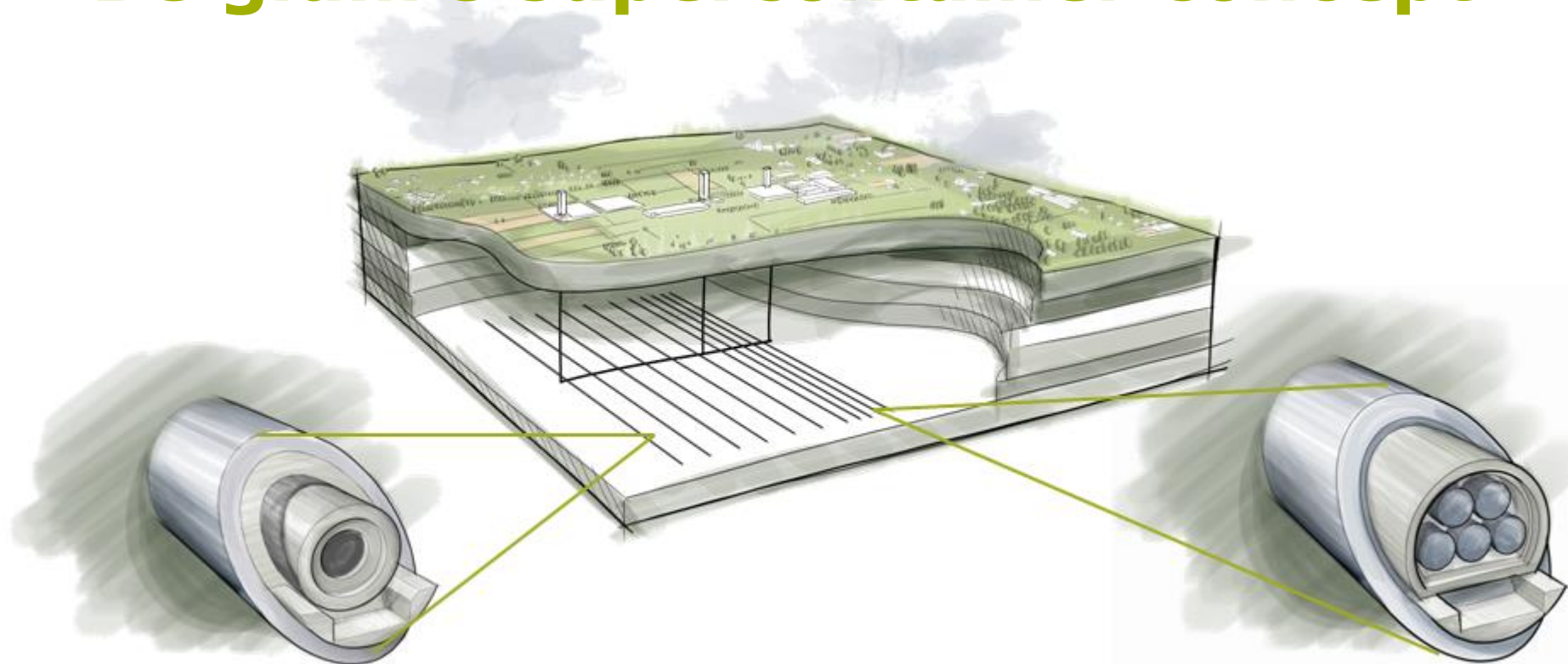


Belgium's supercontainer concept



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**The Belgian Radioactive Waste Management
Organisation**

Outline

- **History & current situation on geological disposal in Belgium**
- **Outcomes of SAFIR 2 (2001-2003)**
- **Re-evaluation of the concept**
- **Selection of a reference concept**
- **Current reference design**
- **Impact of new reference design on RD&D**
- **Recent additional requirements**
- **Conclusions**

History & current situation

short lived LILW – Category A waste

- 1998 Political decision for disposal in voluntary communities or nuclear communities
- Partnerships with mainly Mol and Dessel developed proposal for surface disposal
- 2006 political decision to go for surface disposal at Dessel
- 2013 license application submitted to the regulatory body (FANC)
- Currently: Q&A on license application ongoing
- Planning to start construction of surface disposal facility in 2018, exploitation in 2021

History

long lived LILW and HLW (including spent fuel if declared as waste) – B&C waste

- 1974 : start of first studies by SCK•CEN
- 1976 : inventory geological formations -> promising potential host rock = Boom Clay (Mol)
- 1980-1984 : construction Underground Research Laboratory HADES
- 1983 : ONDRAF/NIRAS takes over the management of the R&D programme (in collaboration with SCK•CEN)
- 1989 : Safety and Feasibility Interim Report (SAFIR)
- 2001 : Second Safety and Feasibility Interim Report (SAFIR 2)
- 2010-2011 : public consultations preparing the Waste Plan
- 2011 : Waste Plan handed over to the supervising authority
- 2014 : EU Directive 2011/70 translated into Belgian Law, authorizes ONDRAF/NIRAS to propose a national policy for the long-term management of B&C waste, which should include reversibility and retrievability
- 2015 : ONDRAF/NIRAS submits such a proposal based on conclusions of Waste Plan
- Currently policy decision pending



Current situation

long lived LILW and HLW (including spent fuel if declared as waste) – B&C waste

More than 40 years of research

Policy decision still pending

Recommended solution for long-term management B&C waste

- Geological disposal in poorly indurated clays
- In a single facility, on Belgian territory
- As soon as reasonably possible, but with the pace of development and implementation being proportionate to its scientific-technical maturity, as well as to the public support it receives
- Incorporating conditions arising from consultations (retrievability, controllability, transfer of knowledge,)



Specialty of poorly indurated clays

- **Limited strength of poorly indurated clays and fast self sealing**
- **During excavation, a liner needs to be installed**
 - In practice a concrete liner is used



Outcomes of SAFIR 2

Based on the assessment and its international peer review

- Geological disposal in Boom Clay is promising
- In the reference evolution scenario and most altered evolution scenarios, the Boom Clay is the major contributor to overall safety
- The feasibility and especially operational safety were not very clear, if not questionable
- The EBS behaviour was rather complex and with the remaining uncertainties on near field evolution it would be difficult to guarantee full containment during the thermal phase

Re-evaluation of the reference concept

- **In line with the stepwise approach a re-evaluation of the design was performed, based on the outcomes of SAFIR 2 (2001) and its peer-review (2003)**
- **A safety strategy was defined which incorporates the following main elements**
 - Full containment during the thermal phase for HLW / SF
 - Do not unduly disturb the host rock
 - Preferences for materials and implementation procedures for which broad experience and knowledge already exists
 - Preferences for permanent shielding of the wastes and for minimisation of operations in the underground

Re-evaluation of the reference concept

Approach

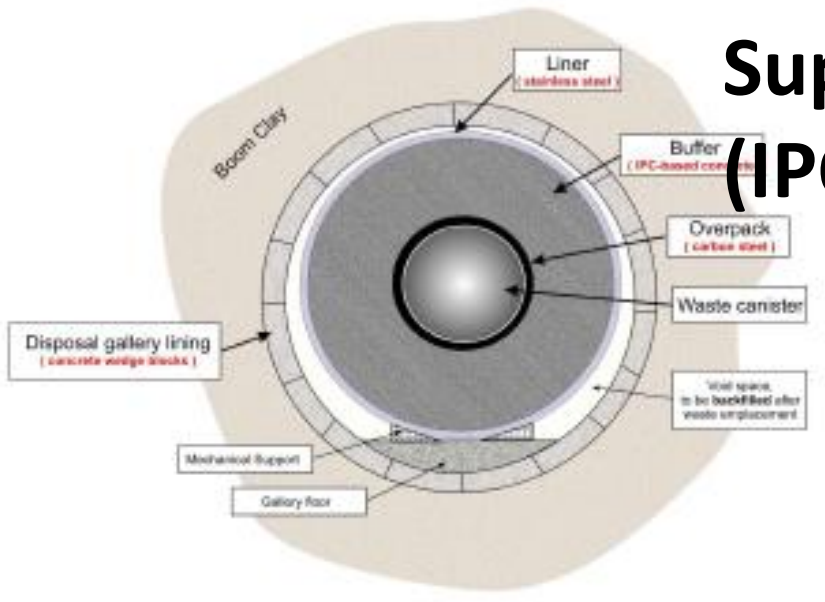
- **Structured** step-by-step approach, with justification of the key decisions taken, based on awareness of the consequences
- **Multi-disciplinary** task force, spanning different organisations from research and industry
- Consultation of internationally recognised experts (corrosion panel)
- Fully **documented** procedure

Alternative concepts and variants

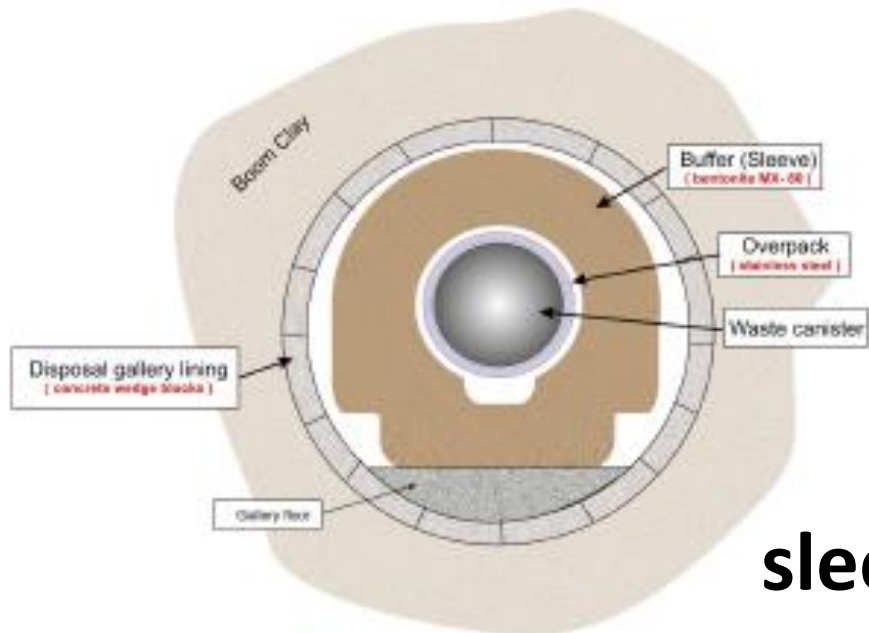
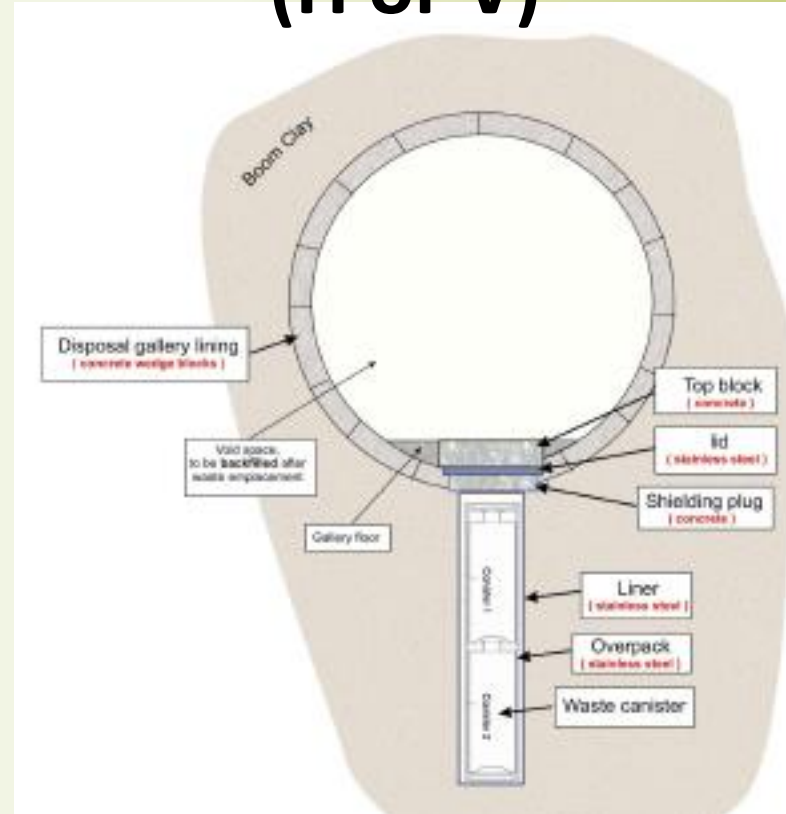
Three basic disposal concepts

- **Supercontainer**
 - Overpack is emplaced in the disposal gallery together with its enveloping radio-shielding buffer
- **Borehole**
 - Overpack is emplaced in a borehole perpendicular to the disposal gallery (transportation/handling needs to be shielded)
- **Sleeve**
 - Overpack is emplaced in a « sleeve », which is emplaced in the disposal gallery prior to the overpack (transportation/handling needs to be shielded)

Supercontainer (IPC or OPC)

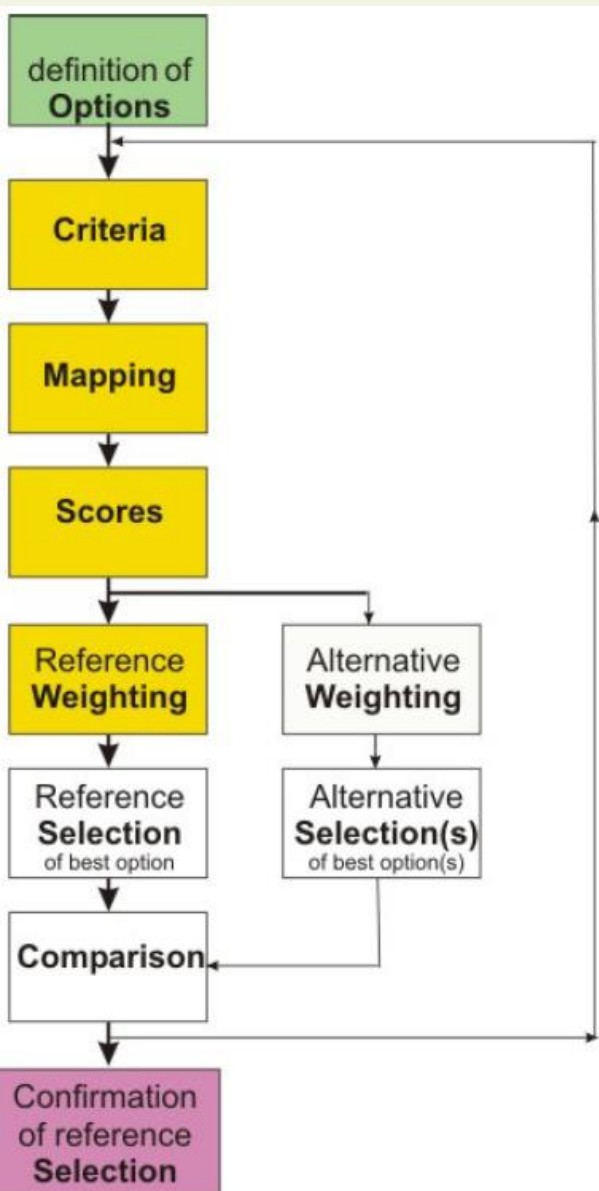


Borehole (H or V)



sleeve

Selection of a reference concept



- **Selection process = multi-criteria analysis**
- **Teamwork : discussion + working sessions**
 - Development of a set of criteria
 - Criteria weighting strategy
 - Agreement scores (proposed by experts)
- **Duration of the selection process**
 - January to November 2003
 - Dedicated sessions during 6 meetings
- **Mechanisms of multi-criteria analysis**
 - Define options
 - Define criteria
 - Define mapping of scores to numerical values
 - Attribute scores
 - Define weighting of criteria
 - Test robustness of selection (alternative weighting)

Aspect	Criterion	Weight factor	
Engineered robustness	Containment	40	80
	Release from waste matrix	40	
	Delay and attenuation by EBS	0	
Host rock perturbation	Gas generation	20	80
	Chemical compatibility with host rock	20	
	EDZ	20	
	Loss of clay layer thickness	20	
Intrinsic robustness	Materials characterisation	50	100
	Materials interaction modelling	50	
Ease of demonstration	Natural and/or archeological analogues	25	80
	Proven technology	25	
	QA/QC implementation	30	
Technical operation	Handling complexity	10	25
	Deposition rate	5	
	backfilling	10	
Flexibility	Transferability (flexibility to waste type)	35	50
	retrievability	15	
Financial feasibility	Construction costs	25	50
	Operation costs	25	

Results

- **Reference weighting (see before)**
- **Alternative weighting**
 - Techno : increased weight on technical operation, flexibility and cost
 - Finance : increased weight on cost
 - Authorities : increased weight on ease of demonstration

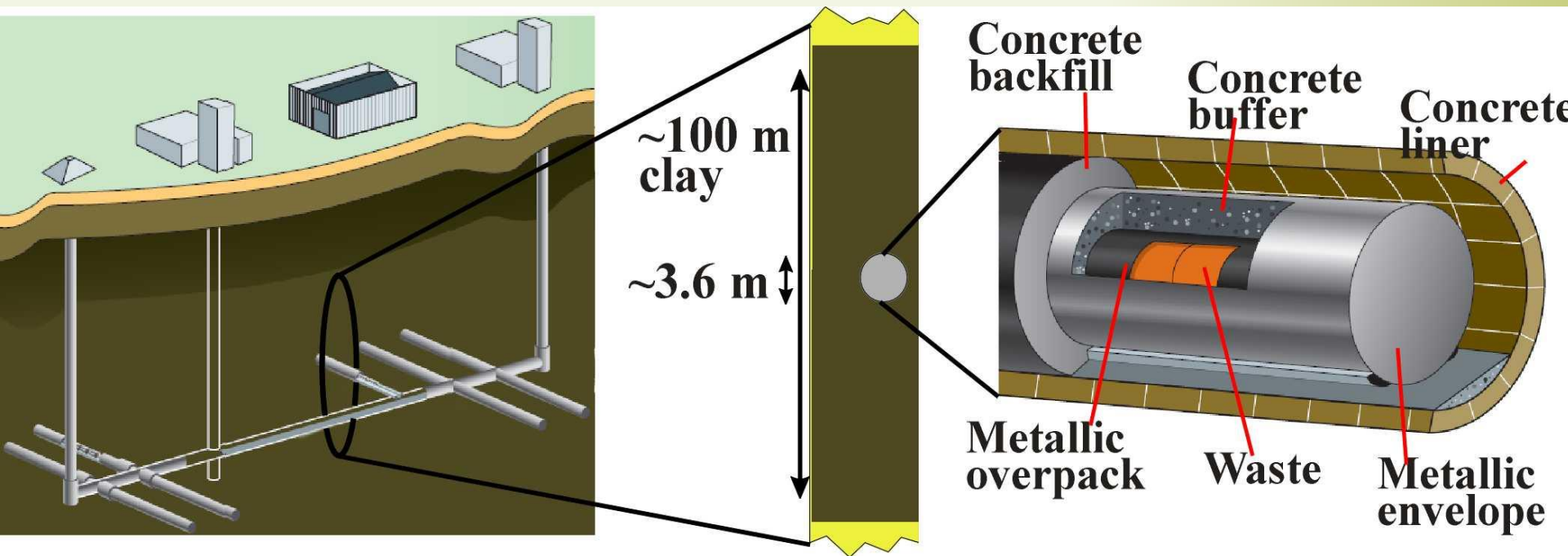
	Reference	Techno	Finance	Ease of demonstration
SC – IPC	57	57	57	55
BH – V	54	54	54	53
SL	52	52	53	52
SC – OPC	61	61	59	59
BH - H	55	55	55	53

Analysis of MCA results and conclusions (in 2003)

- **Key rationale for selection:**
 - The requirement for a **watertight containment** of the waste during a predefined time, which means a design focused on the control of the corrosion of the overpack
 - The **ability to characterize** and to model phenomena (especially in the buffer)
- **Strengths & opportunities of the supercontainer design**
 - Construction of EBS on surface allows better Quality Assurance
 - Permanent shielding of workers (no absolute need for underground remote controlled transfers of waste packages)
 - Allows separation of conventional mining and nuclear operations
 - Use of well known, cost effective and available materials
 - Broad acceptance basis: the concept is the result of discussions within an integrated and multidisciplinary working group, assisted by experts

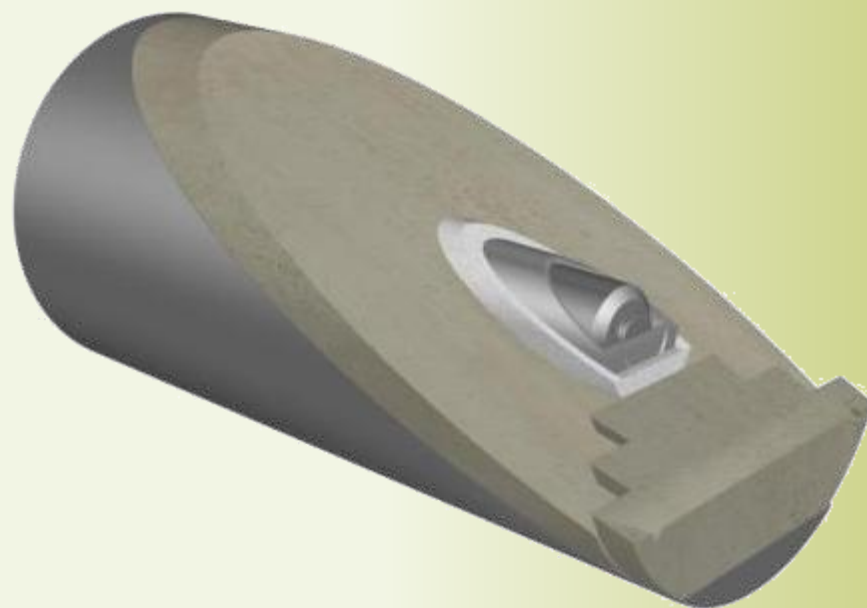
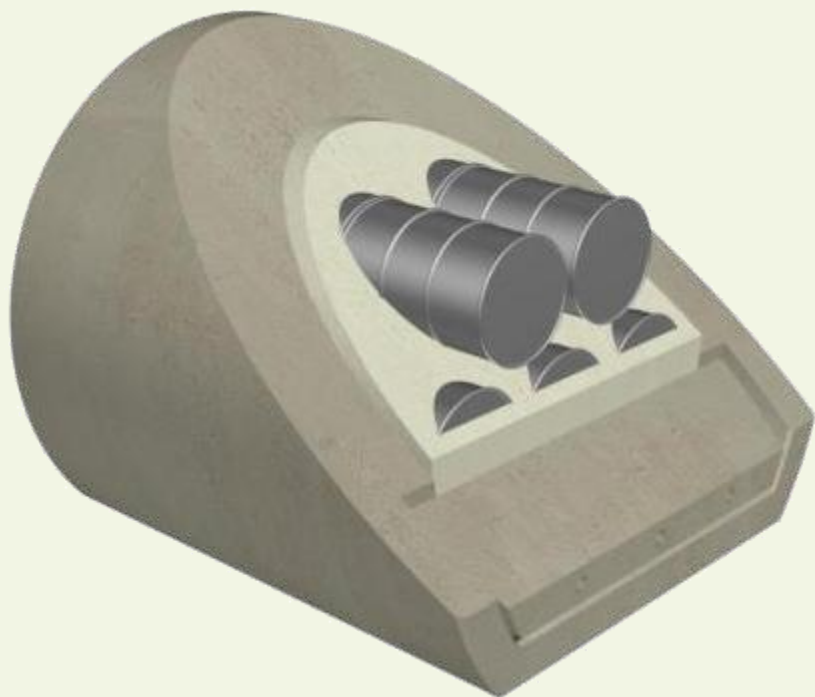


Current reference design: supercontainer with OPC



Derivation of monolith design for B waste

- **A safety strategy was defined which incorporates the following main elements**
 - ~~Full containment during the thermal phase for HLW / SF~~
 - Do not unduly disturb the host rock
 - Preferences for materials and implementation procedures for which broad experience and knowledge already exists
 - Preferences for permanent shielding of the wastes and for minimisation of operations in the underground
- **As one single repository is assumed**
 - Preference to keep the same diameter for the transfer and disposal galleries
 - Preferences to keep commonalities with C-waste, where possible

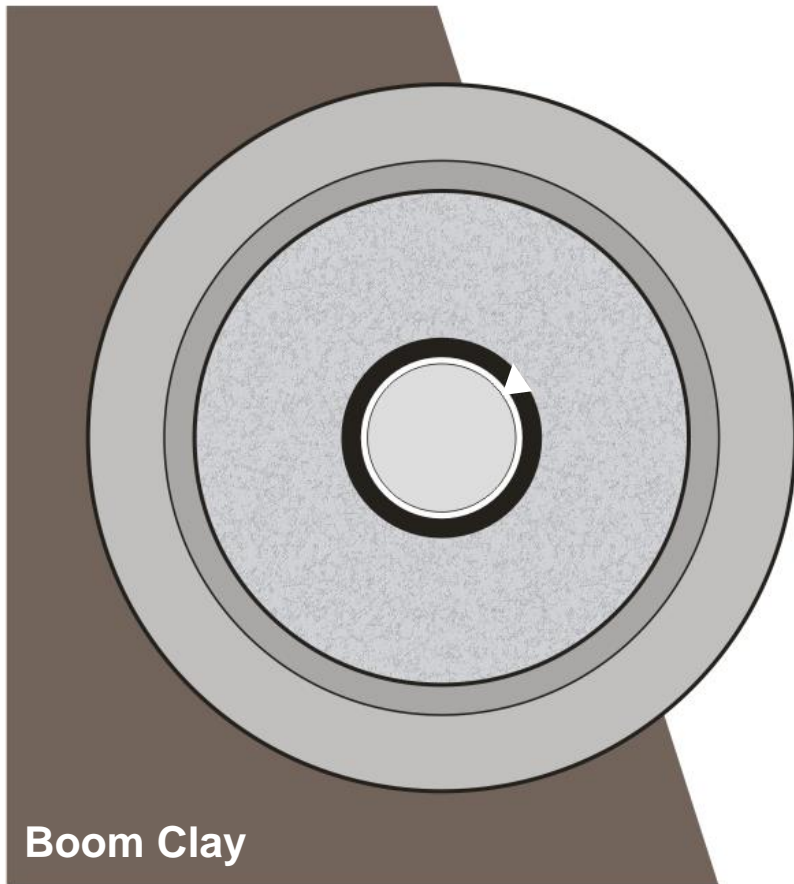


Impact of new design on RD&D

Since 2006, focus on different aspects
Some of these aspects are unique to the supercontainer concept

- **Corrosion**
- **Dissolution rates of HLW and spent fuel**
- **Solubility limits of RN**
- **Sorption of RN**
- **Feasibility of the supercontainer**

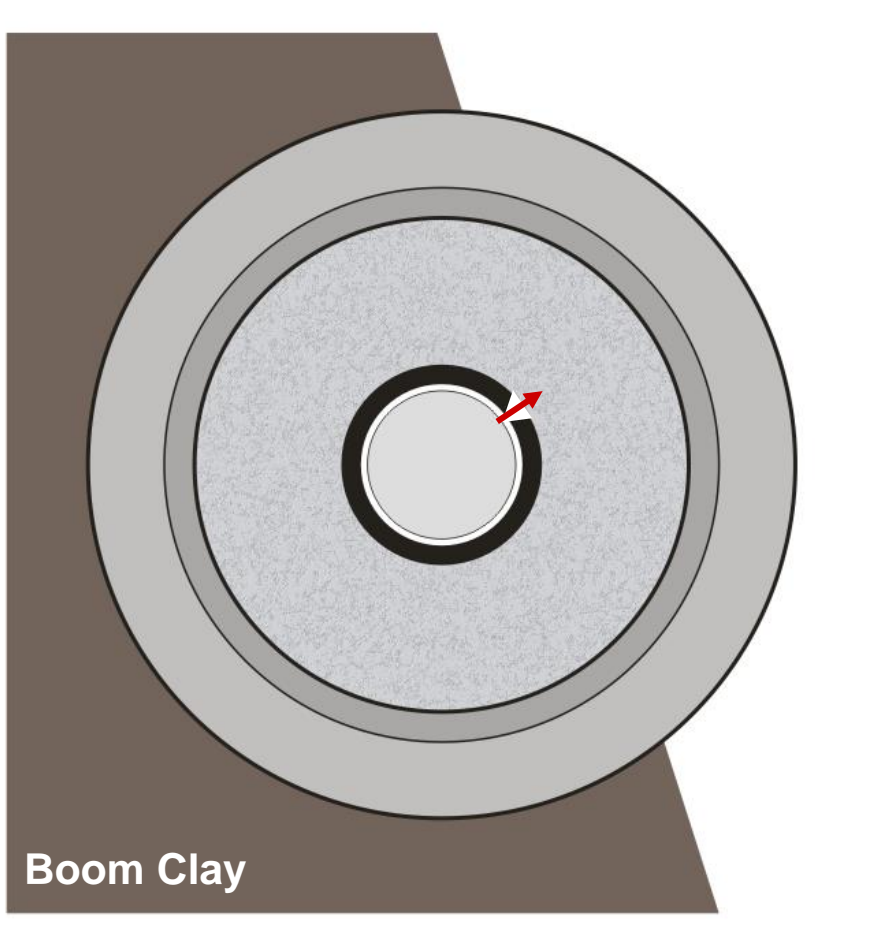
Containment



Well constrained boundary conditions for corrosion to better underpin overpack integrity during thermal phase

- Scoping calculations and sensitivity analysis illustrated that the Near Field would remain highly alkaline for a geological time span
- Very low uniform corrosion rates are confirmed, now focus on localised corrosion, stress corrosion cracking and hydrogen embrittlement

Limited RN release from waste form

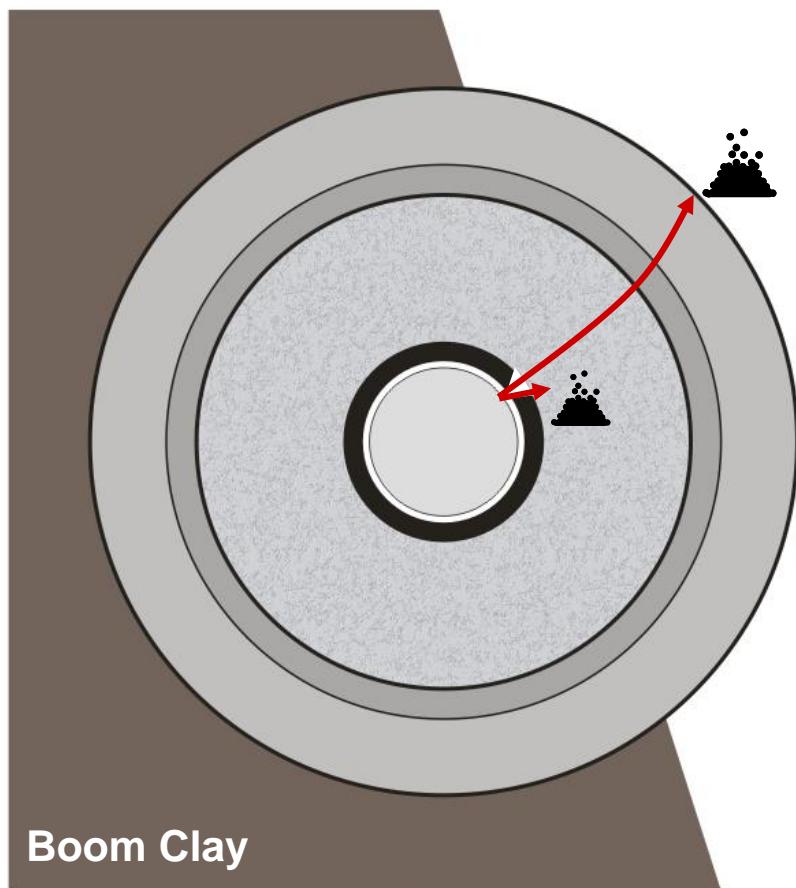


Chemical Near Field environment completely different → dedicated research programmes

- Release from vitrified waste is faster compared to previous concept, BUT strategic choice not to rely too much on this safety function as it has a minor impact on overall safety of the system (at least for vitrified HLW)
- For spent fuel the behaviour is demonstrated to be similar as at near neutral conditions

Boom Clay

Solubility limits



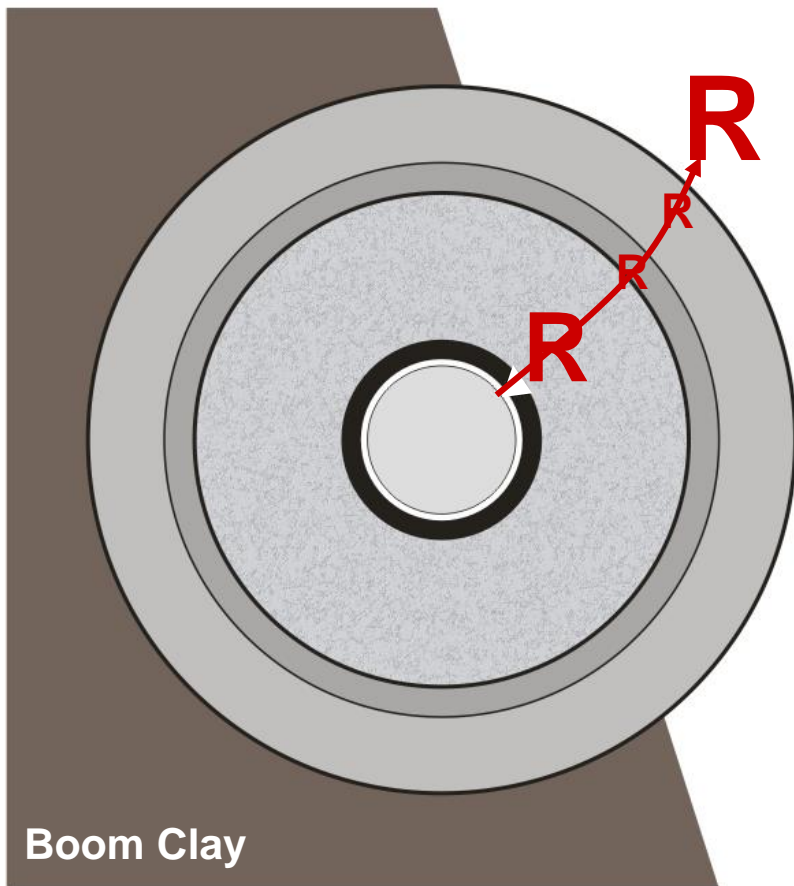
Near Field:

- Prevailing $pH/(Eh)$ conditions of supercontainer design need to be taken into account
 - In general terms, solubilities seem to be comparable or an order of magnitude higher for fission products and comparable or order(s) of magnitude lower for actinides

Far Field:

- No changes compared to other concepts
 - IF extent of disturbed zone not too large → mainly alkaline plume
 - The amount of concrete has only doubled using a supercontainer
 - In the worst case a few meters of clay might be affected

Sorption



Near Field

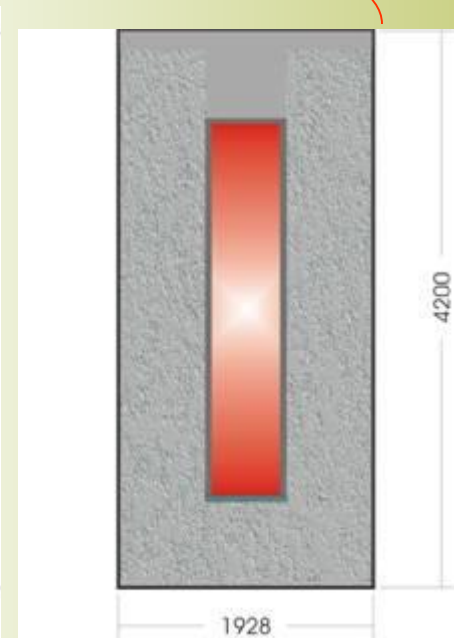
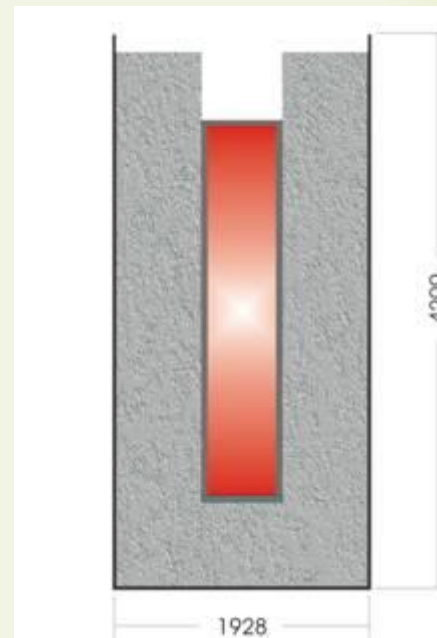
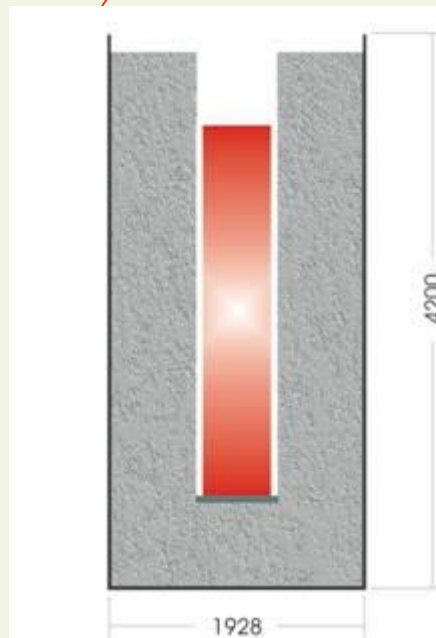
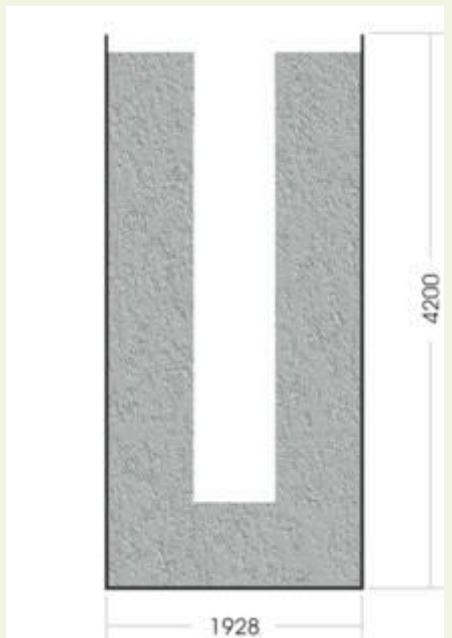
- Prevailing conditions need to be considered
 - Concrete often used as barrier in near surface disposal and for medium-level long-lived waste
 - Limited contribution compared to about 50m of clay

Far Field

- No changes compared to other concepts
 - IF extent of disturbed zone is not too large → mainly alkaline plume
 - The amount of concrete has only doubled using a supercontainer
 - In the worst case a few meters of clay might be affected

Supercontainer construction

In hot cell



Step 1 :
prefab shell
concrete phase 1

Step 2 :
container insert

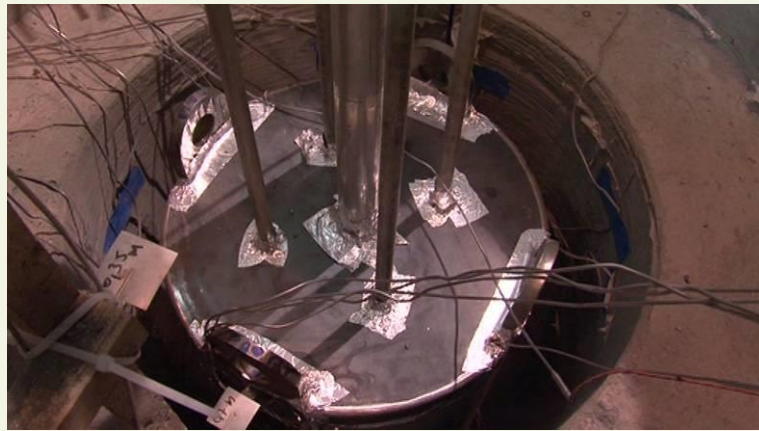
Step 3 :
Second phase
concrete

Step 4 : Third phase
concrete and lid

Desktop and demonstration tests

- Concrete composition developed
- 2 half scale tests performed (full diameter, half height)
 - Demonstration of construction feasibility of the buffer
 - Temperature and stress conditions in the buffer were measured and simulated
 - small fissures appearing at the outer surface of the buffer are further being examined (cause, extent and potential impact on operational and long-term safety)
- Now focus on construction and emplacement of the lid





Additional requirements

- **In the frame of the preparation of the Waste Plan, a Strategic Environmental Assessment was performed in 2010.**
 - According to law this includes a public consultation round
 - ONDRAF/NIRAS performed in addition to those some extra societal interactions
- **Major concerns that were expressed by society were**
 - Reversibility/Retrievability (no clear definition or timing)
 - Monitoring
 - Memory keeping
- **The law of 2014 (transposition of EU Directive 2011/70) explicitly includes reversibility/retrievability**



Retrievability

- **Retrievability was already included in the multi-criteria analysis**
 - SC-IPC = medium (65/100)
 - SC-OPC = medium (65/100)
 - BH-V = good (85/100)
 - BH-V = good (85/100)
 - SL = fair (40/100)
- BH is assumed somewhat easier to retrieve as no backfill present (*« so no danger to damage package during backfill removal »*)
- **Current point of view for RD&D**
 - Keep Supercontainer as reference, however, the optional external envelope of 6mm stainless steel probably will become the reference (easier to remove backfill without interacting with supercontainer buffer and easier to check for contamination once backfill removed)
 - Check development of *« easy to remove »* backfill



Monitoring / KM

- **We see no direct impact on supercontainer design**
- **Important issue to follow-up**
 - Focus on monitoring strategy and interaction with stakeholders on their expectances (explaining them as well the limits)
 - Might impact the lay-out of the repository, e.g. pilot facility
 - Currently, far from implementation, so no immediate focus on technology development for monitoring

Conclusions

- **It is believed that the safety concept has been reinforced as this supercontainer design should provide**
 - Permanent shielding during operational phase
 - Facilitated quality control
 - Adequately understood engineered containment during the thermal phase
- **Moreover, this design**
 - Is based on proven technologies and widely available, affordable materials
 - Has negligible negative impact on the safety functions provided by the most important barrier, the clayey host rock
- **It should be kept in mind that concrete is difficult to avoid in plastic clay (e.g. as gallery liner)**

