The ONDRAF/NIRAS Safety Strategy for the Disposal of category B&C Wastes

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Introduction

- Over 30 years of RD&D on the geological disposal of B&C waste (HLW/ILW-LL) in Boom Clay as solution fo the long-term management of this waste has been synthesized in two state-of-the-art reprots
  - SAFIR report (1990)
  - SAFIR 2 report (2001)
    - + international peer review (NEA 2003)

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The SAFIR 2 exercise and the NEA peer review have led to the following general conclusions

regarding *scientific and technological* achievements

- disposal in Boom Clay has the potential to be safe and feasible
- Boom Clay has excellent barrier properties as regards the migration of radionuclides
- the programme "is well developed and sufficiently advanced to address the siting issue", even though several uncertainties must still be reduced

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Conclusions, ctd

regarding *societal* aspects

- disposal in Boom Clay lacks
  formal political and societal legitimacy

Indeed,

- geological disposal
- argillaceous formations
- Boom Clay
- and, of course, siting

have neither been discussed at the societal level
nor been confirmed at the political level
as the long-term management choice for B&C waste

Currently, they are thus working hypotheses of O/N

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O/N received a « double decision » from its supervising minister

Continue the RD&D

- SAFIR types of reports must be replaced by decision-oriented documents = > **Safety and Feasibility Cases**
- Around 2013: SFC 1 =>Zone Case
- Around 2020: SFC 2 => Site Case

Develop a work programme with a societal focus

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« Belgian » definition of Safety and Feasibility Case

The safety and feasibility case is an integration of arguments and evidences that describe, quantify and substantiate the safety and feasibility of a proposed long-term management solution for HLW/ILW-LL, i.e. geological disposal.

It consists of a series of documents evidencing that:

- the repository can be constructed, operated, closed and monitored in a safe way thus ensuring operational safety,
- the repository system is meeting perforamnce requirements including long-term safety requirements and,
- the solution is based on sound scientific bases and sound engineering practices.

It discusses the significance of any remaining uncertainty or open question in the context of the decision at hand in the process of repository development.

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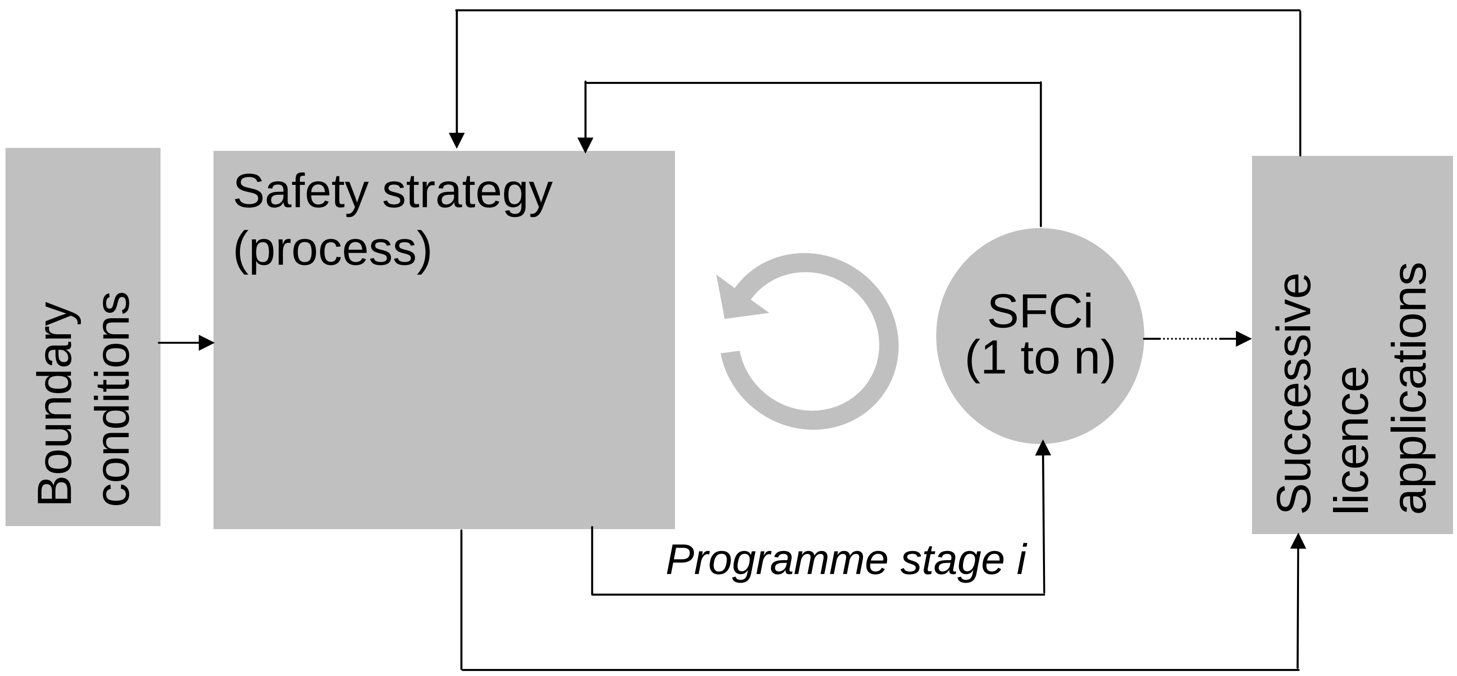
The safety strategy is the iterative process guiding the stepwise repository development and implementation



Safety strategy: definition and objectives

The safety strategy is the iterative process guiding the stepwise development of a geological repository and of its implementation procedures.

It aims at developing

- a concept and design for the disposal of B&C waste in a geological repository and procedures for repository implementation,
- the evidence, arguments and analyses to show, through assessments, that these are both safe and feasible.

It does not attribute specific function(s) to the various repository components over time. (This is done within SFCs.)

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Concept

broad-brush description of the repository and its geological environment and of the functions that they are intended to perform in order to protect the workforce during constuction, operation and closure of the facitiliy and to protect the public and the environment in the longer term.

Design

detailed specifications of the surface and underground facilities and detailed procedures

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Need for a safety strategy

- The safety strategy:
  - Supports the development of the safety and feasibility case that is presented to the authorities at key decision points,
  - Provides a basis or platform for interactions with other interested stakeholders,
  - Guides the research, development and demonstration activities => basis for RD&D plan
  - Ensures that the decisions underlying the concept and design are well founded and take due account of various constraints or « boundary conditions ».

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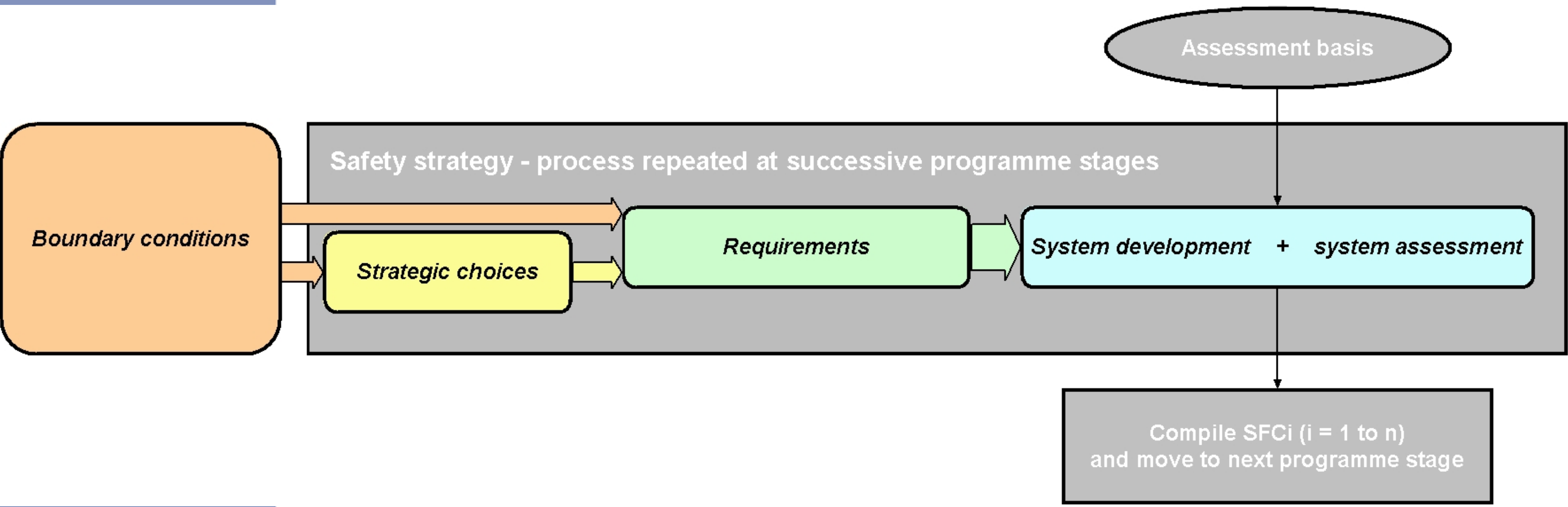

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The three types of input for the safety case

General objective of the solution to be developed

Providing passive long-term safety subject to feasibility (that includes societal acceptability)

Boundary conditions

- international guidance
- Belgian legal and regulatory framework
- O/N working hypotheses
- institutional policy
- other stakeholder conditions

Assessment basis

- knowledge and understanding
- methods, models, codes and databases

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Strategic choices: what?

- are high-level choices, with an impact on concept and on design, not a detailed assignment of safety functions for all different components over time
- are made early in the systematization and formalization process
- are not expected to change much
- are not a 1-to-1 translation of guidance items

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Current list of strategic choices

- Choices related to safety functions
  - for heat-emitting waste, the engineered barriers shall be designed to provide complete containment of the waste and associated contaminants at least through the period when the heat output from the waste is high to avoid the necessity to model transport during the thermal phase
  - for non heat-emitting waste, choice to rely only on Boom Clay for ensuring long-term safety, through the “delay and attenuate” and “isolation” safety functions
  - choice of design, materials and construction techniques that do not unduly perturb the long-term safety functions of the Boom Clay
  - ...

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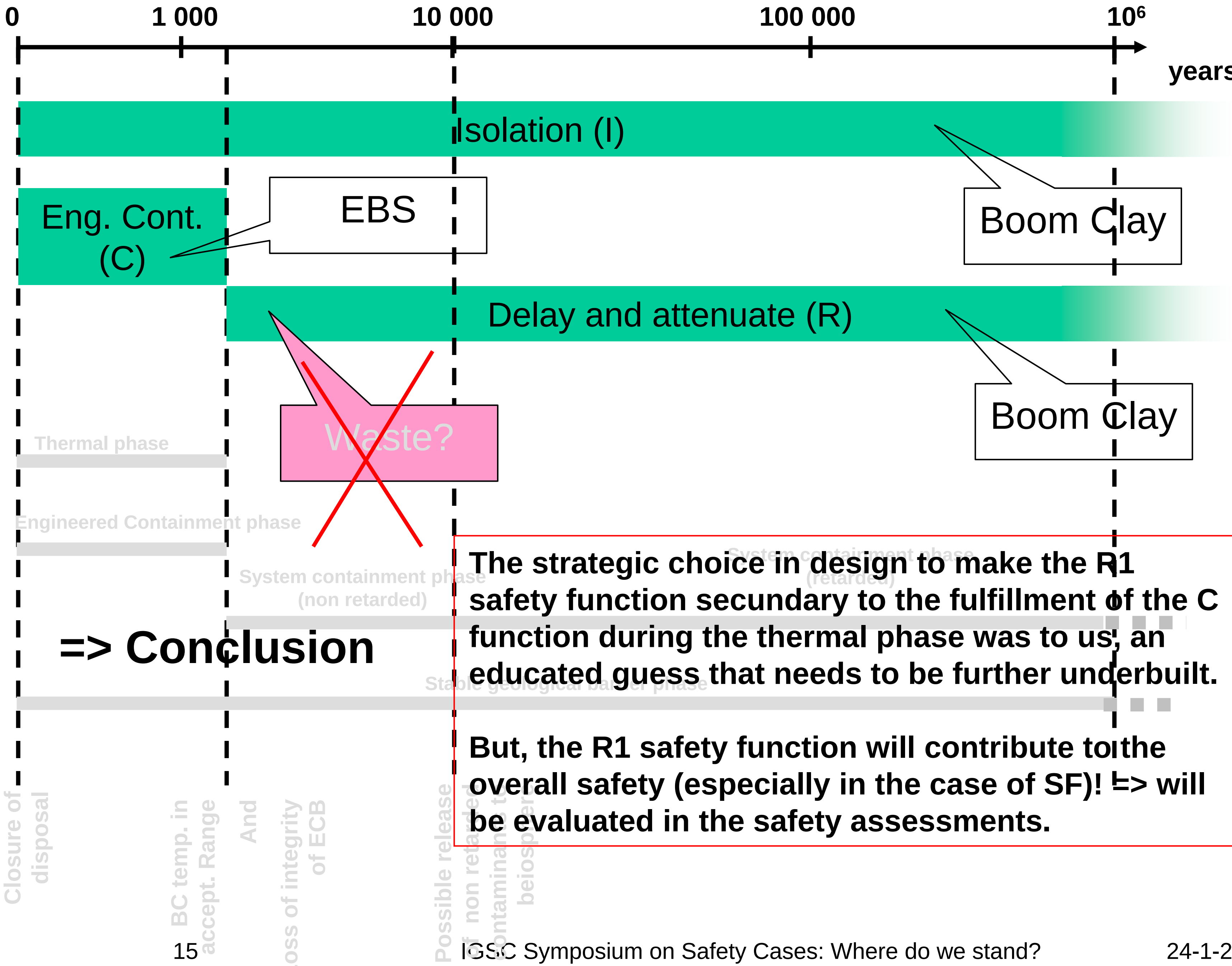

=> Conclusion

The strategic choice in design to make the R1 safety function secundary to the fulfillment of the C function during the thermal phase was to us, an educated guess that needs to be further underbuilt.

But, the R1 safety function will contribute to the overall safety (especially in the case of SF)! => will be evaluated in the safety assessments.

Strategic choices *(continued)*

- choice for avoiding complexity
  - choice for permanent shielding of the waste
  - choice for minimisation of underground operations
  - preference for well-known and widely used materials and implementation procedures
  - …
- responsibilities
  - choice to close the disposal galleries as soon as possible after waste emplacement
  - choice to dispose of the waste as soon as possible
  - …

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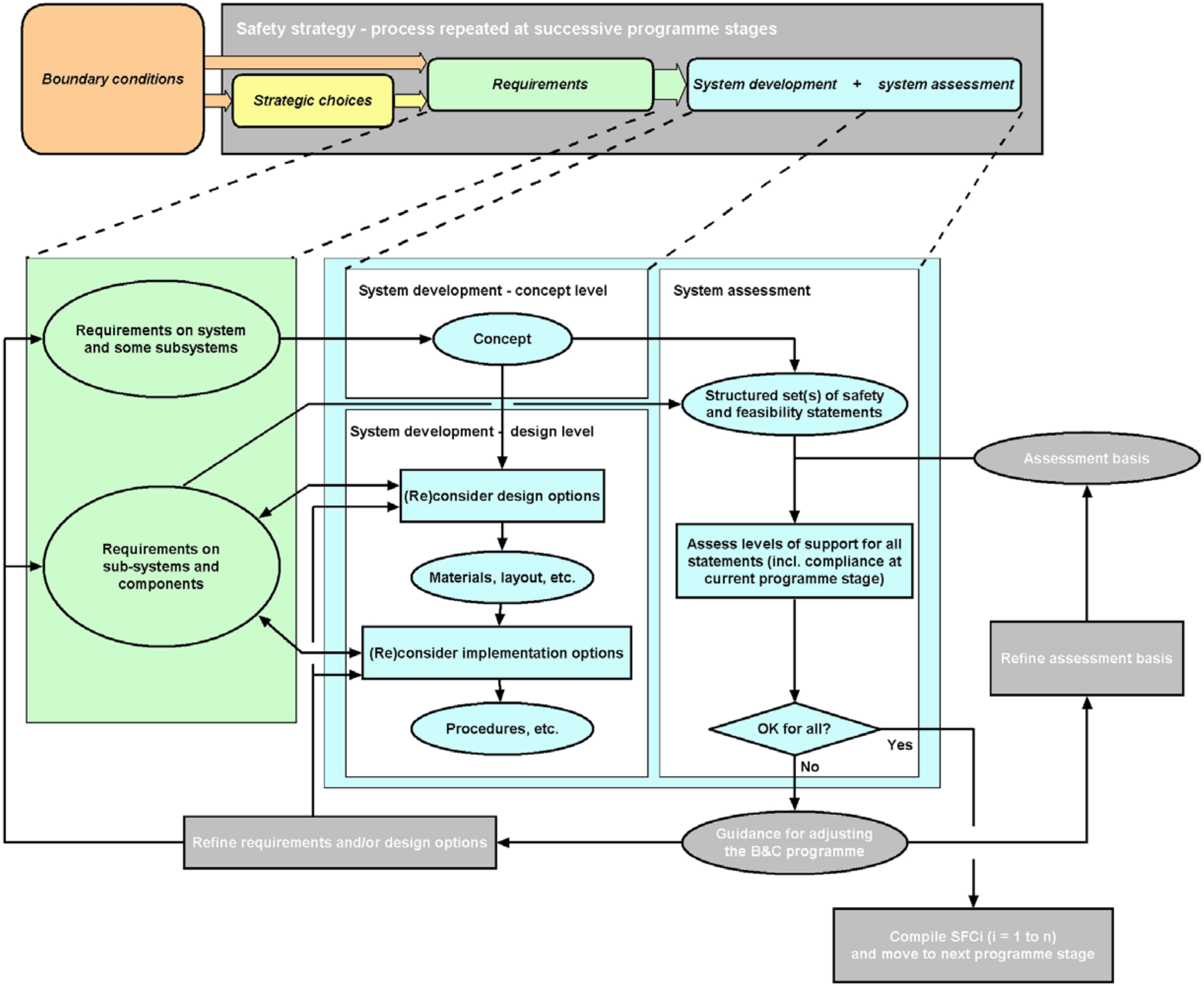

Safety strategy - process repeated at successive programme stages
Boundary conditions
Strategic choices
Requirements
System development + system assessment
Requirements on system and some subsystems
Requirements on sub-systems and components
System development - concept level
Concept
System development - design level
(Re)consider design options
Materials, layout, etc.
(Re)consider implementation options
Procedures, etc.
System assessment
Structured set(s) of safety and feasibility statements
Assessment basis
Assess levels of support for all statements (incl. compliance at current programme stage)
OK for all?
Yes
No
Refine assessment basis
Guidance for adjusting the B&C programme
Refine requirements and/or design options
Compile SFCi (i = 1 to n) and move to next programme stage

From “requirements” to “well-substantiated claims” or from top-down to bottom-up approach

An SFC is a structured set of statements supported by evidence, arguments and analyses.

- When starting to build an SFC, the statements take the form of requirements (“should”; top-down).
- When all statements have become well-substantiated claims (“does”, “is”; bottom-up), the SFC can be finalised.

The objective of the current RD&D is

- To provide adequate supporting elements for turning requirements into claims.
- To develop the appropriate assessment tools (safety assessment methodology, incl. scenario development and statement evaluation, feasibility assessment methodology, incl. aspects of operational safety).

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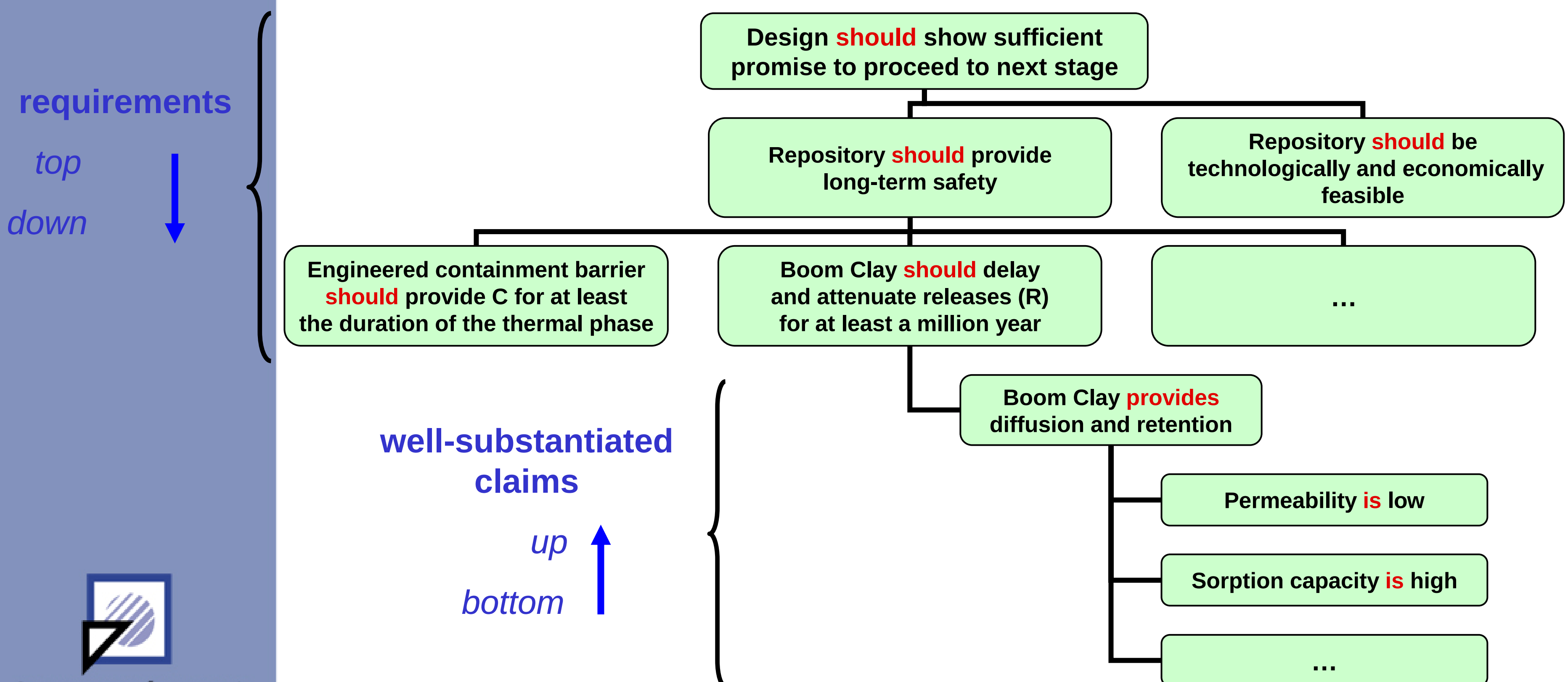
From “should” to “does”: an example for heat emitting waste



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Assessment of a structured set of statements => RD&D plan

		Type of statement	
		"Nice-to-have" (N)	Potential "show-stopper" (S)
Adequacy of the level of support judged to be available (or potentially available) with respect to the programme milestone at hand	Changes to RD&D programme or design changes needed in order for adequate support to be achieved by next milestone	N1	S1
	Good prospects for gaining adequate support with existing RD&D programme	N2	S2
	Adequate support judged to be available	N3	S3

The safety strategy applied

- Design developed for HLW/ILW-LL guided by the safety stragegy

- First evaluation of statements
  - Identification of open questions, knowledge gaps
  - Discussion
    - Risk? Threat?
    - Priority to remediate
  - RD&D plan

Jan 2007 → (Discussion)

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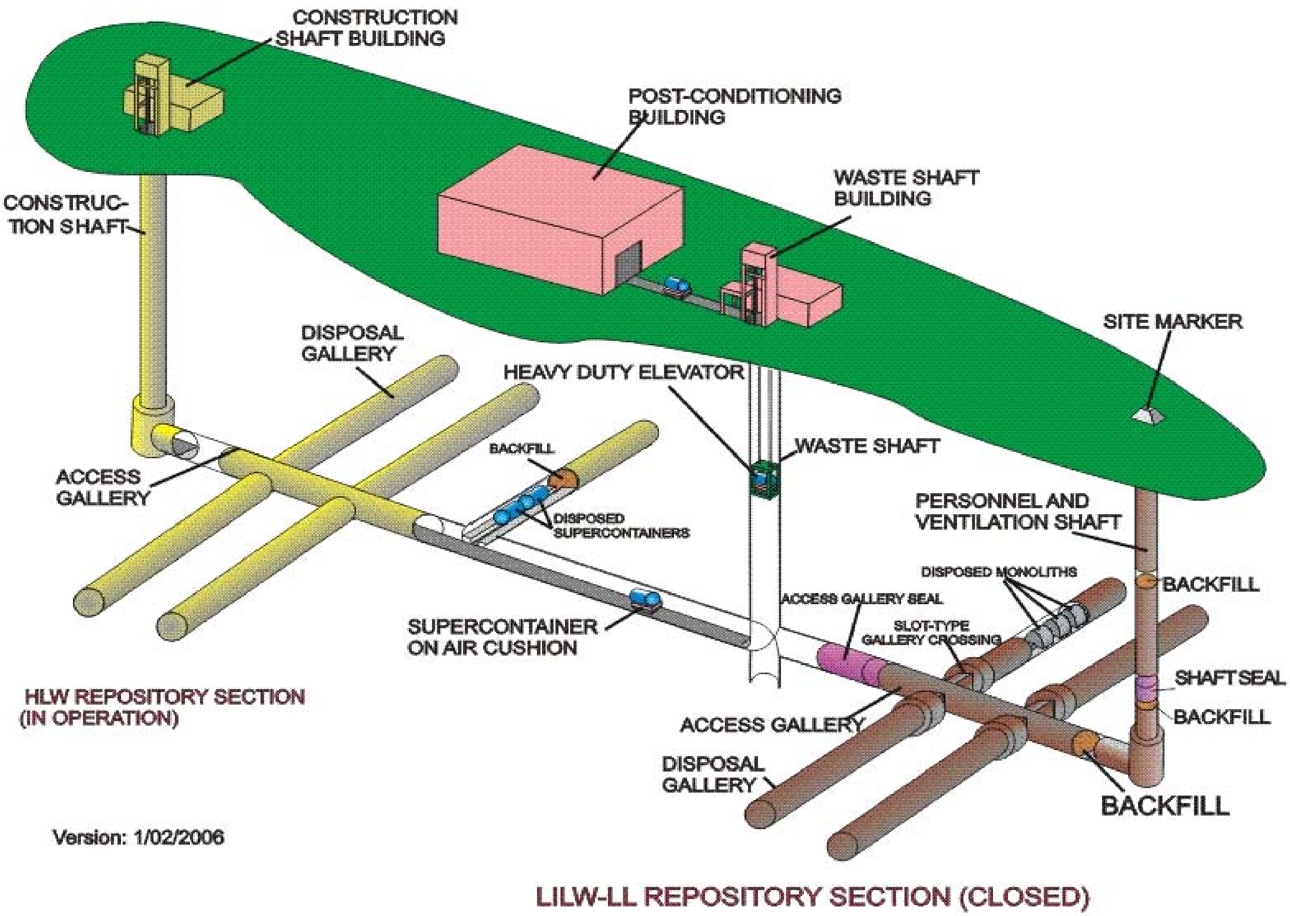
Current reference lay-out and design



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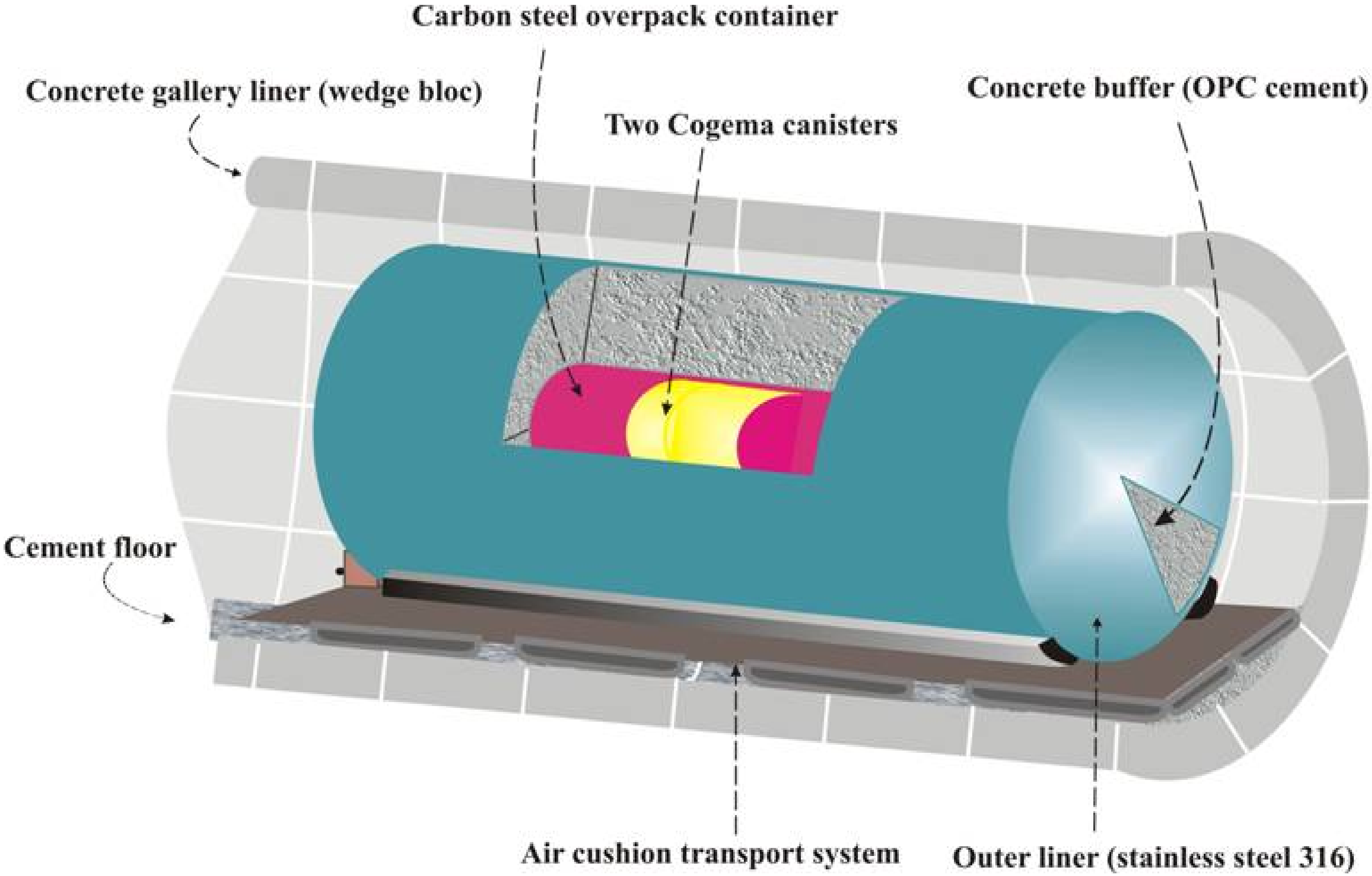
Physical confinement + shielding by a massive supercontainer (C steel and concrete)



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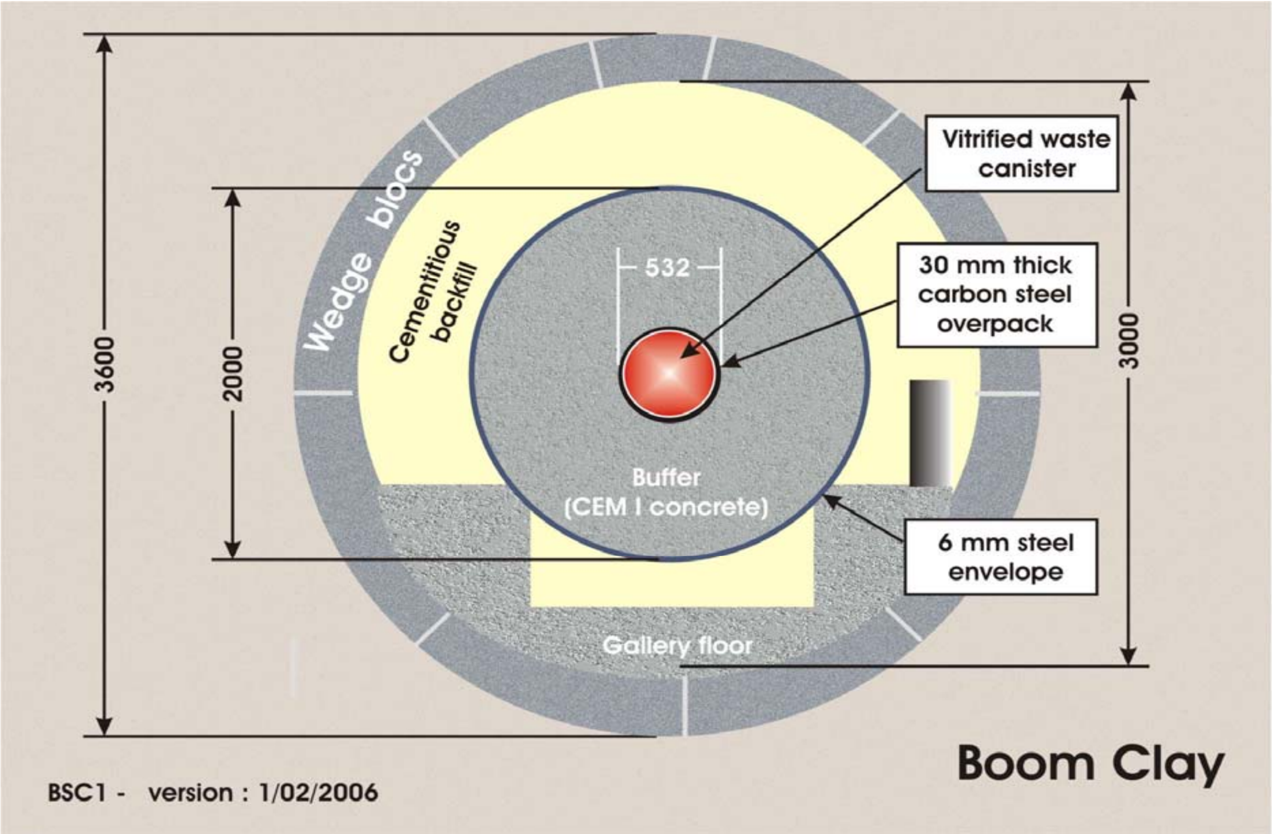
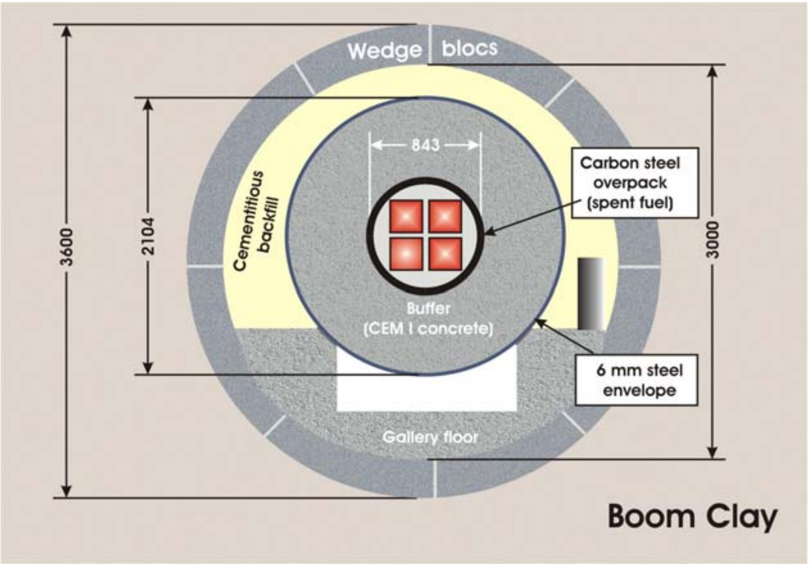
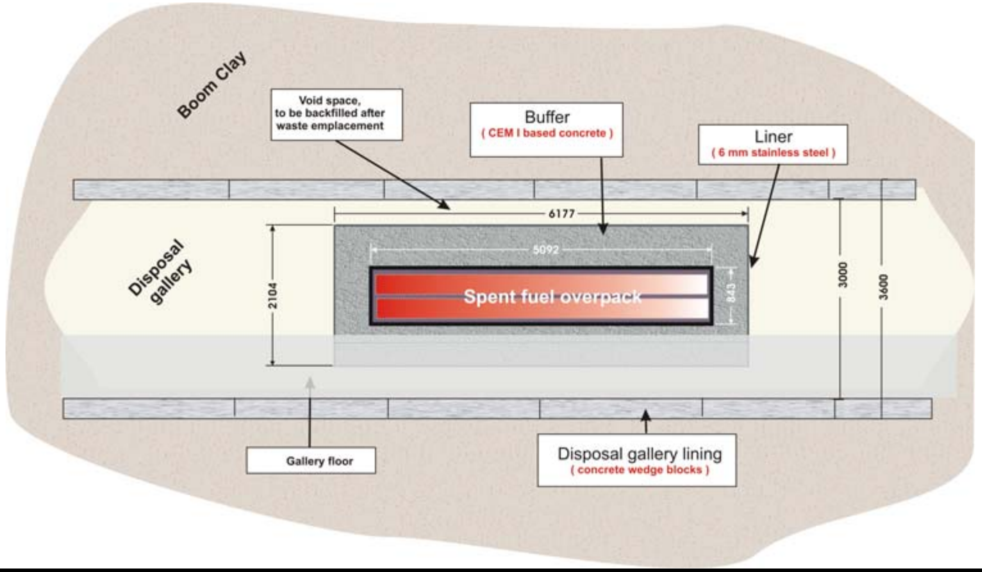
Disposal waste package for vitrified glass



Disposal waste package for spent fuel





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SS The disposal system and its environment conforms to relevant regulatory targets/standards and general guidance concerning long-term safety (via the safety functions that it performs over the required time frames).

SS.1 The disposal system and its environment **isolate** the waste to minimise the probability and consequences of human intrusion, and to protect against surface events and processes during the "stable geological environment phase.".

SS.2 The engineered barrier system provides complete **containment** of radionuclides during the thermal phase.

SS.3 The disposal system (is expected to) **delay and attenuates** releases to the environment during the "system containment phase", ensuring that releases remain below regulatory targets/standards and general guidance.

SS.4 Dilution and dispersion by the environment of the disposal system (biosphere + aquifers) can be sufficiently quantified for the SFC 1 zone

SS.5 Results from long-term safety evaluations confirm the safety of the disposal system for the EES (AES?)

SS 3 The disposal system (is expected to) delay and attenuate releases to the environment during the “system containment phase”, ensuring that calculated end-points remain below regulatory targets/standards and general guidance.

SS 3.1. …

SS 3.2. The transport in the host rock is diffusion dominated and assures this characteristic for a long-term.

SS 3.3. …

SS 3.2. The transport in the host rock is diffusion dominated and assures this characteristic for a long-term.

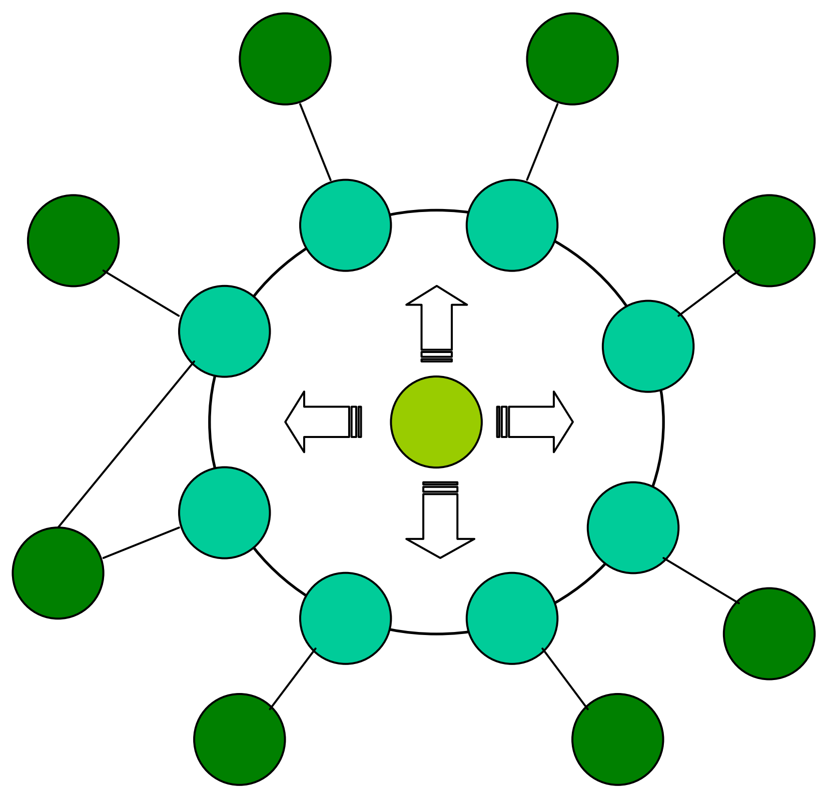
- SS 3.2.1 The h ost rockk has a fine homogeneous pore structure and a low hydraulic conductivity, and no significant variations are expected on the long term.
- SS 3.2.2 The host rock has a very low hydraulic gradient over the host rock, and no significant variations are expected in hydraulic gradient on the long term.
- SS 3.2.3 The host rock possesses a self-sealing capacity to respond to geomechanical and thermo-mechanical disturbances (short term).
- SS 3.2.4 The host rock possesses a self-sealing capacity to respond to geomechanical and thermo-mechanical distrubances (long term).

FS The disposal facility for cat. B&C waste can be constructed, safely operated and progressively closed, with adequate funding provided.

- **FS 1** The **repository** for cat. B&C waste and the **disposal packages** can be **constructed**.
- **FS 2** The **repository** for cat. B&C waste can be safely **operated**.
- **FS 3** The **repository** for cat. B&C waste can be **progressively closed**.
- **FS 4** The **site surface installations** can be constructed, safely operated, and safely decommissioned and dismantled.
- **FS 5** The **costs** for the construction, operation and closure of the disposal facility for cat. B&C waste, including the decommissioning and dismantling of the site surface installations, have been evaluated and can be covered with the current funding mechanism.

SATELITE = Safety, Science & Technology integration team

- **What?** A group of individuals with a broad view on the ongoing research, and the capability to integrate his/her expertise in the SFC



Expert group

Satelite integrator

SFC 1 coordination

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Special thanks to…

- Paul Smith (SAM)
- SCK•CEN: Geert Volckaert, Jan Marivoet, Brigitte Cornelis

NIROND-TR-2006-04. The ONDRAF/NIRAS Safety Strategy for the Disposal of Category B&C Wastes.

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Strategic choices related to the safety functions

- Assignment of safety functions to the various repository components is a stepwise process
  1. Strategic choices driving the concept (and thus the design) => what safety functions are fulfilled by the system and its subsystems (the host formation, the engineered barrier system, the waste)? => 2005-2006
  2. Justification of the *a priori* choice AND phenomenological evaluation of the evolution of the different subsystems, components and subcomponents. => 2006 – 2010
  3. Confirmation of safety functions to the different subsystems, components and subcomponents over time for the formal safety assessments will be based on the confidence in the phenomenological understanding => 2010 - 2011

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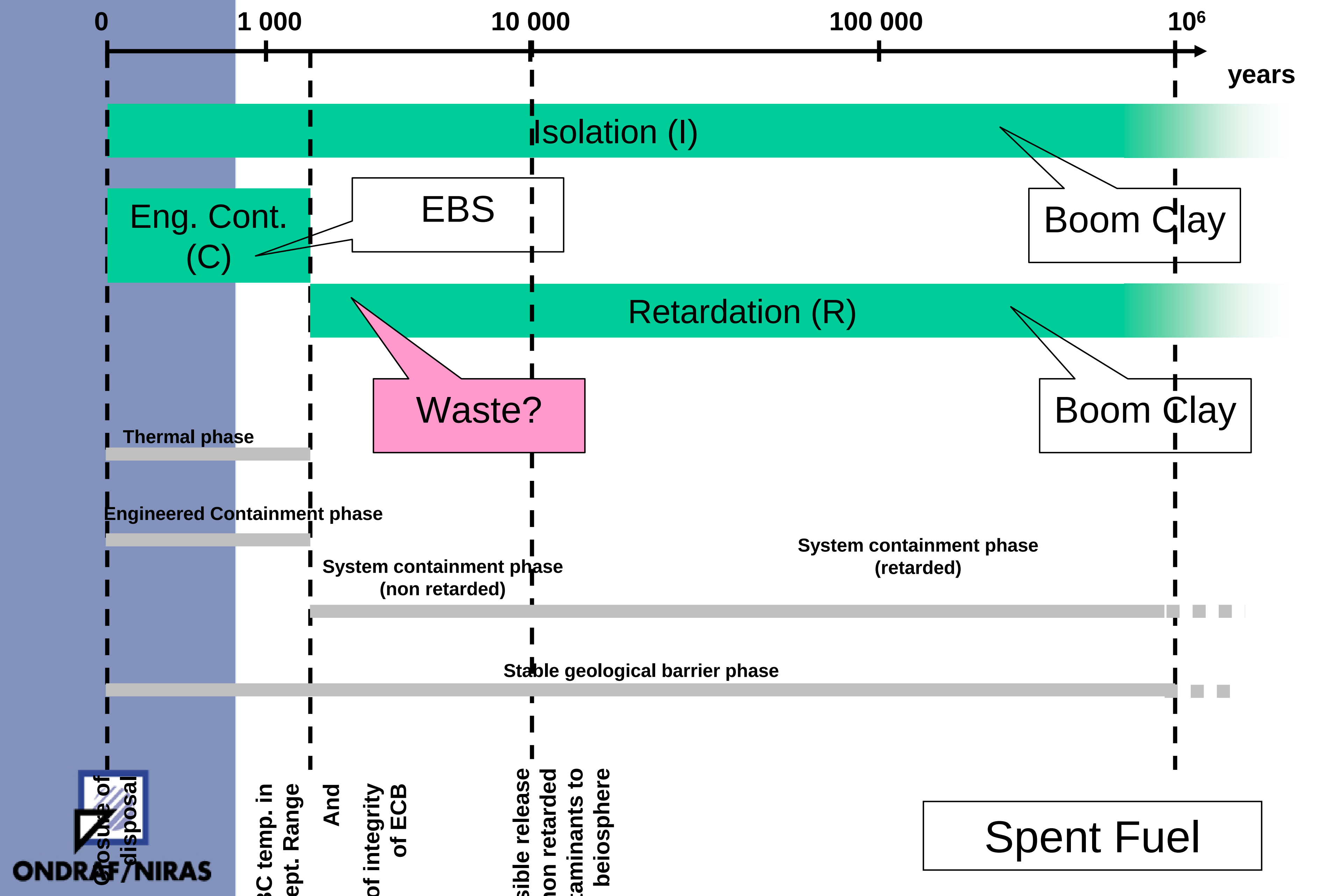
0
1 000
10 000
100 000
10^6
years
Isolation (I)
Eng. Cont.
(C)
EBS
Boom Clay
Retardation (R)
Waste?
Boom Clay
Thermal phase
Engineered Containment phase
System containment phase
(non retarded)
System containment phase
(retarded)
Stable geological barrier phase
disposal
BC temp. in
accept. Range
And
Loss of integrity
of ECB
Possible release
non retarded
taminants to
beiosphere
Spent Fuel
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Strategic choice for heat-emitting waste

- In view of the development of the repository concept and design, there are generally two « choices »:
  - The need for an engineered containment phase: safety function C
  - The need to limit the release of radionuclides from the waste form: safety function R1

We choose to design for maintaining a C function of the engineered barrier, minimally as long as the thermal phase lasts => to overcome former problems of **demonstrable** LT safety

The impact of the chosen design on the R1 function will be evaluated

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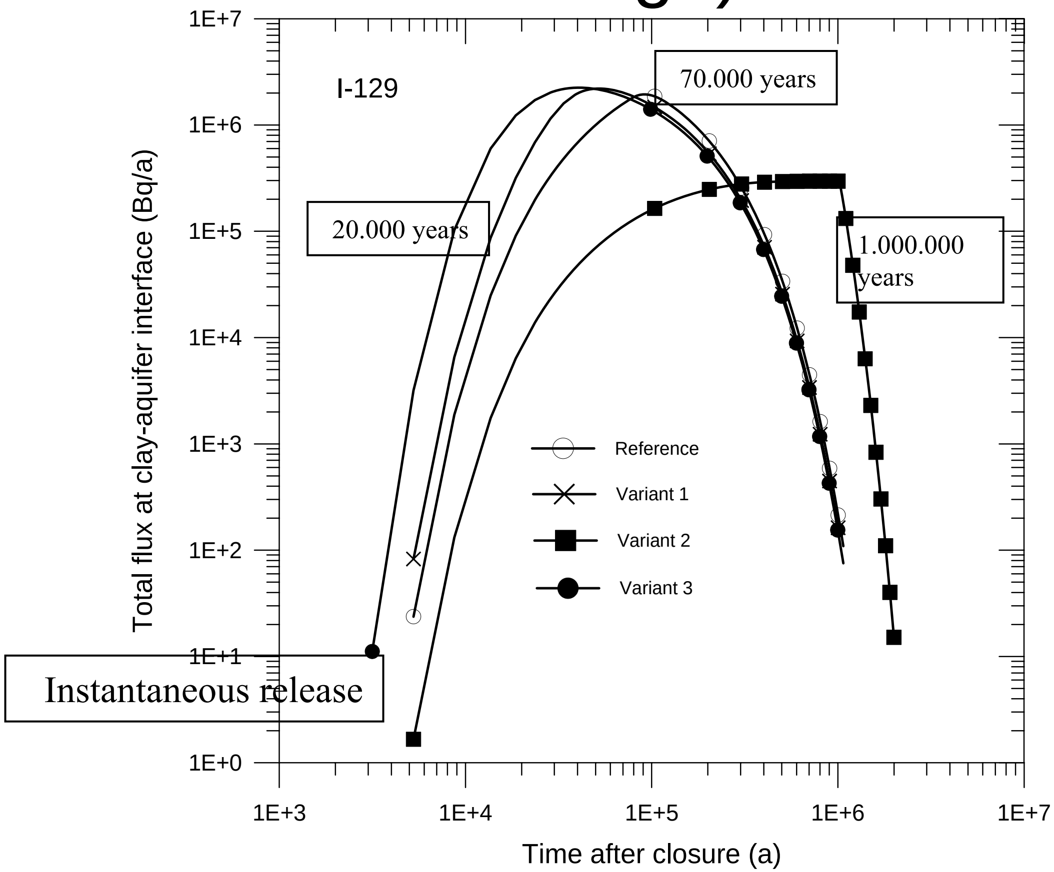
Vitrified high level waste: I-129 (Safir 2 design)



Only a very stable glass waste matrix (several hundreds of thousands of years) will have some influence on the calculated doses.

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The case of Spent Fuel

- Knowing that:
  - The instantaneous release factor (IRF) is rather independent from pH;
  - After an initial period of high α-dose rate, a solubility controlled dissolution seems to take place; and this implies a very long durability (millions of years).
    - A few experiments were known, where the solubility of uranium increases with a factor of 10; so *a priori* the influence on the durability seems not to be insurmountable

➢ O/N didn’t constrain the choices of the materials *a priori* too much

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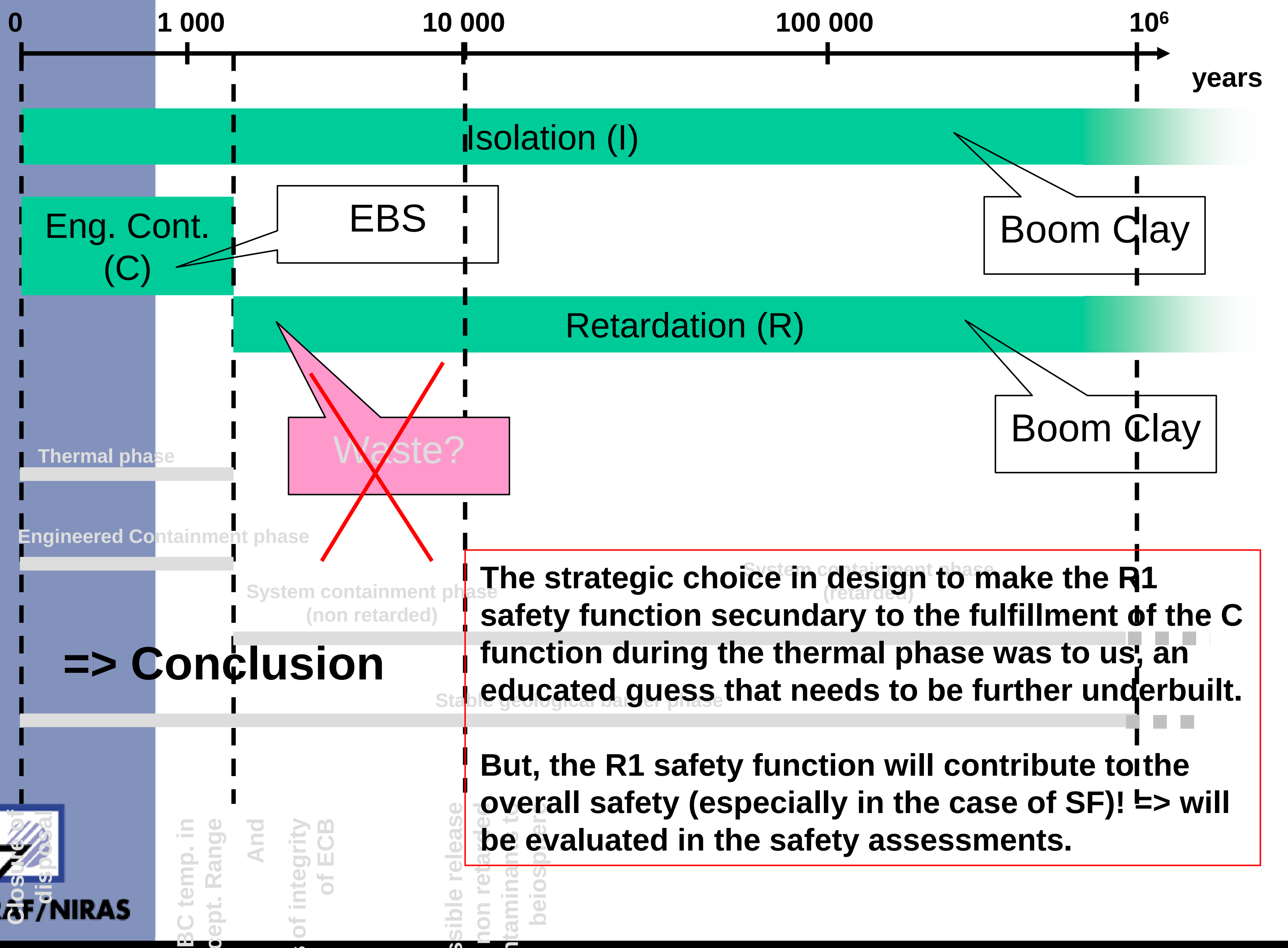

=> Conclusion

The strategic choice in design to make the R1 safety function secundary to the fulfillment of the C function during the thermal phase was to us, an educated guess that needs to be further underbuilt.

But, the R1 safety function will contribute to the overall safety (especially in the case of SF)! => will be evaluated in the safety assessments.

Safety statement 1.3.2

=> example worked out by SCK•CEN

Safety statement

- Safety statement 1
  The disposal system and its environment conforms to relevant regulatory targets/standards and general guidance concerning long-term safety (via the safety functions that it performs over the required time frames).

- Safety statement S1.3
  The disposal system (is expected to) delay and attenuates releases to the environment during the "system containment phase", ensuring that calculated end-points remain below regulatory targets/standards and general guidance.

- Safety statement S1.3.2
  The transport in the host rock is diffusion dominated and assures this characteristic for a long-term.

Breakdown of the statement

- Transport is diffusion-dominated
- Long-term

Definition of claims

- S1.3.2-C1
  The host rock has a fine homogeneous pore structure and a low hydraulic conductivity, and no significant variations are expected on the long term.

- S1.3.2-C2
  The host rock has a very low hydraulic gradient over the host rock, and no significant variations are expected in hydraulic gradient on the long term.

- S1.3.2-C3
  The host rock possesses a self-sealing capacity to respond to geomechanical and thermo-mechanical disturbances (short term).

- S1.3.2-C4
  The host rock possesses a self-sealing capacity to respond to geomechanical and thermo-mechanical disturbances (long term).

Inventory of support evidence

- S1.3.2-C1 The host rock has a fine homogeneous pore structure and a low hydraulic conductivity, and no significant variations are expected on the long term.

Available literature

- *fine homogeneous pore structure*
    - SAFIR 2 (2001), Montoto M. (2003), Hg porosimetry
- *low hydraulic conductivity (general information)*
    - SAFIR 2 (2001)
- *low hydraulic conductivity – laboratory measurements (Mol)*
    - SAFIIR 2 (2001), Put et al. (1991), Wemaere et al. (2002), Aertsens et al. (2004, 2005)
- *low hydraulic conductivity – small scale in-situ measurements (Mol)*
    - Put et al. (1993), De Cannière et al. (1996)
- *low hydraulic conductivity – large scale in-situ measurements (Mol)*
    - De Cannière et al. (1995), Ortiz et al. (1996)
- *low hydraulic conductivity – laboratory measurements (regional boreholes)*
    - Wemaere et al. (2004a,b,c, 2005), Aertsens et al. (2003, 2005)

Inventory of support evidence

- S1.3.2-C1 The host rock has a fine homogeneous pore structure and a low hydraulic conductivity, and no significant variations are expected on the long term.

Current R&D

- Different types of porosity and pore sizes of Boom Clay on samples from HADES boreholes: study performed in the frame of the NF-PRO project by CIEMAT
- Hydraulic conductivity in the Essen borehole: study performed by SCK•CEN
- Hydraulic conductivity in the Herenthout borehole: study performed by SCK•CEN

Inventory of support evidence

- S1.3.2-C2 The host rock has a very low hydraulic gradient over the host rock, and no significant variations are expected in hydraulic gradient on the long term.

Available literature

- *very low hydraulic gradient over the host rock*
  - Patyn, J. (1987), EVEREST (1997), SAFIR 2 (2001), Labat & Wemaere (2001)

- *expected variations in hydraulic gradient*
  - Patyn, J. (1987), EVEREST (1997), SAFIR 2 (2001), Labat & Wemaere (2001)

  - short term: pumping for drinking water: in 1981 the hydraulic gradient was 2 m, in 2001 the hydraulic gradient was 3 m
  - long term: on the one hand the impact of climate change may change the hydraulic gradient, but on the other hand, because of the flat relief, no major change in hydraulic gradient is expected

Current R&D

Inventory of support evidence

- S1.3.2-C3 The host rock possesses a self-sealing capacity to respond to geomechanical and thermo-mechanical disturbances (short term).

Available literature

- SELFRAC - Blümling et al. (to be published).
- EDZ development and evolution (NF-PRO) - Alheid et al. (2004)
- RESEAL - Van Geet et al. (2003)

Current R&D

- Migratie op de MEGAS piezo

Inventory of support evidence

- S1.3.2-C4 The host rock possesses a self-sealing capacity to respond to geomechanical and thermo-mechanical disturbances (long term).

Available literature / Current R&D / Knowledge gaps

- Will the thermal stress (re-)create fractures?
  - Info from TIMODAZ
- Gas break-through
  - Will anaerobic corrosion induce a gas pressure that leads to gas breakthrough? Input from corrosion and PA.
  - to be proven: no other transport mechanism associated with gas break-through and long-term sealing: info from MEGAS?
  - more or less proven: once sealing occurs, transport mechanism is again mainly diffusion: RESEAL borehole (Van Geet et al. 2006); huidige in-situ migratie op MEGAS piezo (publicatie?); huidige migratie testen op EDZ rond shaft seal; TIMODAZ
- Concrete degradation
  - to be proven: no illitisation occurs (info from TIMODAZ) that would limit the continuous sealing during gradual degradation of the concrete

Judgment of substantiation level

- S1.3.2-C1 The host rock has a fine homogeneous pore structure and a low hydraulic conductivity, and no significant variations are expected on the long term.
  - GREEN LIGHT, but with open question
- S1.3.2-C2 The host rock has a very low hydraulic gradient over the host rock, and no significant variations are expected in hydraulic gradient on the long term.
  - It is not sure that no significant variations for the hydraulic gradient are expected → Scenario development
  - RED/ORANGE LIGHT
- S1.3.2-C3 The host rock possesses a self-sealing capacity to respond to geomechanical and thermo-mechanical disturbances (short term).
  - Well-documented, but research is ongoing
  - ORANGE LIGHT
- S1.3.2-C4 The host rock possesses a self-sealing capacity to respond to geomechanical and thermo-mechanical disturbances (long term).
  - Knowledge gap!
  - Some information from MEGAS, RESEAL, TIMODAZ but not enough.
  - RED LIGHT