FROM THE FEASIBILITY ASSESSMENT TO THE LICENSING: APPLICATION ORGANISATION OF THE SAFETY CASE INTERACTIVE DEVELOPMENT OF ENGINEERING/PA/KNOWLEDGE MANAGEMENT, KEY ISSUES ADDRESSED BY GEOSCIENCE

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A step by step process within Iterative loops from feasibility to license

The analysis conducted within the "Dossier 2005" exercise (Andra 2005b) shows that in all envisioned situations (normal or altered) through complementary indicators, the repository and surrounding host rock fulfil the three major safety functions,[1] without relying excessively on any single component – no elements that jeopardise the technical feasibility. In any event, the Callovo-Oxfordian host rock plays a major role in immobilising radionuclides and in delaying and reducing their migration to the environment. In all scenarios – even accidental or altered – the repository performance provides significant margins to the dose objective recommended by the RFS III.2.f. In conclusion, "Dossier 2005 Argile" supports, with both qualitative and quantitative arguments as results from a robust methodology and a multidisciplinary iterative process, the feasibility of a reversible and safe repository in Meuse-Haute-Marne Callovo-Oxfordian clay. Some key design features and orientations have been developed to meet safety requirements. The various reviews of the Andra "Dossier Argile" that was published in 2005 and the existing design experience has helped to identify the key areas needing further development and design evolution in order to apply for a license to build a repository in 2015 according to the new French Act of 2006.

An evolution of the regulatory framework

The December 30, 1991 French Waste Act entrusted Andra, the French national agency for radioactive waste management, with the task of assessing the feasibility of deep geological disposal of high-level and long-lived waste (HLLLW). The emphasis placed on the demonstration of safety was gradually combined with considerations of prudent repository management (CNE, Premier Ministre 1998). As a result, one safety guiding principle – long-term safety– is a fundamental requirement inherent in Andra repository design concept in order to protect the rights of future generations, by providing them with a viable solution, without restricting their control over the waste management process. Of course, other key concerns, such as the operational safety are also essential in the design of the facility.

The Basic Safety Rule RFS III.2.f of June 1991, set by the French nuclear safety authority, have helped in the design option selection and scientific studies since the 1991 French Act. It provides a framework for the studies to be conducted as such: the protection of man and the environment are to be demonstrated; studies should show the ability to limit potential consequences to a level as low as reasonably possible; the concept should include a multiple barrier system, and rely on passive repository evolution without institutional control beyond a given timeframe (500 years).

1. Nb: Three main safety functions were assessed through indicators "preventing water circulation", "limiting radionuclides release and immobilising them in the repository" and "delaying and attenuating radionuclide migration".

The new French Act published on June 2006 (Loi n°2006-739) paves the way to go for siting and construction of a repository in the transposition zone of the Meuse-Haute-Marne laboratory. Future R&D must lead Andra to apply for a construction license in 2015, in order to be able to operate the repository ten years later, if the siting and licensing process is successful. This law confirms geological repository as the reference solution. It sets milestones and requirements:

- Uncertainties must be reduced, to meet the robustness and ALARA criteria.
- Retrievability is to be demonstrated by Andra, with conditions to be determined by a law in 2016. The conditions posed by this future law are *sine qua non* conditions to be issued a permit to operate.
- Andra still have to demonstrate safety and operability at a detailed level, confirming design options; using studies, underground experiments and demonstrators, when possible.
- Andra has to conduct safety analyses for both surface and underground installations.
- If issued a permit in 2016, Andra must be able to build the repository and operate it in 2025.

In addition, an updating version of the Basic safety Rules (namely safety guide) was published in 2008 by the safety Authority; it took stock on "Dossier 2005" lessons learnt and on exchanges with safety authority and experts conduct to an updated version that confirms the importance of the long-term safety[2] but they also led to the following challenging issues:

- The design concept may rely on a multi-functions and related multi components system.
- Balancing long term safety with operational safety (not be opposed).
- Reversibility options may not degrade safety (oxidation phase duration…).
- Developing a methodology in order to consider timescales beyond 1 My (uncertainties on phenomenology on this timescale); comparison with the natural radioactivity (in mSv)? to what extend may erosion be considered?)

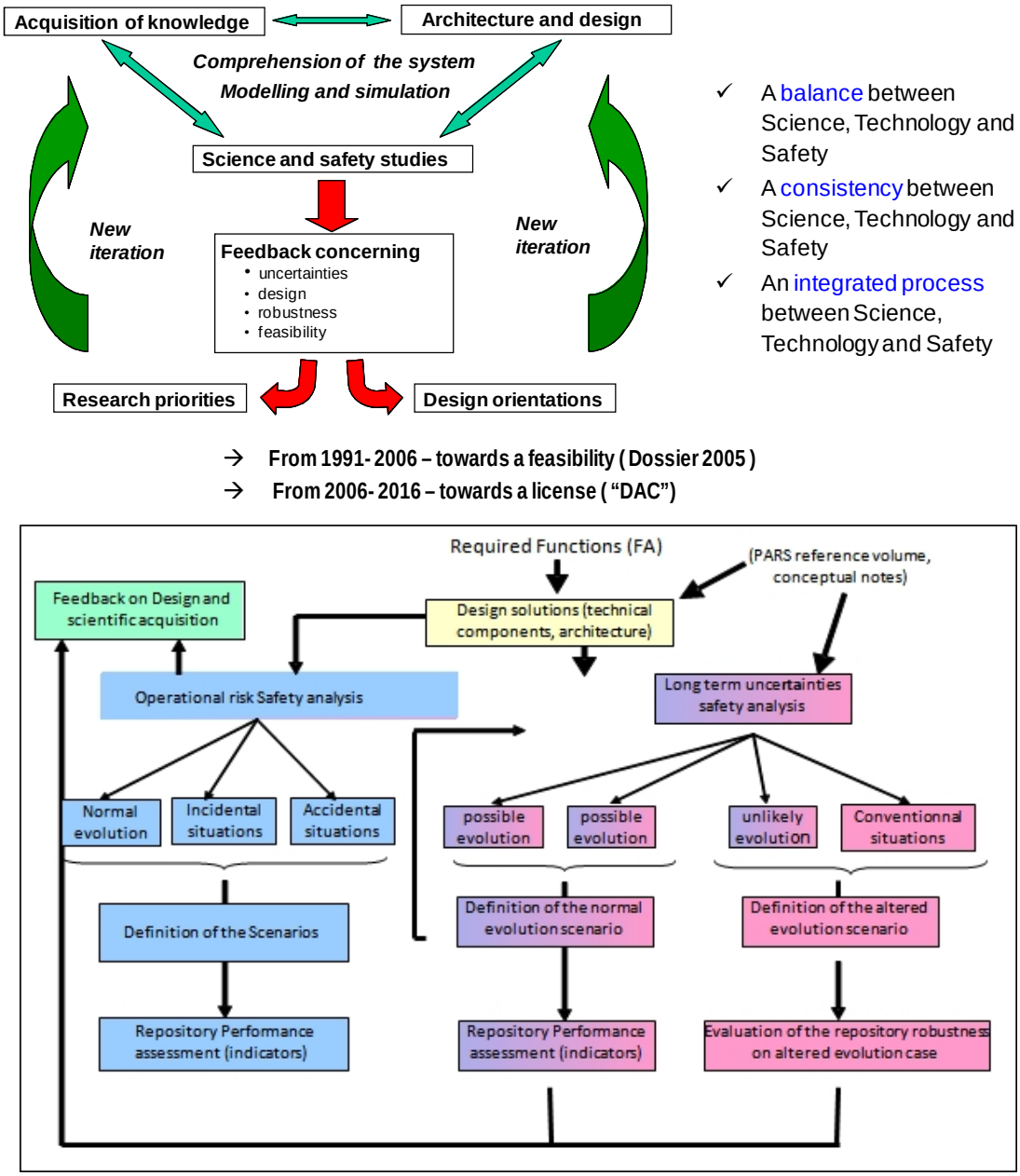
Towards the license – a need for intermediate milestones

In order to meet the French 2015 goal of a licensing permit in 2016, Andra has planned a step by step process with iterative loops until 2015. In that frame, and taking stock on previous steps, Andra will continue to build it "dossiers" upon the following key elements:

- Basic inputs such as the inventory model of the waste and the geology of the site.
- Safety functions and requirement management (operation and post-closure phases).
- Technical solutions based on industrial experience.
- Management and monitoring, to allow retrievability (reversibility).
- Phenomenological analysis of repository situations (PARS) and detailed, coupled process modelling.
- Qualitative safety assessment, namely QSA (Fr: AQS).
- Quantitative assessment results.

2. The fundamental objective of the repository with respect to safety in the basic safety rules RFSIII.2.f consists of "protecting the human being and the environment against hazards associated with the dissemination of radioactive substances" in the short and long term. This objective is formally restated in the functional form "to protect humans and the environment from the dispersal of radioactive nuclides" and is considered as the main safety function for the post closure phase.

Figure 5. **A Step by step process within Iterative loops**



For each milestone, Andra has defined a list of key endpoints as such in 2009, the design and safety options based on waste packages inventory and characteristics, the Safety Strategy (principles, requirement, approach) and host rock data consolidation [2]supported by simulations (performance indicators). Until that milestone, Andra will reconsider design options taking stock of operational and post closure safety outcomes of the "Dossier 2005" and the subsequent internal and external reviews.

Towards license-challenging issues

Despite similarities, the safety approach for a deep geological repository differs from a "conventional" nuclear installation safety approach, by a few general aspects: (i) the necessity of approaching in a coordinated way the operation and post closure life phases and related requirements;

(ii) the long timescales which extend beyond human experience; (iii) the strong relationship between design, knowledge acquisition and safety assessment for the feasibility assessment with a key importance given to the notion of uncertainties control and, in particular, for the post-closure phase. This peculiarity requires calling on many disciplines (mining and nuclear engineering, earth sciences, material sciences, safety) and implementing specific methods at the interface between these disciplines. It relies on the use of specific management tools, since a variety of scientific and technical domains are covered by the studies. In this context, the integration of the scientific knowledge and the definition of a clear safety approach are key elements in the development of a coherent safety case. Andra has developed a safety approach that consists of implementing two complementary safety approaches according the repository phases. The first one concerns the operating safety, which is close to a conventional approach supported by a risk analysis. The other one concerns assessment of the long term safety in the post-closure phase in order to evaluate the repository robustness. The design options presented hereafter are a result of the feedback of the application of those two safety approaches. The methodology developed towards the "Dossier 2005" will be reconducted towards the license. While the safety analysis revealed that the repository appears to be robust and fulfil the safety functions, the different internal and external reviews that were conducted (in 2005 and 2006) led Andra to think back to its design option in order to respond to challenging issues.

Operational safety – Challenging issues towards 2014

While the "Dossier 2005 Argile" reached the point that no element jeopardise either the technical feasibility; results need to be confirmed by tests on demonstrators (drop test for ILW package, handling test for HLW packages, etc.) and various alternative options remain to be investigated on safety grounds as such reduction of the number of drifts: layout of underground installations (Ventilation versus long-term hydraulic circulations), transfer of packages by shaft or ramp (operational risks versus post closure hydraulic effect). Those design evolution will permit to better mitigate operational risks. The resulting new design options must still fulfil the post closure safety functions and in some cases, Andra will need to balance both operational and post closure safety. In that context, each alternative design option is analysed through both operational and post closure criteria. As an illustration, taking into account the hydraulic properties of the Callovo-Oxfordian and its surrounding, the ramp and the related layout which is considered as an alternative option to mitigate against Shaft "Fall" needs also to fulfil the two functions "preventing water circulation", and "delaying and attenuating radionuclide migration" (Fall risks versus Long term hydraulic circulations).

Post closure safety – Challenging issues towards 2014

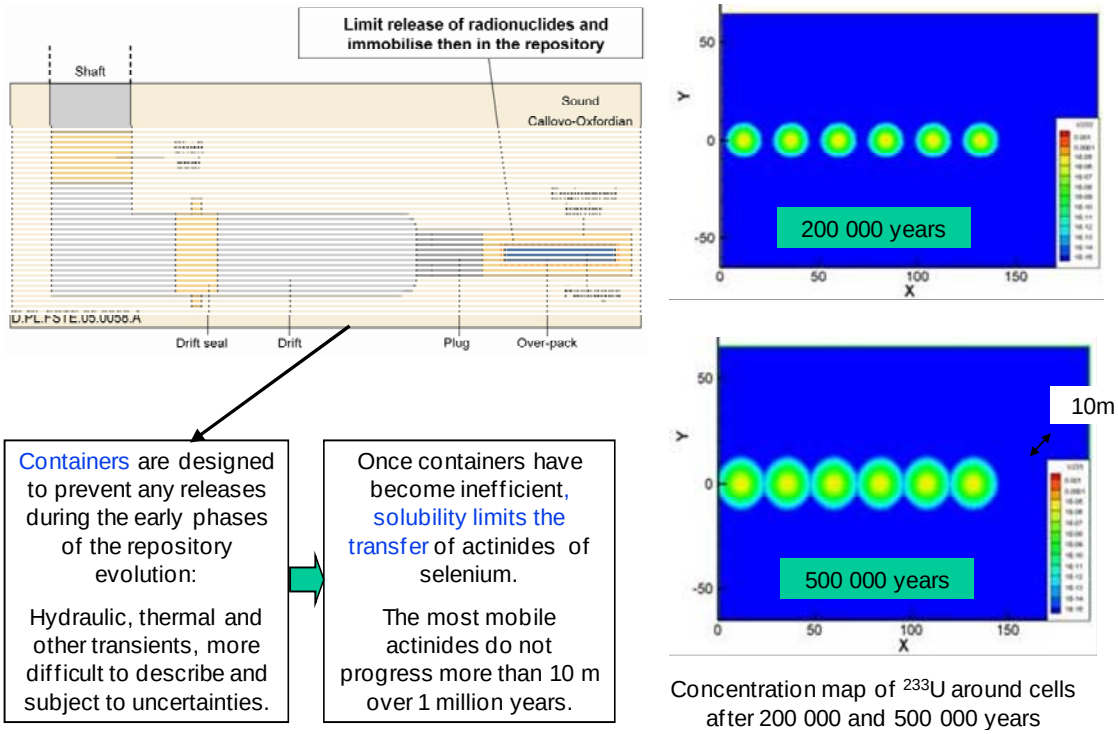
The "Dossier 2005 Argile" showed that high level waste containers play a role in controlling releases during the first millennia of the repository, only few radionuclides are potentially released to the Callovo-Oxfordian. Only a very few radionuclides can migrate through the host formation as such ^{129}I, and ^{36}Cl due to the importance of geochemical properties of the formation that permits retention and precipitation of the majority of radionuclides.

Additionally, the "Dossier 2005 Argile" and the subsequent reviews concluded that the host formation is an essential component of the system, and the rock's properties are now well-known because a major characterisation programme and experimental data acquired within the drifts of the Meuse/Haute-Marne laboratory with good consistency. The potential extent and effects of perturbations suffered by the host formation due to the exogenous materials placed within it on the properties of the argillites have been identified. Regarding the knowledge of the geological medium: (i) the host formation uncertainties seem to be well under control, but observations on the transposition zone need to be furthered, and (ii) no safety functions allocated to surrounding formations, but representation needs to be furthered. Moreover, uncertainties on thermal and hydraulic transients and

on coupled phenomena require a further knowledge and a finer modelling of the transients (e.g. transfers under thermal environment). The damage zone (EDZ) of the argillites plays a role in the analysis of uncertainties: seal failures and potential radionuclide transfers through the EDZ are situations that were revealed by the qualitative analysis. While the feasibility study concluded to a sound data base to support the safety case, the various internal and external reviews led Andra to plan work in order:

- To consolidate the THMC data acquired within the Meuse/Haute-Marne laboratory (through diffusion, thermal, retention experiments…).
- To set up full-scale technological tests (e.g. sealing) to support design and safety demonstration.
- To set up additional investigations to establish flow directions in the dogger in greater detail and specifying the role of regional faults and their environment in the hydrogeological model.
- To develop a better comprehensive model for ion diffusion (cations versus anions) and representation of retention processes at pore scale.
- To better modelling of transient phases through representation of the coupled phenomena.
- To assess the potential extent and effects of perturbations suffered by the host formation due to the exogenous materials placed within it on the properties of the argillites to be assessed.

Figure 6. **Function – Limiting releases and immobilising radionuclides**



Concentration map of ^{233}U around cells after 200 000 and 500 000 years

Conclusion

According to the new French Act studies and investigations shall be conducted by Andra with a view to selecting a suitable site and to designing a repository in such a way that, on the basis of the conclusions of those studies, the application for the license of building such a repository will be examined by the ASN in 2015 and, if the authorisation is granted, the repository will be commissioned in 2025.

The safety assessment is not an autonomous domain of the repository feasibility study. It forms an integral part together with the engineering (design) and research studies on site characterisation and phenomenological evolution of the repository. Research and design work is by nature an interactive activity between engineers, scientists and safety assessors. The repository architecture proposed within the framework of the “Dossier 2005” takes into account what was learned from the preliminary safety assessment (risk analysis and quantification of selected scenarios) which rely on safety functions. At the current stage, no study has detected elements that jeopardise either the technical feasibility of the construction, operation and closure of the repository, or its stepwise reversible management. Regarding the future, Andra programme is moving towards a more detailed repository design and a related more detailed safety case combining both operational and long-term safety needs and assessments through a stepwise design process. A challenging issue for safety will be to balance operational safety and long-term safety (e.g. mainly gas versus LT hydraulic management), the next stage being the evaluation of a set of options (shafts position, underground installations layout: drifts/cells…).