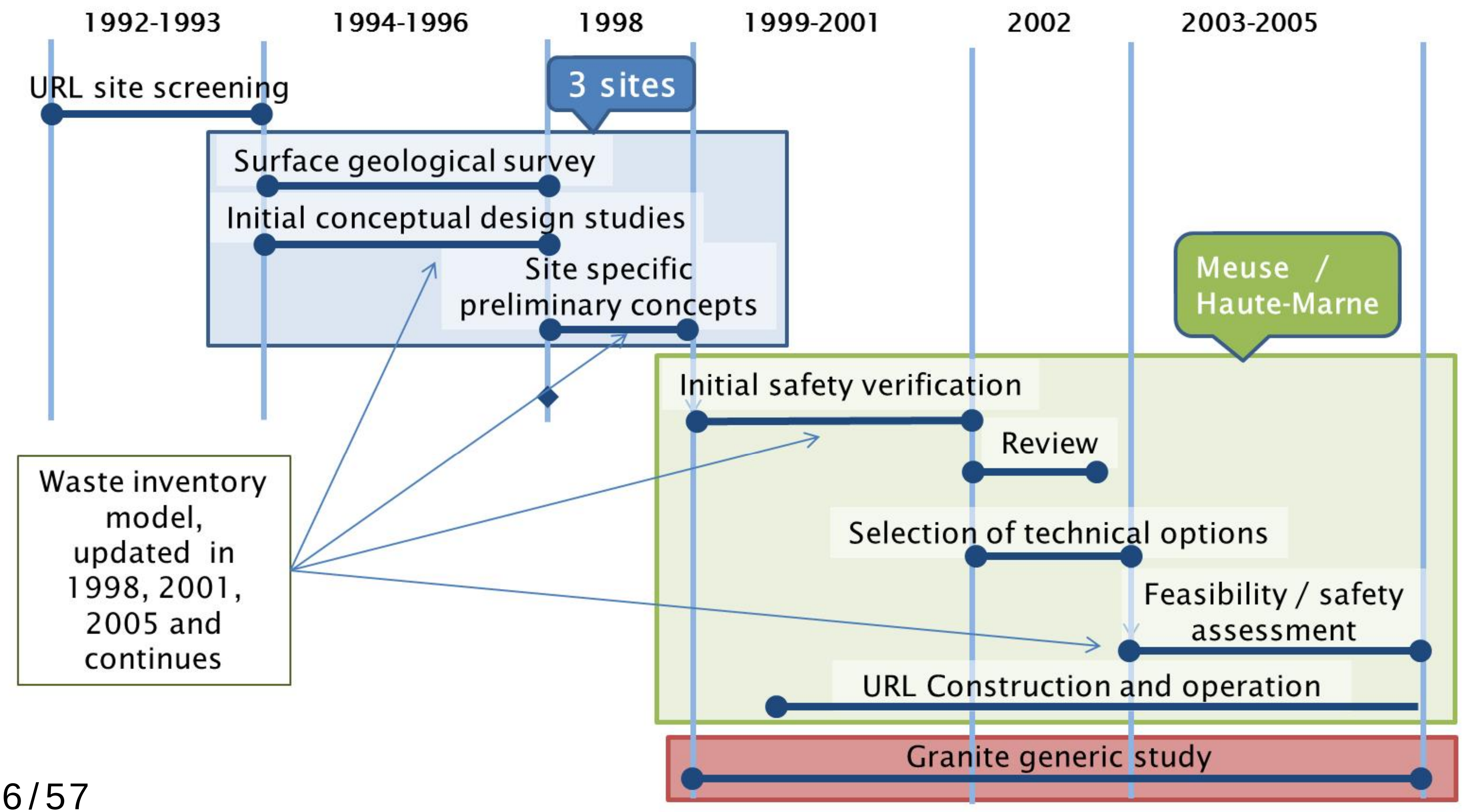


1994-1996: Above/ground geological survey in the 3 preselected areas, with regard to safety criteria defined by ASN (in basic safety rule 1991)

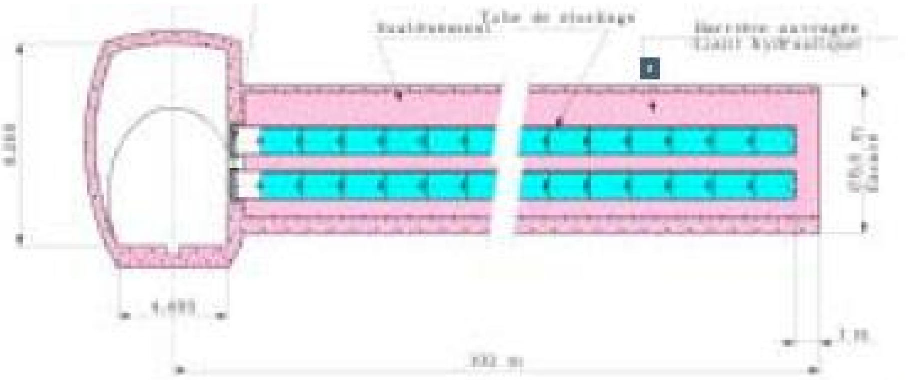
- 150 m thick clay layer in Meuse/Haute-Marne, depth around 500 m
- Thick high strength clay layer in Gard (depth around 700 m)
- Granite under sedimentary cover in Vienne

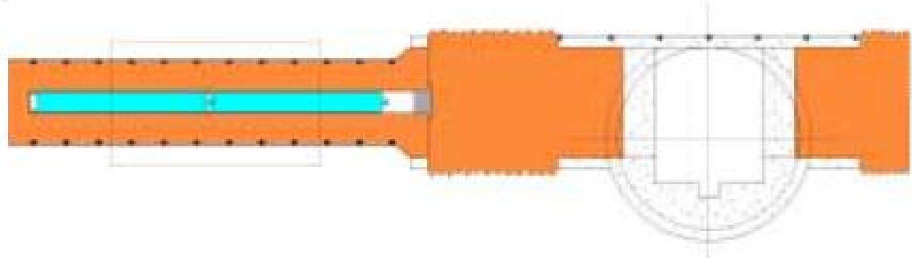
- 1996: Licence application for 3 URLs, reviewed 1997-1998 by CNE (National review board) and ASN
  1998: URL licenced in Meuse/Haute-Marne

The 1991-2005 period: From generic to site specific concepts

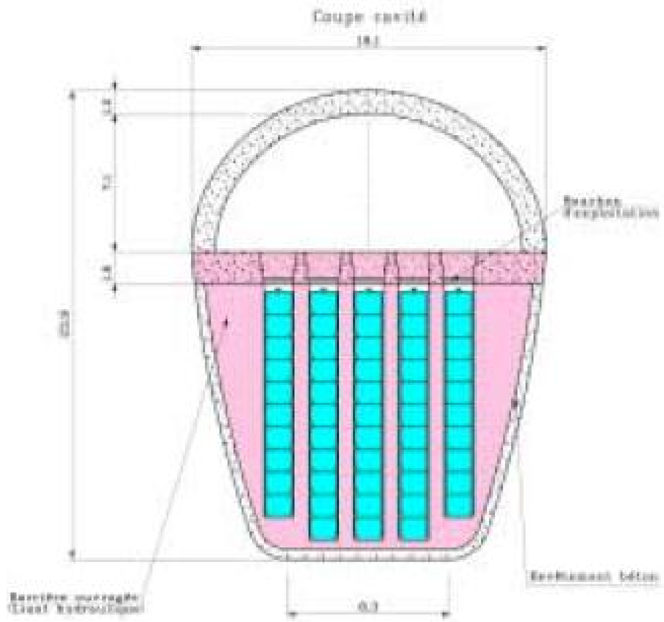


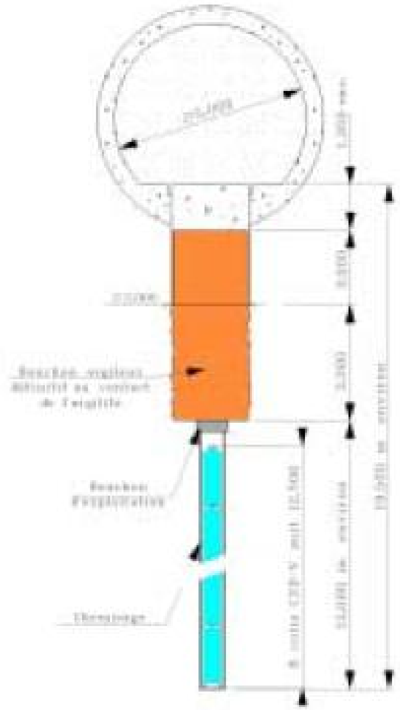
The 1991-2005 period: Andra's preliminary concepts in 1998-2001





No Heat emitting ILW





Heat emitting HLW

The 1991-2005 period: organisation

Basically two sub phases:

- Up to 2001, this is a very Research intensive phase, and the functional approach is shared between the project team and the safety department to guide the concept related work and structure the safety analysis.
- Between 2001 and 2005, in view of the 2005 milestone, there is a strong need to structure the overall approach:
  - The FA is developed by the project team for use both:
    - *By the safety department to work on the safety analysis (see the level 2 Dossier 2005 document "safety evaluation")*
    - *By the design team to describe very clearly the functions allocated to each of the main components (see the level 2 Dossier 2005 document "architecture and management of the geological disposal").*
  - The PARS is developed by the Research department (see the level 2 Dossier 2005 document "phenomenological evolution of the geological disposal"). The results are used for safety evaluations (quantitative).
  - The QSA combines both above approaches to define safety scenarios.

General history of deep underground repository in France

- The 1991-2005 period (the feasibility phase)
- The 2006-2012 period, the Cigéo project today

The 2006-2015 period: French HLW-ILW management scheme

2006 Act

UOX fuel reprocessing, Pu+U recycling (MOX, URe)

Heat decrease storage of final HLW

Disposal of HLW
- from 2025 for older HLW
- after 60-90 y. for currently produced HLW

- Vitrified fission products and minor actinides
- Experimental/special spent fuel

Interim storage of final ILW

Disposal of ILW from 2025, with a view to making the best use of storage capacities

- Fuel tubes, nozzels...
- Maintenance/dismantling waste
- Waste from liquid effluent treatment

Interim storage of reusable matter (MOX SF)

Reuse in GenIV reactors ?

Processing of minor actinides ?

Prospective studies of GenIV waste disposal

Heat decrease storage + disposal ?

As a precaution, direct disposal of spent fuel has been explored.

The 2006-2015 period: Stepwise siting combining geology/industrial/local integration criteria on a concertation basis

Area defined after local consultation (2009) for location of repository U/G facilities and detailed geological survey from the surface

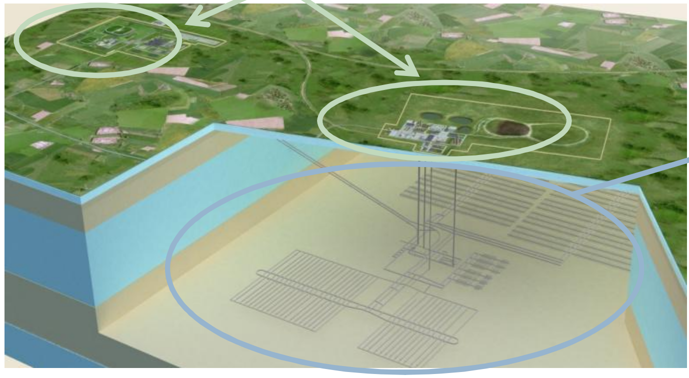
- Geological quality is a key factor
- Dialogue with local stakeholders

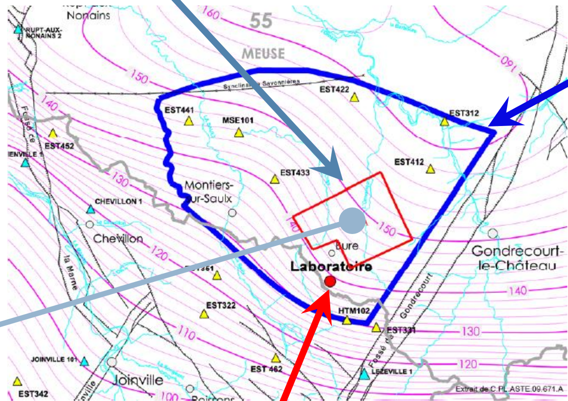
Detailed survey in 2010

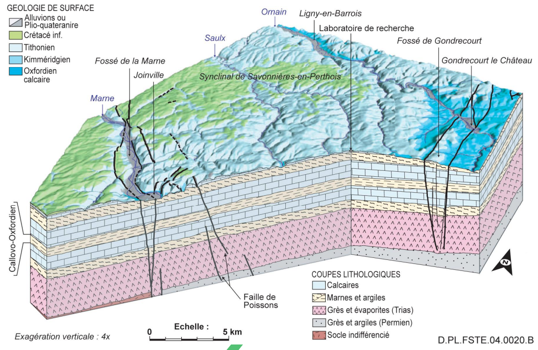
Additional above-ground geological survey 2007-2008

Transposition zone of URL results (proposed 2005)

Location of repository surface facilities under progress



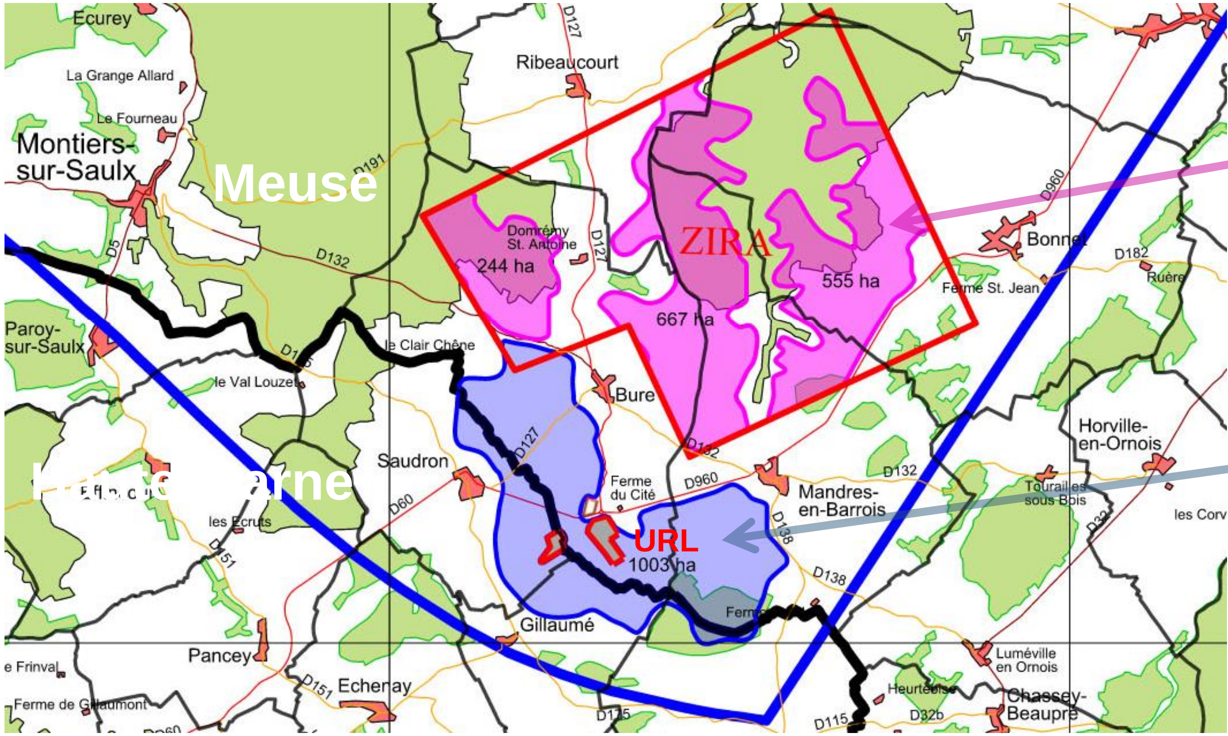




Siting started in 1992; URL licensed 1998

The 2006-2015 period: Stepwise siting combining geology/industrial/local integration criteria on a concertation basis

- Andra has set up a new dialogue phase to implement the surface facilities:
  - Meuse and Haute-Marne wish a sustainable partnership for hosting Cigéo.
  - The selected site will be validated for the DAC (2017)



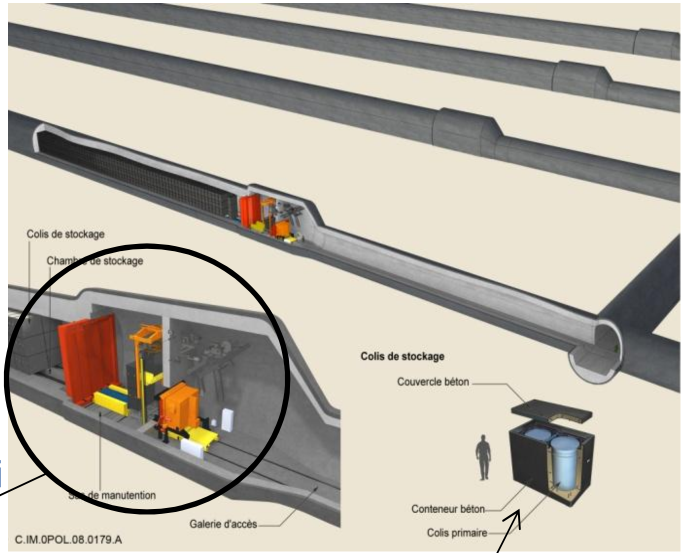
Potential areas for shafts

Potential areas for surface nuclear facilities and access ramp

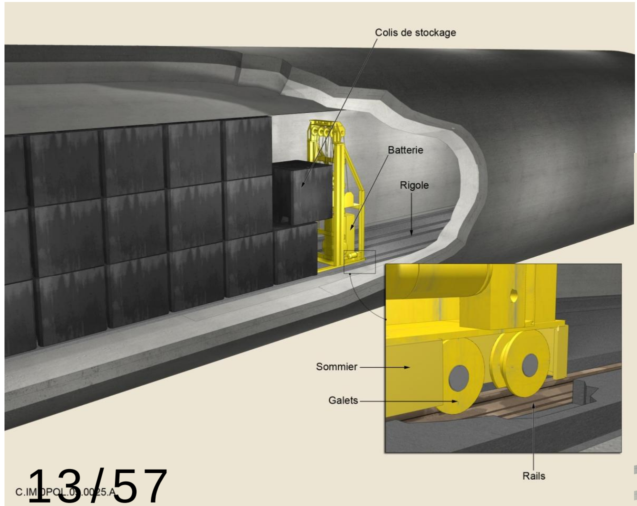
The 2006-2015 period: ILW disposal cells

ILW disposal cells are 500 m long horizontal tunnels located at the median of the host clay layer:

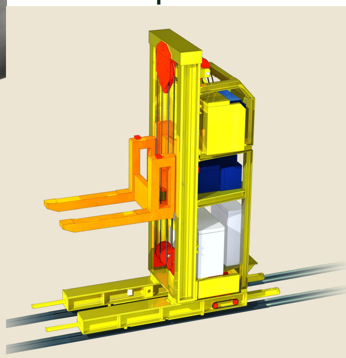
- Thick concrete lining to limit long term deformations;
- Ventilation of ILW repository cells as long as they are not closed.

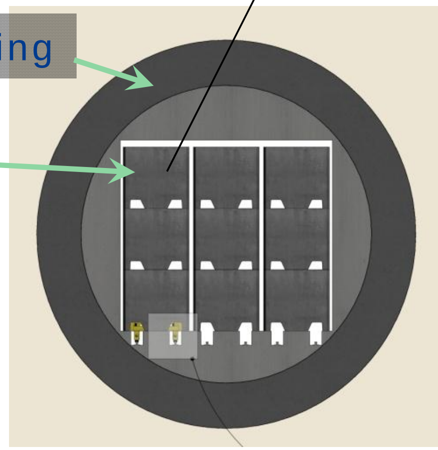


Emplacement/retrieval processes and equipments are beei developed and prototyped:



Trolley Stacker Technique

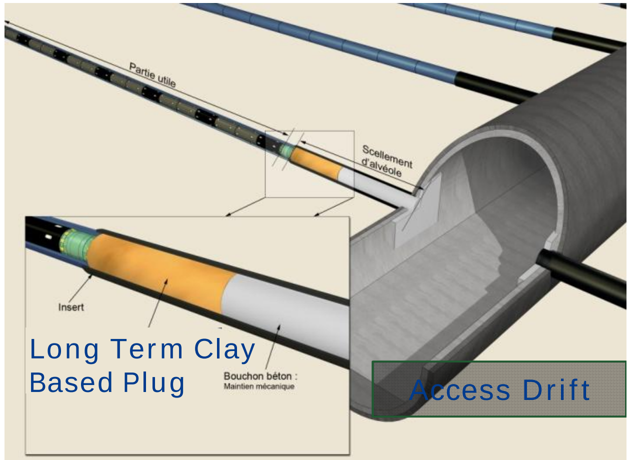


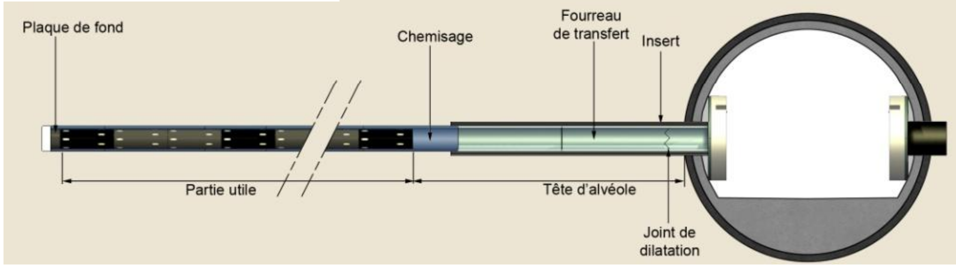


The 2006-2015 period: HLW disposal cells

HLW will be disposed of in lined horizontal micro-tunnels (80-100 m long : 0,8 m in diameter):

- Heat conduction in clay
  - Ø max. temp in clay rock: 90 °C
- Steel liner
- Cell length to be optimized with regard to technological limits and cost
- Emplacement/retrieval equipments tested in worst conditions.





The 2006-2015 period: Organisation (I)

2006-2010: towards the optimization of the repository concepts

- 2006-2007: Feedback from 2006 reviews
- 2007-2009: New iteration between design/knowledge/safety
- 2009: Safety/reversibility options, reviewed in 2010

The previous methodologies (Functional Analysis, PARS, QSA,...) are maintained:

- For working on these different documents, the 2009 dossier in particular (this document is used to support the more detailed siting of Cigeo)
- For continuing the concept development work (iteration between design/knowledge/safety),

The responsibilities remain (compared to the previous period)

The 2006-2012 period: Organisation (II)

2010-2012 : The Cigéo Project has entered its industrial design phase:

- 2011: Completion of project requirements (next slide), waste inventory and delivery planning;
- 2012: Signature of the Cigéo system prime-contracting agreement between Andra and the “Gaiya group” (Technip, Ingérop)
- 2013: Signature of subsystem contracting agreements (conventional surface facilities, nuclear surface facilities, nuclear processes, underground facility).

This implies significant changes to the organisation and the project requirements document is used for the industrial development

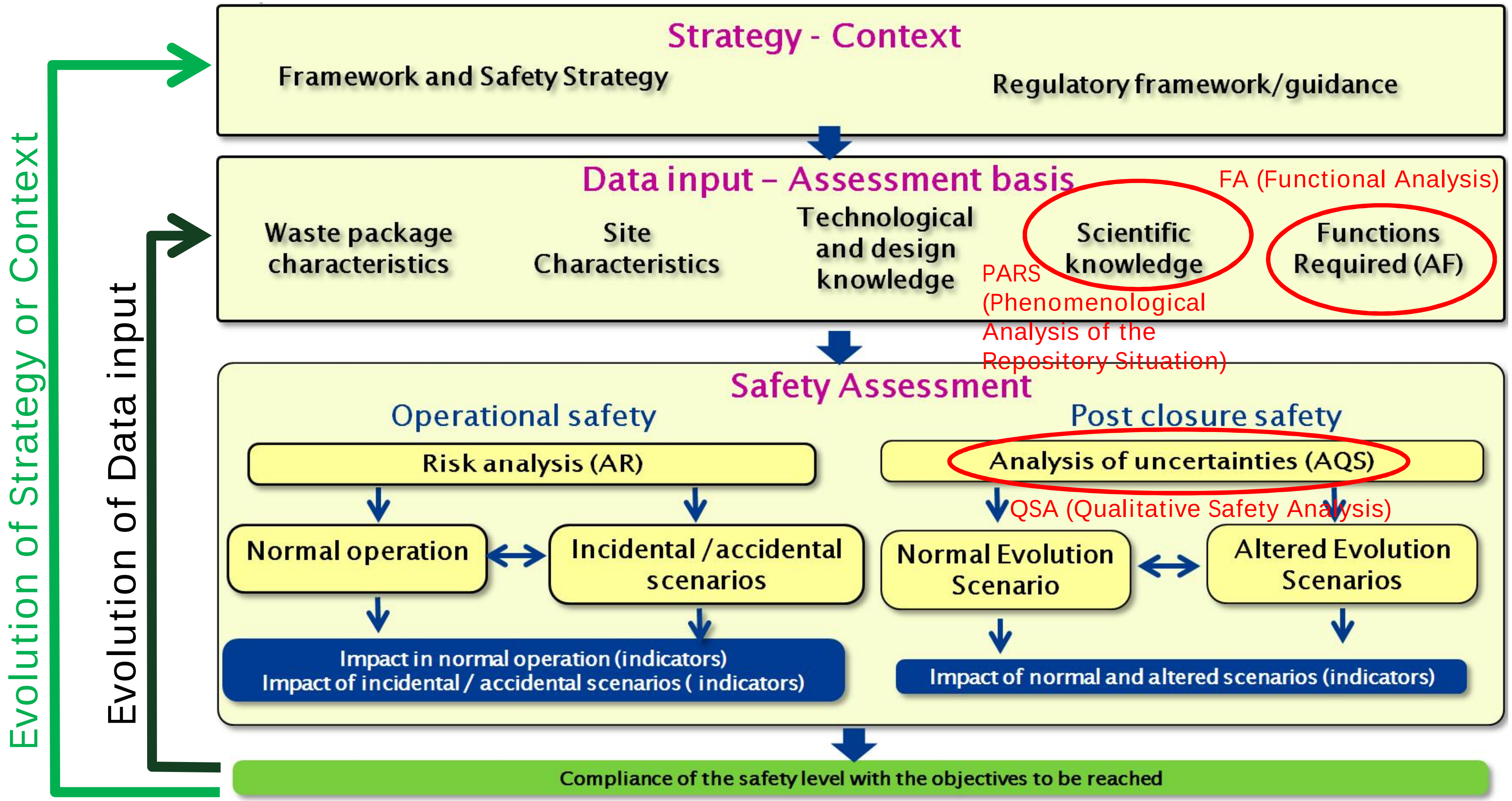
Period 2006-2015: Cigéo Project requirements

In 2011, the results of 20 years of R&D have made it possible to issue detailed project technical requirements.

- Postclosure Safety
  - Protect humans and the environment from radioactivity and toxicity of waste
  - Oppose groundwater flow
  - Limit the release of radionuclides and immobilize them whithin repository
  - Delay and mitigate the migration of radionuclides
  - Preservation of the favorable properties of host clay
- Nuclear safety and security in operation
  - Contain radioactive substances, protect people against exposure to ionizing radiation, control of nuclear criticality, remove the thermal power, vent gases
  - Failures and internal and external hazards risk management
- Waste emplacement and retrievability
  - Receive, prepare and emplace waste packages
  - Close the repository
  - Allow retrieval of the waste packages
- Control, monitor, observation
- Sustainable development, corporate and social responsibility
- Project governance

The safety approach procedure

Safety approach : a global approach with key steps



Safety approach : FA (Functional Analysis)

Functional analysis is a method for describing a system or a product.

This method was seen as being the basis for developing « well adapted » products (initially in a military environment), based on the belief that the well adapted product must be user needs “driven” and that functions were probably the best way of describing the needs.

Safety approach : FA (Functional Analysis)

The basic approach is the identification of the expected functions of the object in view of developing a satisfactory answer to the user needs:

- *Needs* : a product is developed to satisfy needs
- *User* : person or organisation for which the product or system is conceived and who uses at least one of its functions at one point in time
- *Function* : Intended effect of a system, sub system, product
- *Product* : a solution to needs through the satisfaction of the functions

Safety approach : FA (Functional Analysis)

The starting point is, once the scope has been well defined, the function identification

This initial identification can be based on:

- User needs analysis
- Previous systems
- Brainstorming
- Environmental analysis
- ...

The top level, or main functions, must then be broken down based on the why?/how? Rule

The result:

- First level functions
- Functional tree
- Criteria
- Performance levels
- Flexibility

Safety approach : FA (Functional Analysis)

This approach has advantages:

- A simple methodology
- The description of needs is more durable than the description of the technical solutions
- Useful for correct management of costs

Functional analysis can be applied to different objects:

- Systems, such as space systems
- Products, such as standard industrial products
- Software packages
- Organisations

Results:

- A Coherent system, a valid product for a given market or use, a coherent and bug free software package, …
- The best solution:
  - ☐ From a performance/cost point of view (product)
  - ☐ With respect to competition (product)
  - ☐ For system integration (system)
  - ☐ For the organisation (Enterprise Resource Planning)

A few rules

In such a functional expression of needs there is no reference at first to the technical solution.

This allows the user of the method to focus on needs before going into the technical details.

It therefore stimulates the user of the method to optimize the product and find the best proposal in view of the needs.

The amount of detail of the analysis is to be set according to the time left before the system is required:

- Feasibility study : overall needs analysis
- Conception phase : sub system analysis
- Detailed design : component analysis

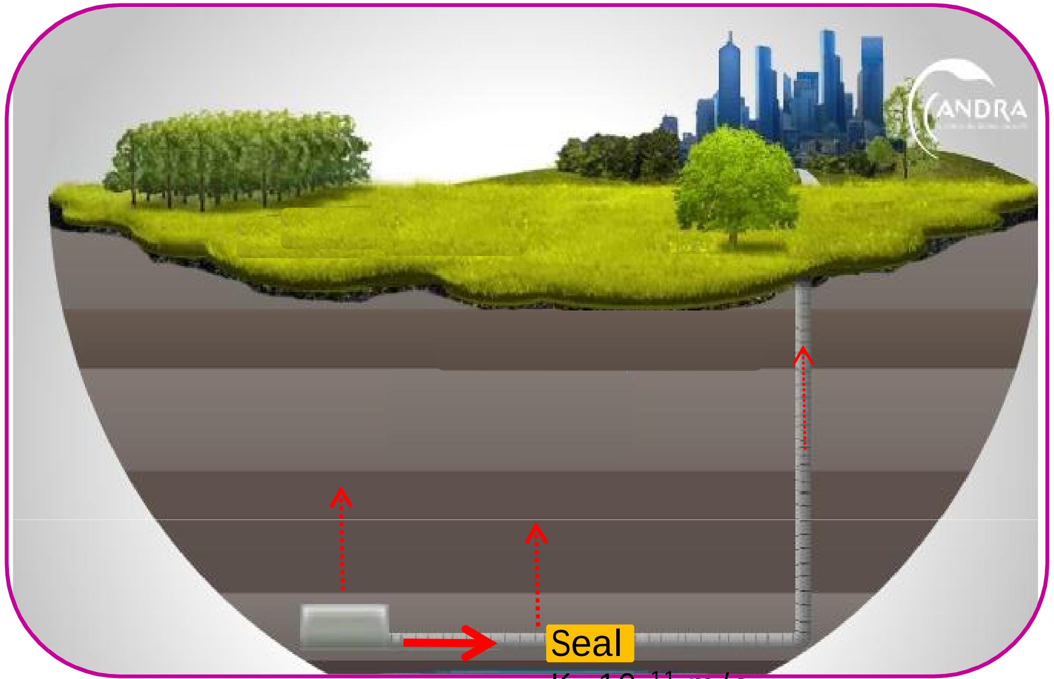
How to apply to waste management

The functional approach is well suited to:

- The long time frames of radionuclides repository projects, since the initial functional break down is a lasting description
- The few relevant past systems from which to benefit and the need to break new grounds
- The need to demonstrate to stake holders, safety authorities, … that the solution we put forward is fully justified by allowing to trace from high level functionalities to detailed requirements, at the component level (a traceable link between the product (or system) and the solution)

Safety approach : FA (Functional Analysis)

Seal example



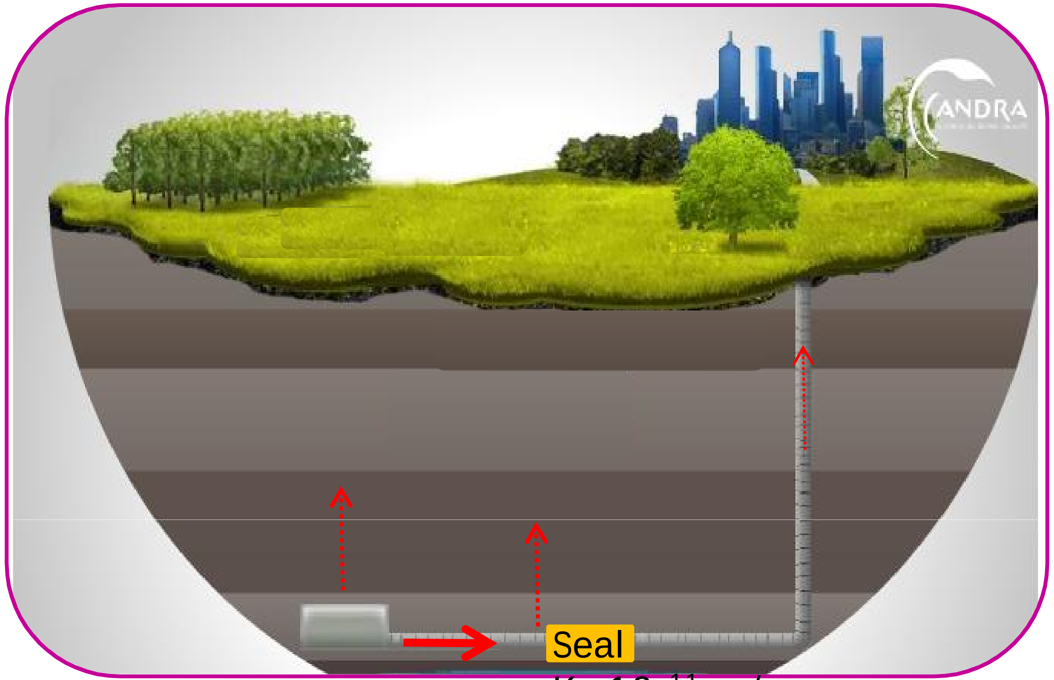
Initial need/question: How to limit the migration toward the surface ?

- Not possible via the host rock, chosen for its low permeability
- Possible in the highly permeable gallery network

➡ Put a component in the gallery network to try to come back to the natural (host rock) properties: “low permeability seals”
Performance needed by the seals ? Trial and error hydraulic numerical simulations to find a suitable value : let’s say 10^{-11} m/s

Safety approach : FA (Functional Analysis)

Seal example



K=10^{-11} m/s
Bentonite

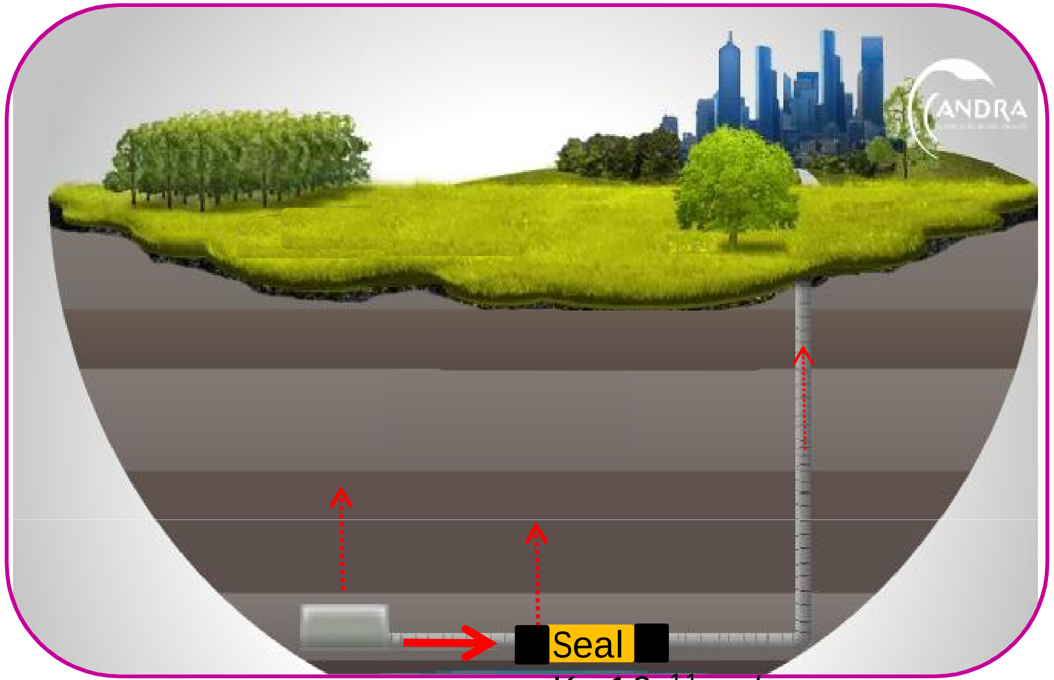
<u>Sub question</u>: How to achieve such a low permeability ?

- Very low permeability of the seal itself
- Recompression of the EDZ around it to reduce its permeability

➡ Use of a swelling clay (bentonite)

Safety approach : FA (Functional Analysis)

Seal example



$K=10^{-11}$ m/s
Bentonite

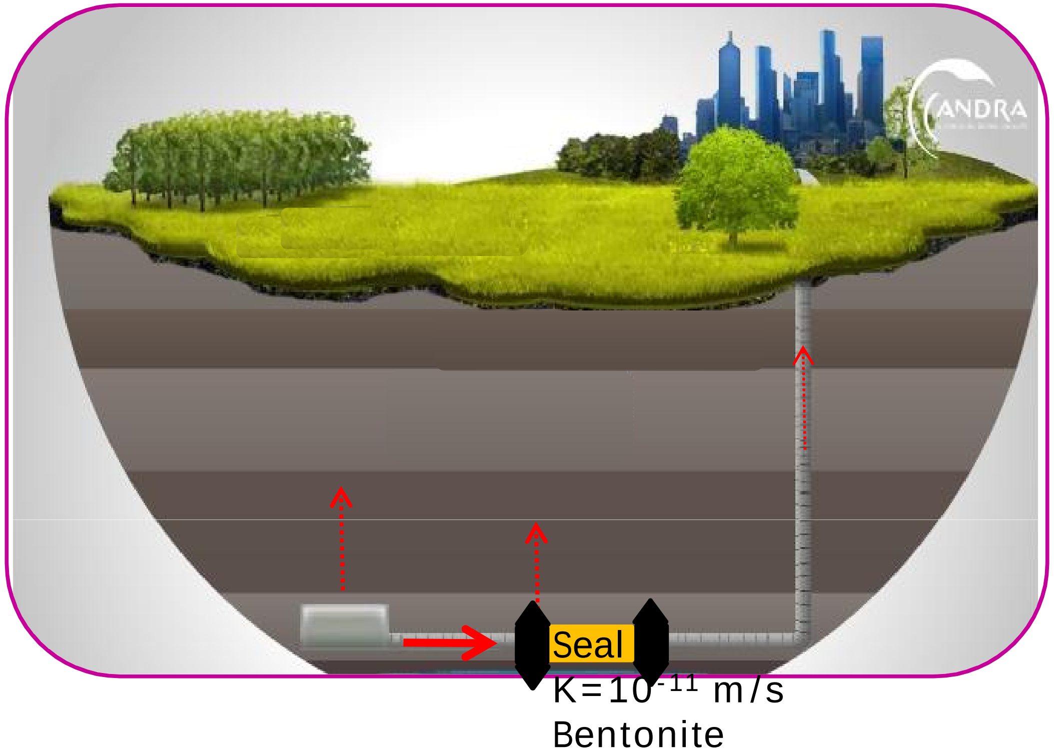
<u>Sub question</u>: How to maintain the swelling pressure of the clay ?

- Swelling clays are developing a swelling pressure if their volume is constrained during resaturation

➡ Use of concrete walls to maintain the volume of the bentonite core

Safety approach : FA (Functional Analysis)

Seal example



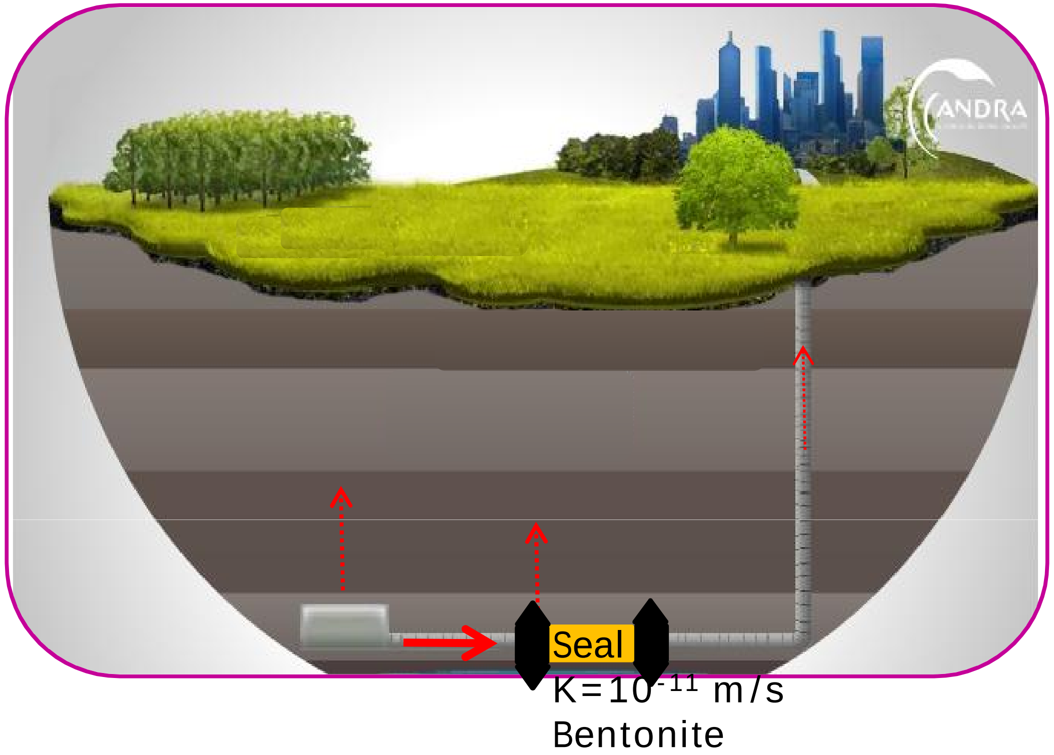
Sub question: How to maintain the concrete wall during the swelling of the clay?

- The concrete walls must be calibrated so has to be able to support the mechanical contraints due to the swelling of the clay core

→ Anchor the concrete walls into the host rock

Safety approach : FA (Functional Analysis)

Seal example



Initial need/question: How to limit the migration toward the surface ?

- The bentonite core is the main component to the function
- The recompacted EDZ is a contributor to the function
- The concrete walls have no direct contribution to the function but are a necessary support.

Safety approach :
FA (Functional Analysis)

The final result is a table component-functions

FAT : Function Allocation Table

Safety functions (needs)

Components and sub-components

Long Term safety	R1				R2a				R2b				R3				I1			
Component	III	IV	V	VI	III	IV	V	VI	II	IV	V	VI	III	IV	V	VI	III	IV	V	VI
1. Multi-Layer cover																				
1.1 Biological Layer					M	M(1)	M(1)	C									C			
1.2 Bio-intrusion Barrier					M	C	C	C									C			
1.3 Infiltration Barrier					M	C	C	C									C			
1.4 Sand Layer					M	C	C	C									C			
1.5 Impervious Top Slab					M	M	C										M	M	C	
1.6 Floating Slabs					C															
1.7 Bitumen layer					C															
1.8 Side Embankment																	C			
3. Module Roof																				
3.1 Structural Top Slab					M	M	C										M	M	C	
3.2 Precast Shielding Slab					C	C	C													
4. Module Middle																				
4.1 Gravel																				
4.2 Module Wall					M	M	C		M	C			M	M	M	C	M	M	C	
5. Monolith																				
5.1 Caisson					M	M	C		M	M	C		M	M	M	C	M	M	C	
5.2 Mortar					M	M	C		M	M	C		M	M	M	C	M	M	C	
5.3 Waste Form	M	M	C														M	M	C	
6. Module Basis																				
6.1 Support Slab									M	M			M	M	M	C				
6.2 Backfilled drainage system									C	C			M	M	M	C				
6.3 Precast Element									C	C			M	M	M	C				
6.4 Columns									C	C			M	M	M	C				
6.5 Backfilled inspection room									M	M			M	M	M	C	M	M	C	
6.6 Foundation Slab									M	M			M	M	M	C				
7. Backfilled Inspection Gallery																	M	M	C	
8. Foundations																				
8.1 Sand-Cement Embankment													M	M	M	C				
8.2 Drainage layer					M	M	C													
8.3 Site Sand Leveling																				
9. Site																				
9.1 Site Geology													C	C	C	C				
9.2 Site Surveillance (Nuc. Class I Facility)																	M			
9.3 Markers and archives																	C	C	C	

Legend:
M (Main) - C (Contribute)
III - Nuclear Regulatory Control Phase
IV - Isolation Phase
V - Chemical Containment Phase
VI - Post Containment Phase

Extract from Belgium low level waste FAT

Safety approach : FA (Functional Analysis)

Some references

BS EN 1325:2014, Value Management. Vocabulary. Terms and definitions

- Value analysis, Functional analysis, Vocabulary, Management, Management techniques, Enterprises, Organizations, Personnel, Performance, Terminology, Definitions

Some systems orientated project management standards (XPX 50-400 series)

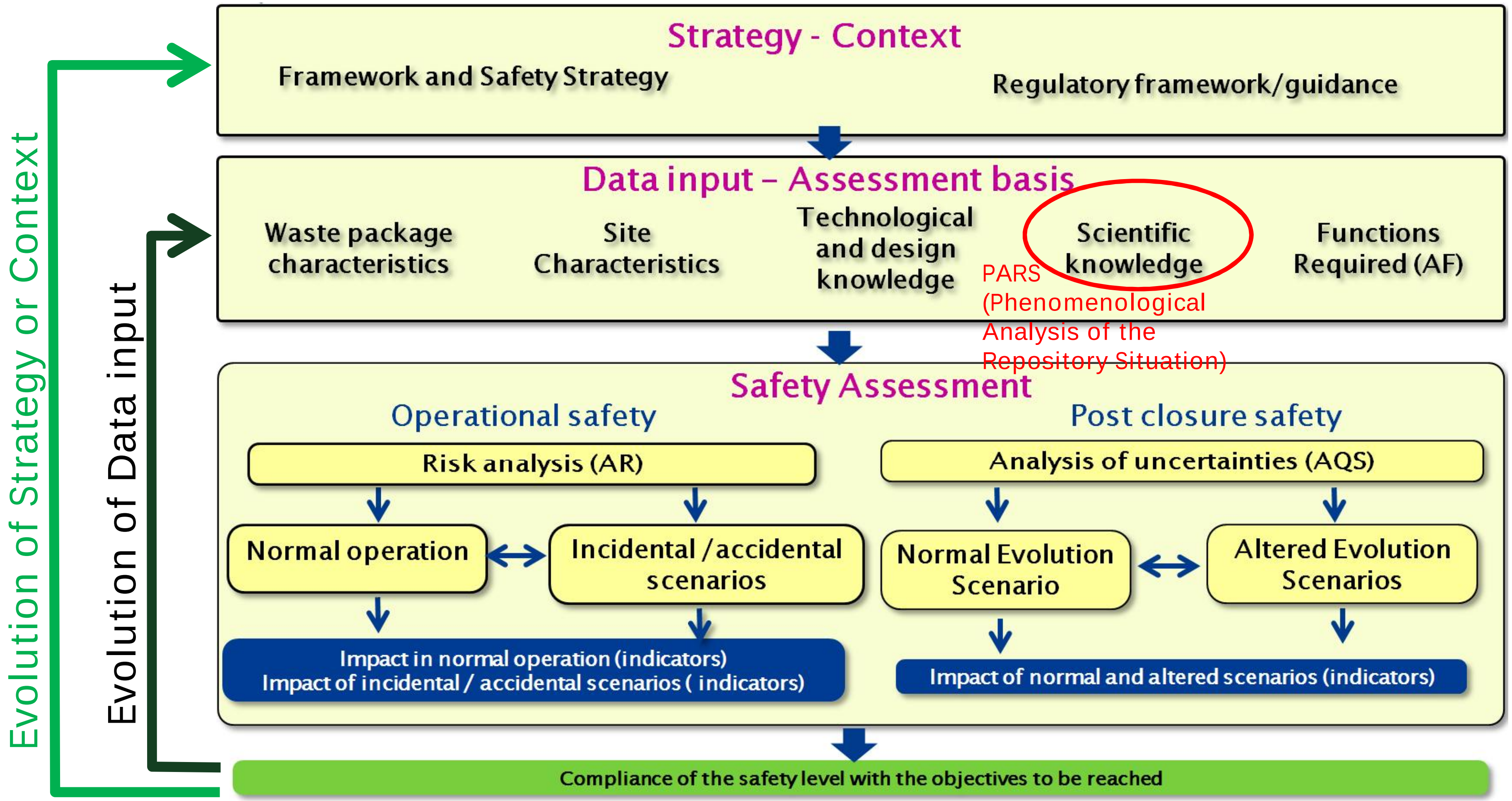
Functional analysis is quoted in IAEA (and NEA) documents

- Safety Assessment Methodologies for Near Surface Disposal Facilities (ISAM methodology)

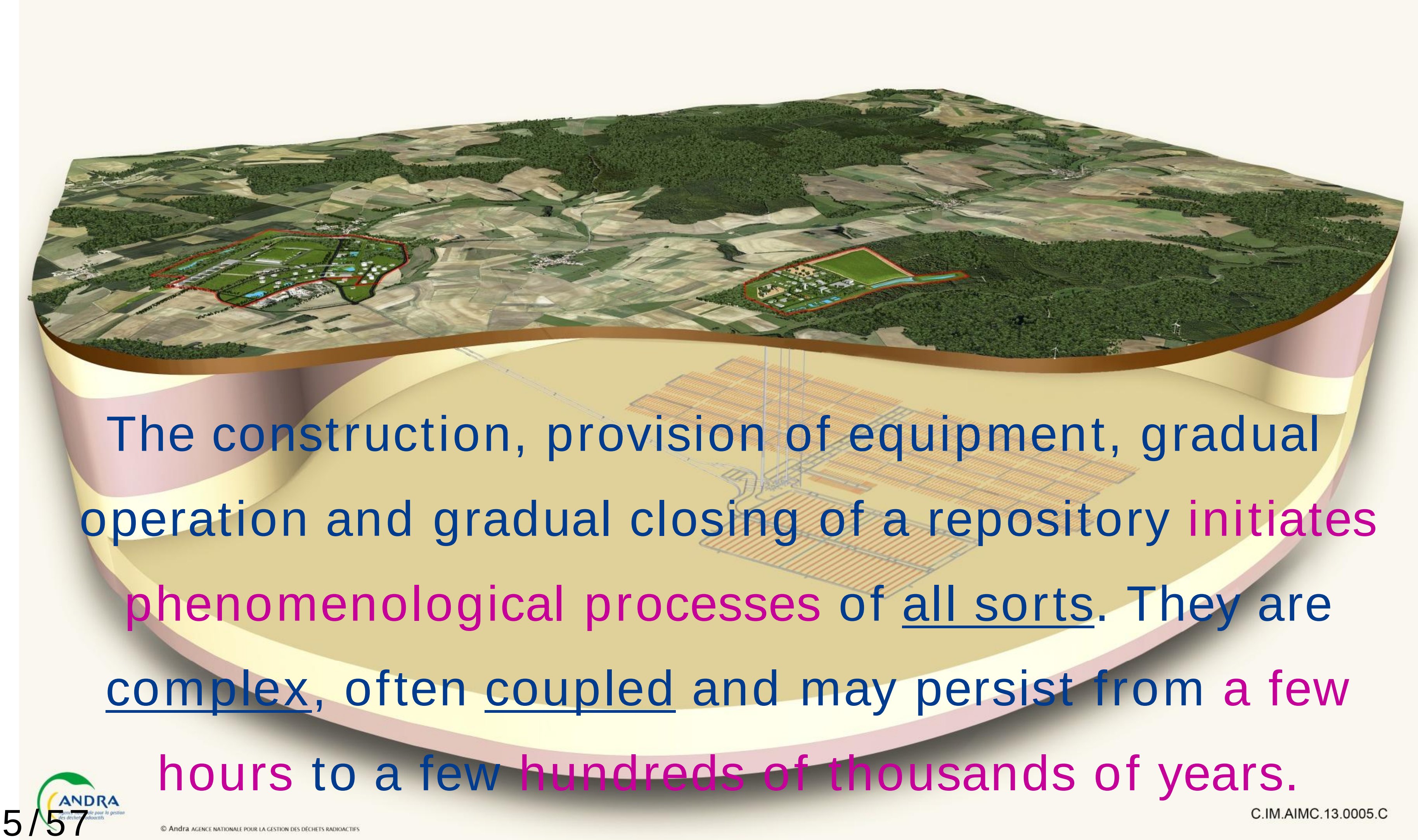
PARS (Phenomenological Analysis of the Repository Situations)

This section is also available as pptx since it contains animations.

Safety approach : PARS (Phenomenological Analysis of Repository Situations)



Safety approach : PARS (Phenomenological Analysis of Repository Situations)



The construction, provision of equipment, gradual operation and gradual closing of a repository initiates phenomenological processes of <u>all sorts</u>. They are <u>complex</u>, often <u>coupled</u> and may persist from a few hours to a few hundreds of thousands of years.

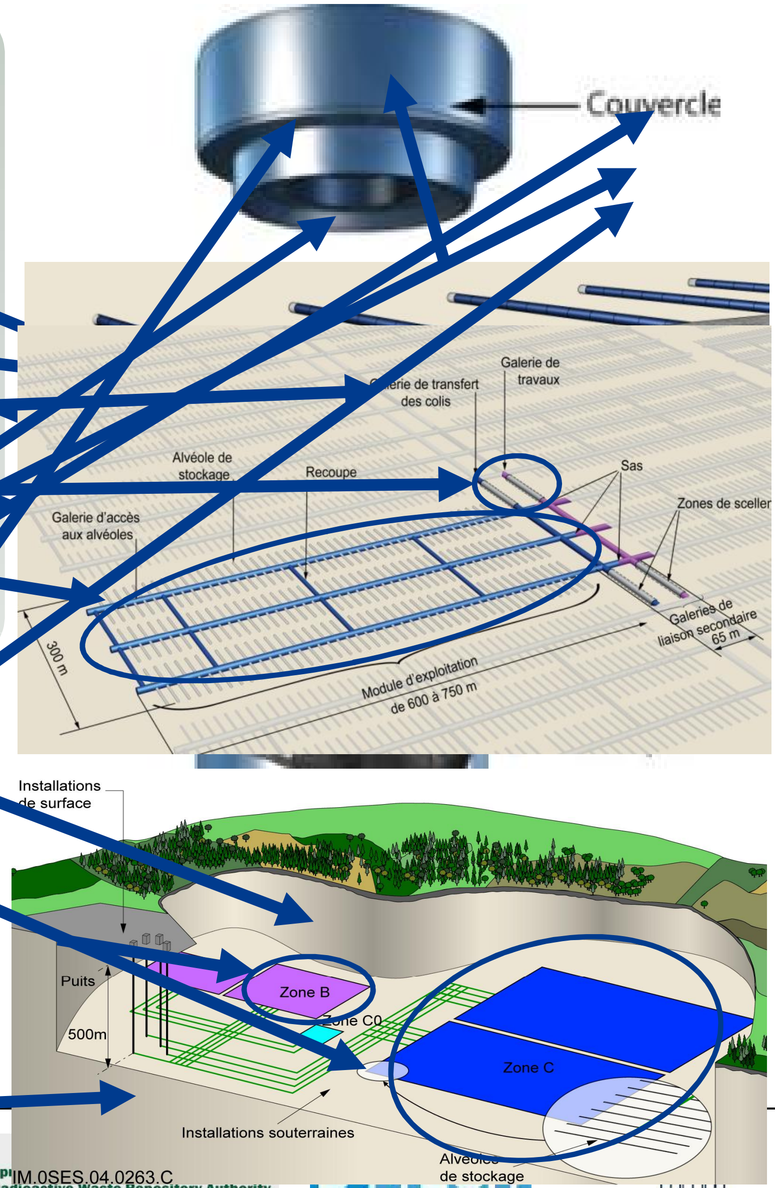
Safety approach : PARS (Phenomenological Analysis of Repository Situations)

Multiple components

- Primary matrix (waste)
- Primary container
- Disposal package
- Cells and cell equipment
- Connecting drifts and their structural components, shafts, etc.
- Modules and seals
- Zone
- Geological medium

Multiple materials

- Glass (e.g.: waste)
- Metal
- Concrete
- Ceramic (e.g.: skids)
- Structure clay (bentonite)
- Clay from the site



Safety approach : PARS (Phenomenological Analysis of Repository Situations)

Multi-physical

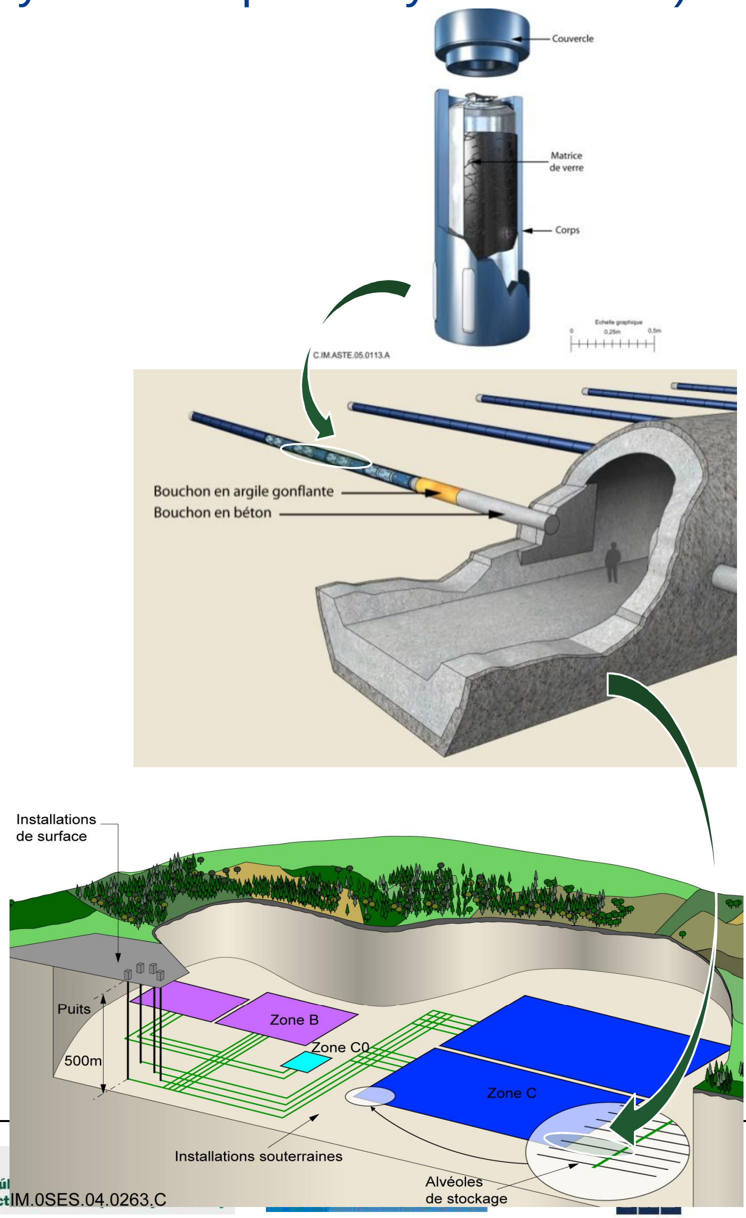
Thermal (T), Hydraulic-Gas (H),
Mechanical (M), Chemical (C), Radiological (R)
Solute transfer in porous media (Tr).

à Multiple physical processes interacting unilaterally/bilaterally
à With high and low coupling levels
à Either concomitantly or sequentially

Multiple spatial scales

- centimetres to metres: waste
- metres to decametres: cell
- hectometres to kilometres: repository
- several kilometres: geological medium

à Management of > 7 orders of magnitude in space



Management of :

à 6 orders of magnitude in time

à 7 orders of magnitude in space

Need to structure the knowledge/uncertainties to

à isolate/frame phenomenological situations

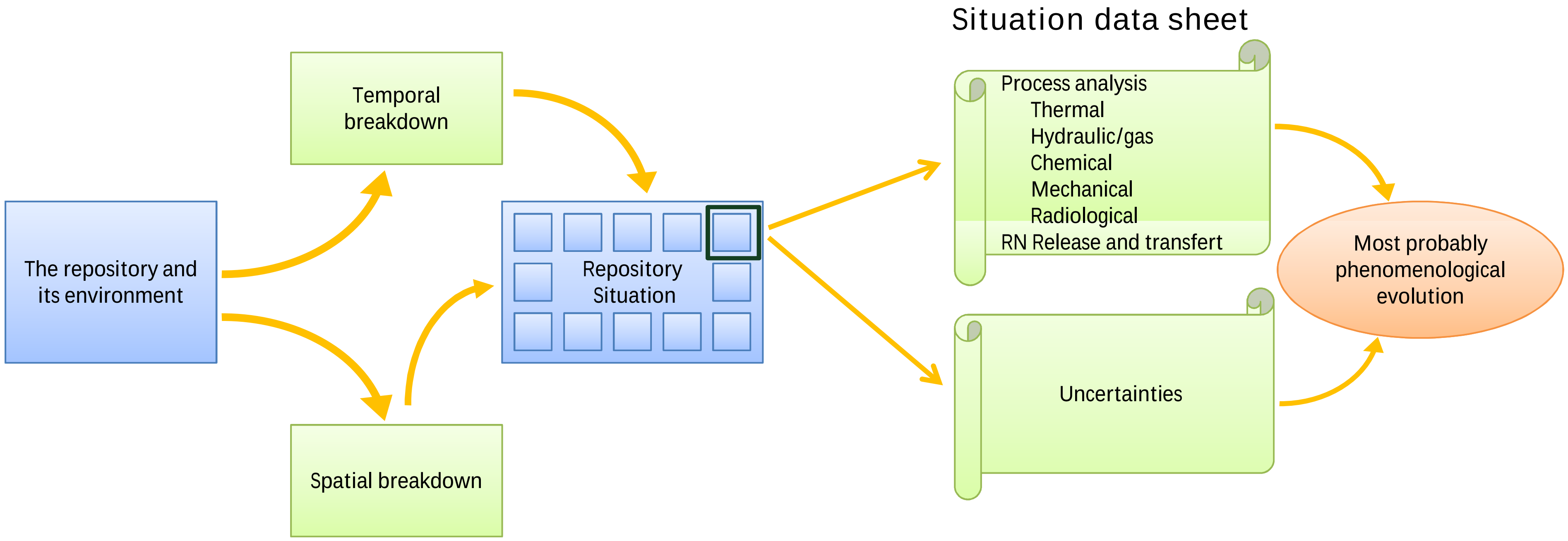
à to organize the knowledge restitution (source, verification, hypothesis and simplifications… traceability)

à to prepare the data bases for numerical simulations

"Phenomenological Analyse of Repository Situations (PARS)"

The complexity of the system requires that it be broken down into subsystems

è *Spatial/temporal segmentation of the evolution of the repository into "situations"*



Spatial/temporal segmentation è ± 80 situations

Years		**Operation** 0 – 50 – 100	**Post-closure** 1000 – 5000 – 10000	10000 – 50000	50000 – 100000	100000 – 1000000
Surface installation		1	54			
Under-ground structures	Shaft	4, 6, 5	65, 61		66	
	Connection and service drifts	3, 7, 8	62		59	
	B CE/DT waste repository zone	10, 42, 47, 48, 43, 44, 45, 46	66, 76	64	70	79
	B BB waste repository zone	49, 50, 51, 52, 53				
	Vitrified waste repository zone	11, 18, 25, 24, 19, 20, 21, 22, 23	67, 75	57	68	80
	UOX spent fuel repository zone	12, 26, 32, 33, 27, 28, 29, 30, 31	68, 77	71	72	82
	MOX spent fuel repository zone	13, 34, 41, 40, 35, 36, 37, 38, 39	69, 78	73	74	83
Geological medium *far field*	Callovo-Oxfordian clay	14				81
	Dogger carbonate	9			63	
	Oxfordian limestone	15				
	Kimmeridgian marls	16		60		
	Tithonian: Barrois limestone	17				
Surface environment		2	55			

Safety approach : PARS (Phenomenological Analysis of Repository Situations)

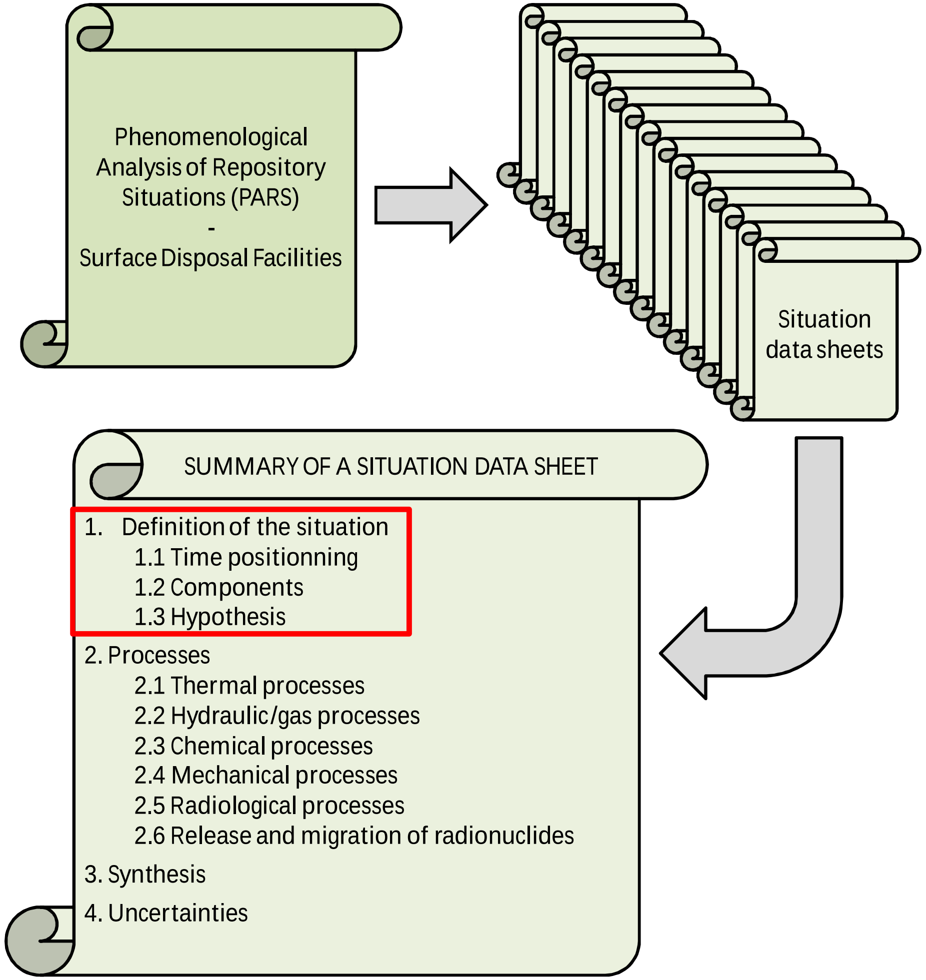
Situation data sheets structured in four parts :

q Chapter 1 : Definition of the situation

This chapter deal with the presentation of the current situation. It includes:

- *Time positioning :*
  - à *Beginning/ending time of the situation*
  - à *Positioning of the situation within the situation matrix*
- *Components*
  - à *Presentation of the "components tree" highlighting natural and engineering components which are concerned*
  - à *Description of components (from engineering studies) : materials, dimensioning, functions…*
- *hypothesis*
  - à *Trace back assumptions at the current state of art (design hypothesis, neglected couplings,…)*

Size : ~ 2 or 3 pages (including figures)



Safety approach : PARS (Phenomenological Analysis of Repository Situations)

Situation data sheets structured in four parts :

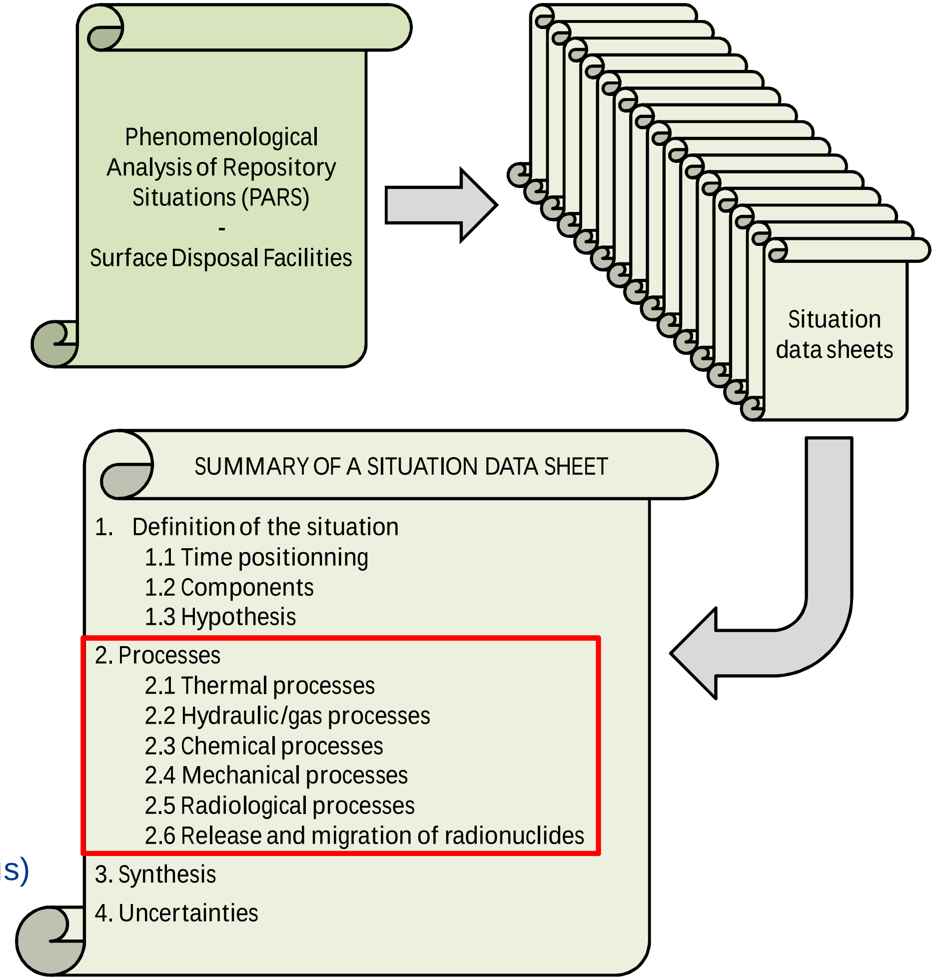
q Chapter 2 : Description of processes

This chapter deal with the description of THMCR processes (including couplings) which affect components over the space/time.

- Description of processes (nature, level of couplings, sequencing,...)
- Quantification of processes (order of magnitude, characteristic timescales,
  - à Beginning/ending time of the situation
  - à Positioning of the situation within the situation matrix

Factually, without value judgment or safety consideration

Size : unlimited. Depends on :
- the number of processes involved and
the necessity of describing/quantifying them (includ. couplings)
- the current level of knowledge



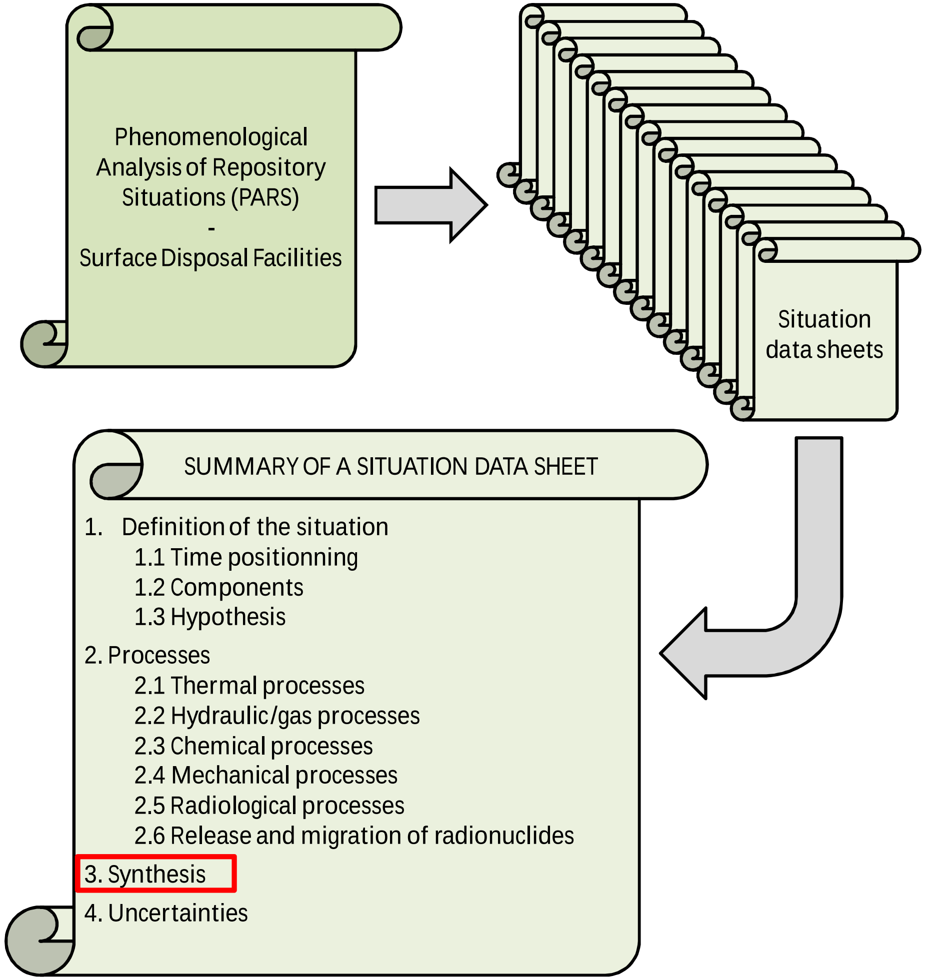
Safety approach : PARS (Phenomenological Analysis of Repository Situations)

Situation data sheets structured in four parts :

q Chapter 3 : Synthesis

This chapter deal with the synthesis of the phenomenological state specifying:

- *Major phenomena (order of magnitude, characteristic timescale)*
- *And/or phenomena which drive the evolution of the disposal.*



Size : ~ 1 page

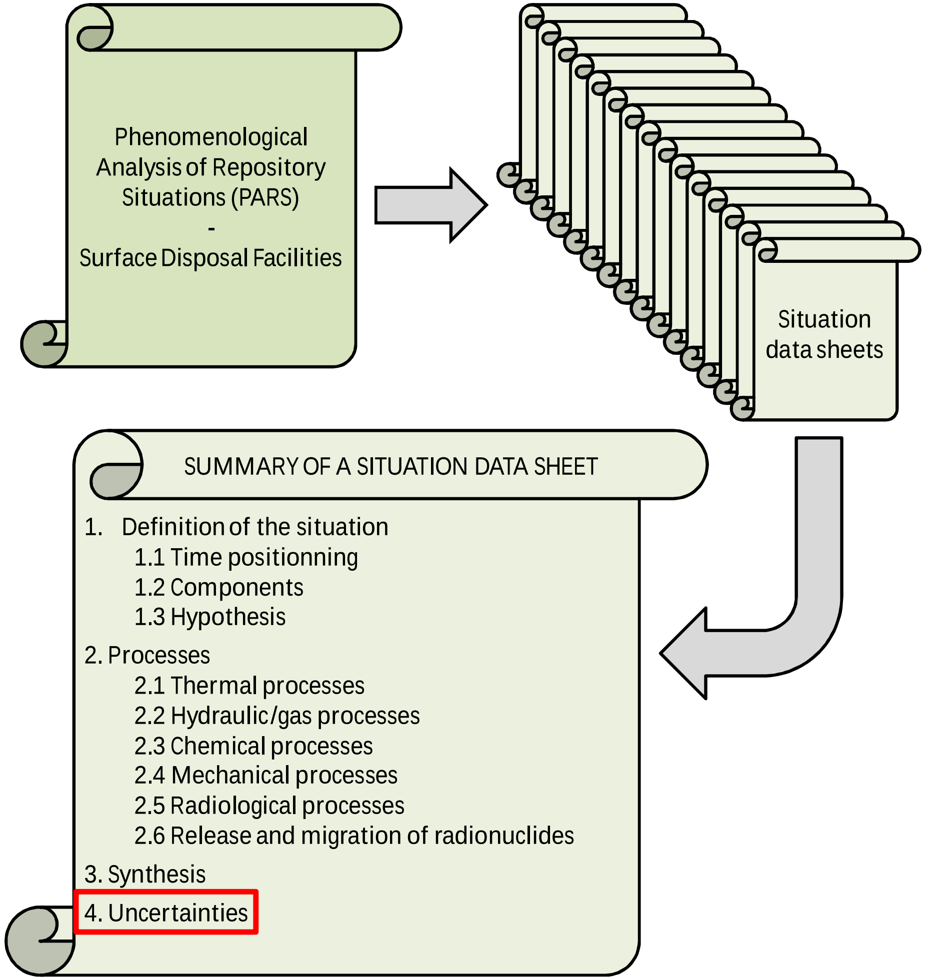
Situation data sheets structured in four parts :

q Chapter 4 : Uncertainties

This chapter deal with the identification of uncertainties of all sort:

- *Characterization / lack of knowledge*
- *Qualitative uncertainties (processes, coupling effects,...)*
- *Quantitative uncertainties (uncertainties on parameters, natural variability, approximations/simplifications,...)*
- *Identification of bifurcation: Could the story of the phenomenological evolution be different? Is there an alternative evolution possible ?*

Size : unlimited : depends on the level of knowledge and the current state of art.



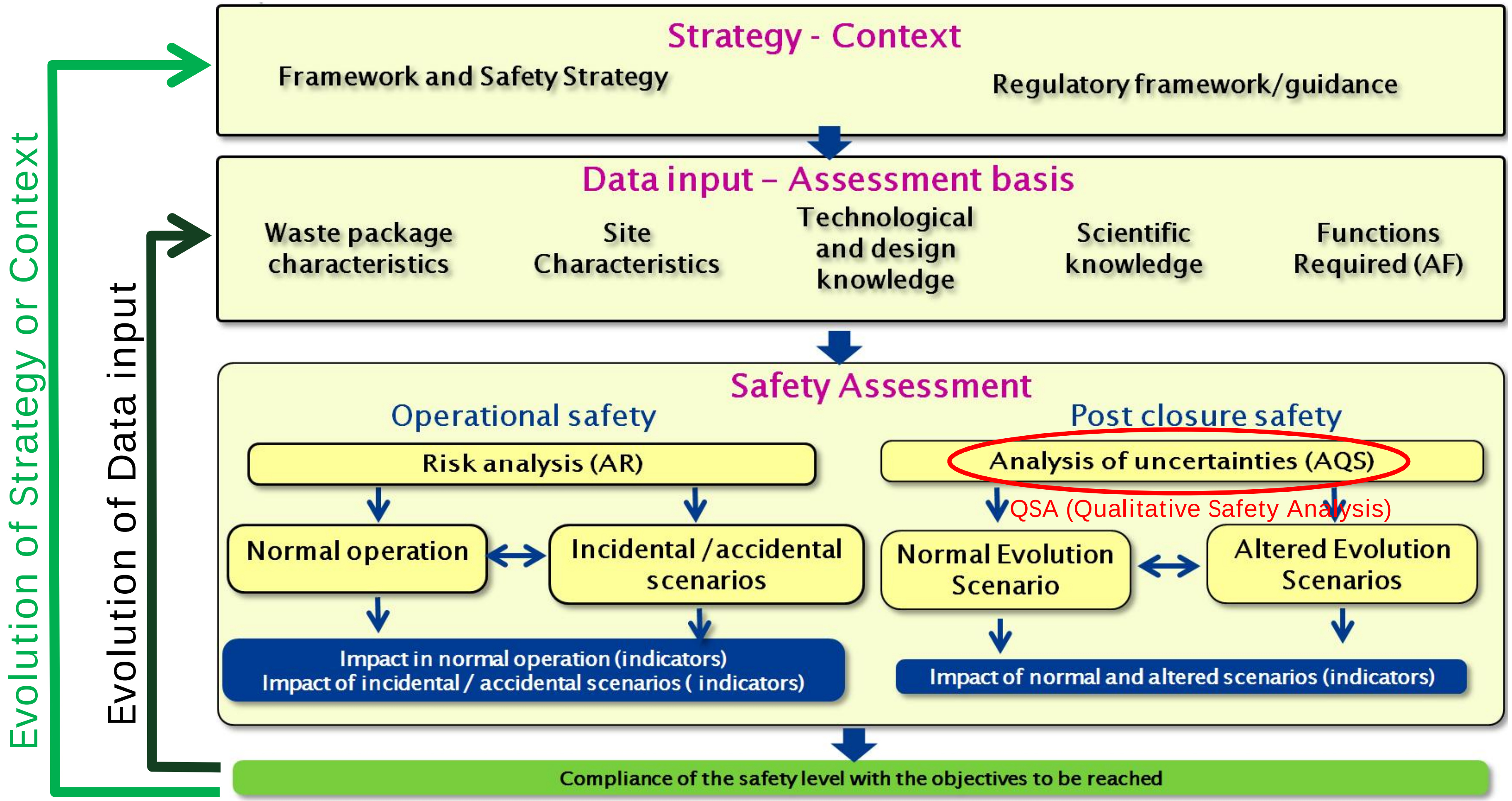
Writing requirements

To make a description base on factual and clearly referenced scientific arguments (with regard to the current knowledge):

- Identifying the source of information (simulation, experiment, analogues, expert opinion,...)
- Showing references in a systematic way (traceability)
- Crossing as much as possible different sources of information to make the description robust and consistent
- Adopting a rigorous style, factually, without making any safety or value judgment
- Stepping back towards the origin of information by focusing on their representativeness (samples, full scale experiments/modelling,...)

QSA : Qualitative Safety Analysis

Safety approach : QSA (Qualitative Safety Analysis)



Managing uncertainties and events

To explore possible dysfunctions

- Inventory of all uncertainties
  - *Scientific and technological knowledge*
- Examine if uncertainties can:
  - *Affect the ability of a component to fulfil a safety function and its associated performance(s),*
  - *Have an influence on the ability of another component to fulfil a safety function and its associated performance(s),*
  - *Modify the environment of the component in such a way that it can influence the manner in which the component fulfils its functions.*

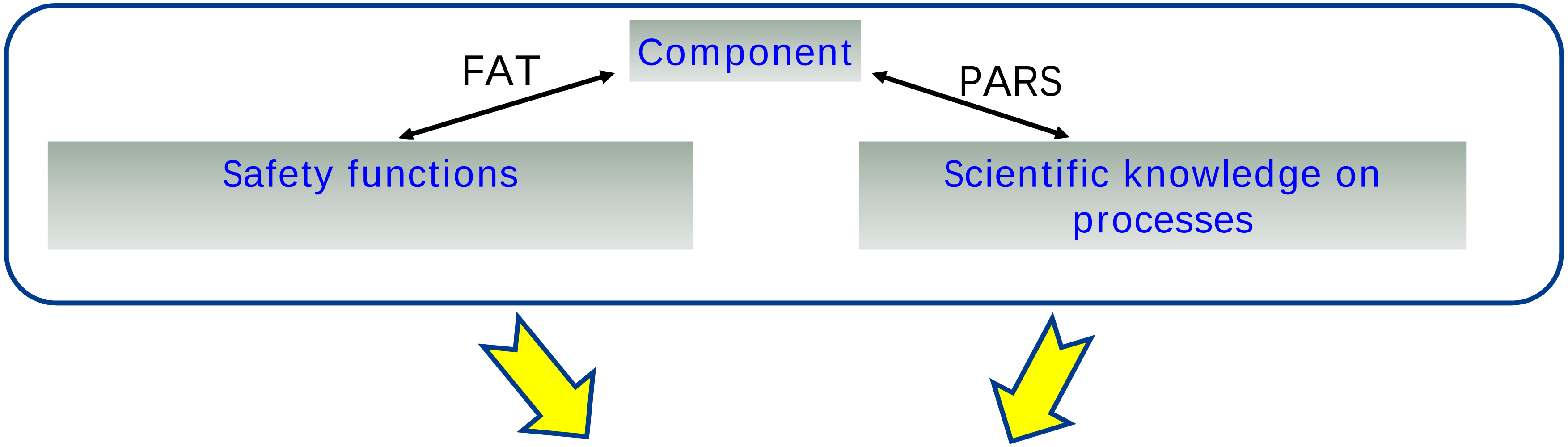
Proposes Management of Uncertainties

- By design measures:
  - *Specific or generic measures*
- By the definition of calculation cases in scenarios:
  - *Through conservative choices or sensitivity analysis in the normal evolution scenario (NES)*
  - *Through the definition of calculations cases in an altered evolution scenario (AES), including sensitivity analyses*

- Base of the methodology
  - Integrated and structured approach for the treatment of uncertainties
    - + *their impact on safety functions and*
    - + *how they are managed*

- A two steps method
  - Analysis of uncertainties component per component
  - Global analysis (of all functions) and identification of failure mode (including combination of uncertainties)

Safety approach : QSA (Qualitative Safety Analysis)



Analysis for each uncertainty:

- *Examine if it can affect the capacity of the component to fulfil (contribute to) a safety function,*
- *Examine if it can have an influence on the ability of another component to fulfil a safety function,*
- *Examine if it can modify the environment of the component in such a way that it can influence the manner in which the component fulfils its functions.*

Safety approach : QSA (Qualitative Safety Analysis)

According to 2008 regulatory guidance, need to evaluate normal and altered scenarios

The normal-evolution and altered scenarios describe the spatial-temporal combination of FEPs and models in line with safety functions based on QSA results:

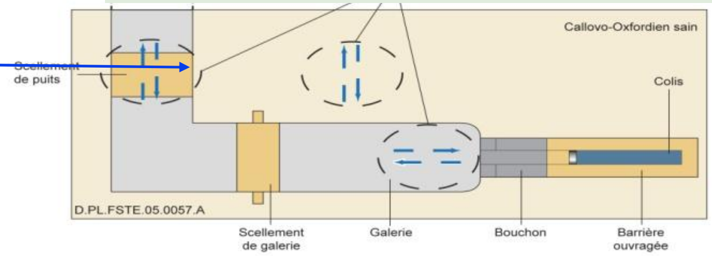
- Verification of the performance of the safety functions and robustness of the design by relying on relevant indicators (dose and other complementary indicators)
  - *uncertainties leading to a certain number of hypotheses for calculation purposes.*
- Normal Evolution Scenario (NES)
  - *Covers all features/events/process coupled or not considered as sufficiently certain or probable*
  - *Is a verification step in the design and acquisition of knowledge by presenting an integrated view of disposal components with the expected function*
- Altered Evolution Scenarios (AES)
  - *Describes "uncertain" or "conventional" situations corresponding to two main categories:*
    - *Failure of one or more safety functions of disposal*
    - *Human intrusion (after monitoring period)*

Safety approach : QSA (Qualitative Safety Analysis)

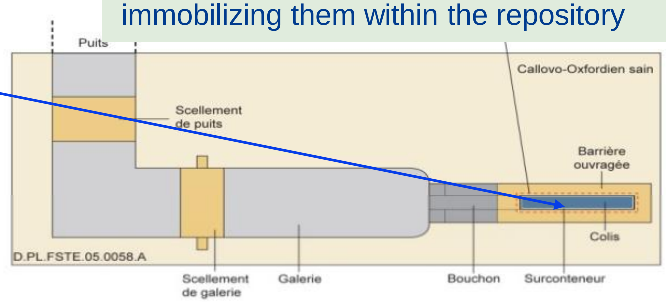
Illustration of AES based on the QSA (2005 Dossier)

- "Seal-failure" scenario
  - ☐ Failure of shaft or drift seals, or of all seals.
  - ☐ Sensitivity studies at the containment parameters of the EDZ, seals, etc.
- "Package-failure" scenario
  - ☐ Failure of all or part of overpack for ILW waste or of spent-fuel containers.
  - ☐ Sensitivity study to test the influence of the hydraulic transient.
- "Borehole" scenario
  - ☐ Different locations, one or two boreholes.
  - ☐ Sensitivity studies to the containment performances of the EDZ, of packages, etc.
- "What-if" scenario

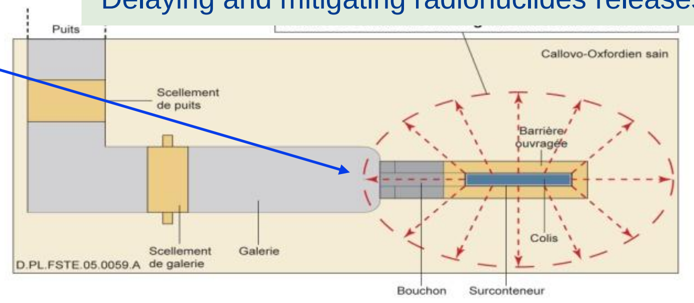
Preventing water circulation



Limitating radionuclide release and immobilizing them within the repository



Delaying and mitigating radionuclides releases



The actual safety loop

Major milestones in terms of safety loops

The 1991 Waste Act

- Creation of « Andra » as a public independant body
- 3 research areas for High Level Long-lived Waste: P/T; long term storage; geologic disposal

1996: Licence application for 3 URLs (clay; granite)

1998: Government decision to licence the Meuse/Haute-Marne URL licence,

1ST SA → 2001: Intermediate Clay report, first NEA peer review…

2nd SA → 2005: Feasibility /safety assessment of safe geological disposal in Meuse/Haute-Marne clay layer, reviewed 2005-2006

The 2006 Programme Act: Reduce/avoid the burden on future generations

- Reduce volume and harmfulness of wastes
- Reference option for final waste that can no longer be treated: geological repository with respect to reversibility (100 y at least)
- Continue research on P/T (CEA) and interim storage (Andra) on a complementary basis.

3rd SA → 2009: Safety, reversibility and design options, reviewed 2010

2010-2012: Launch of the industrial design phase

2013: Public debate

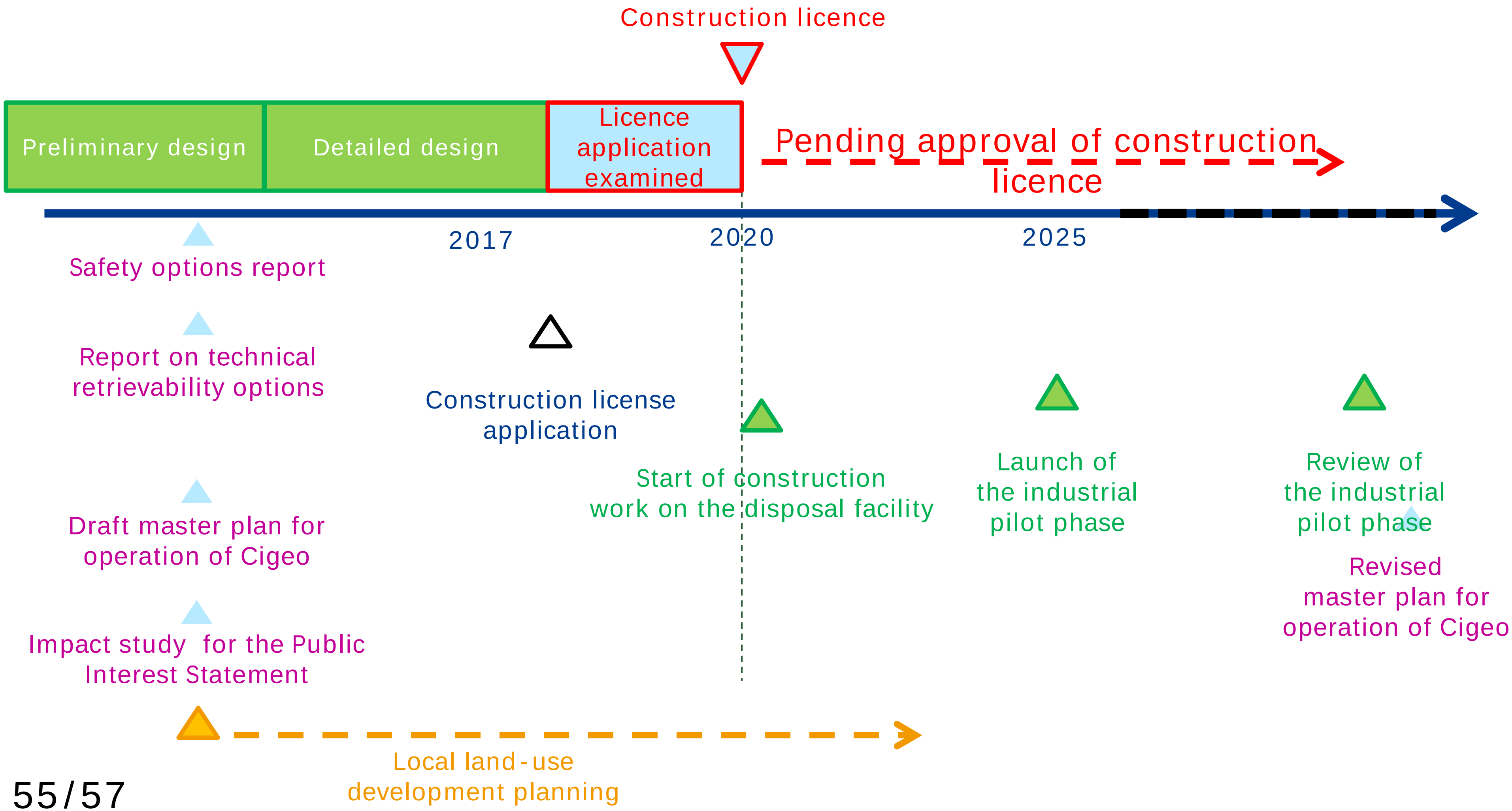
4th SA → *2015-17: DOS (Safety Opiions) and Licence application*

Actual loop

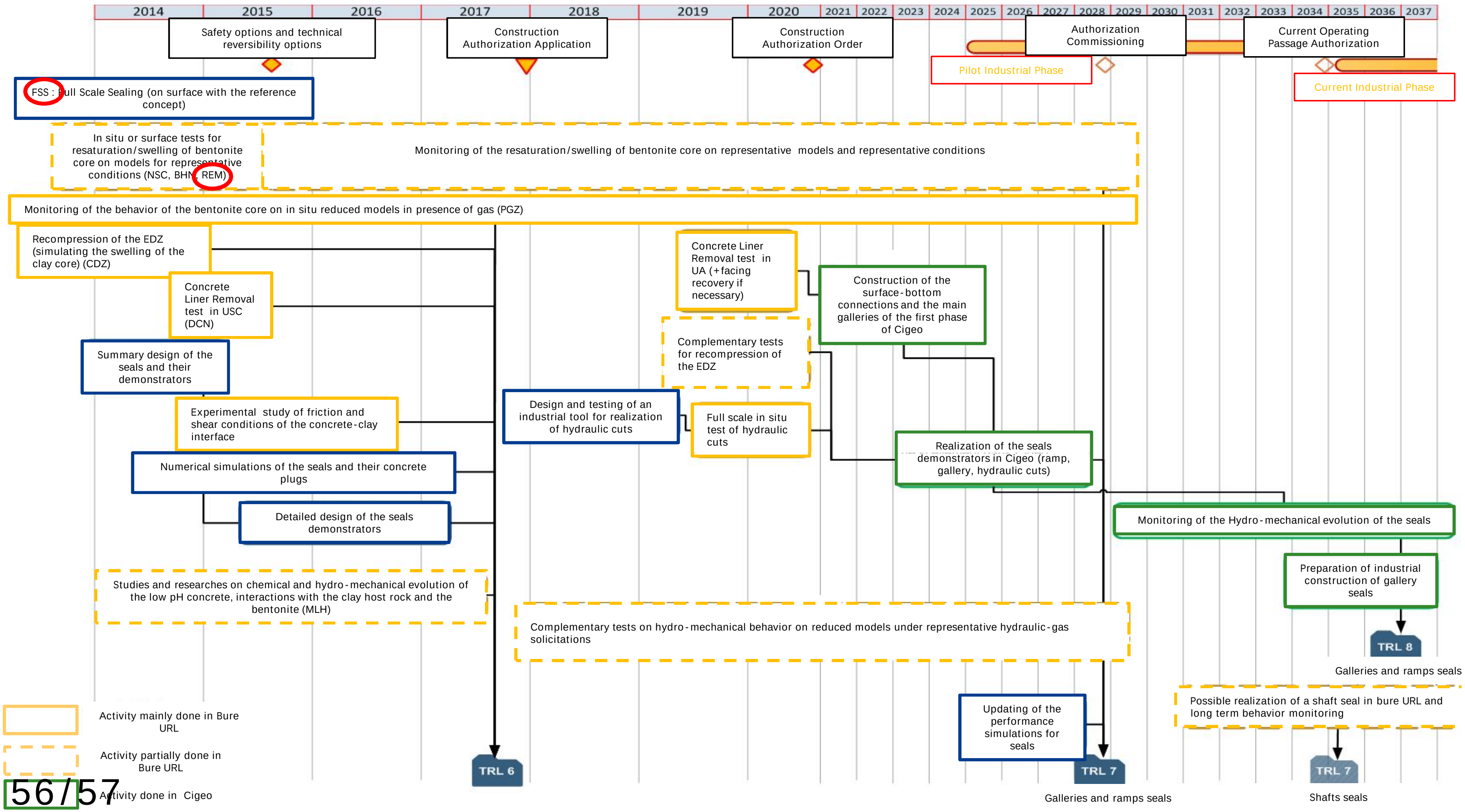
Around 2018-2019: Law defining reversibility conditions

2029: Beginning of operation

The current schedule



The actual RD&D development plan for seals



Thank you