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LUCOEX

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EXPERT GROUP REPORT -DELIVERABLE (D1.11)

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Dissemination Level		
PU	Public	**PU**
RE	Restricted to a group specified by the partners of the LUCOEX project	
CO	Confidential, only for partners of the LUCOEX project	

EURATOM

1 Introduction and overall Expert Group objectives

The LUCOEX Project was launched in May 2011. Its overall objective is to demonstrate the technical feasibility ***in situ***, in European Underground Research Laboratories (URLs), of key technical activities for safe and reliable construction, manufacturing, waste emplacement and sealing of repositories for long-lived, high-level radioactive waste. The LUCOEX Project is implemented under the umbrella of the Implementation of Geological Disposal Technology Platform (IGD-TP Project).

The LUCOEX Project consists of four large-scale demonstration activities developed to the present state-of-the-art in national programmes. The activities take place in four different URLs in Europe, which have been constructed for the specific purpose of developing repository technology under repository-like conditions. The key technical areas to be addressed are drift construction, manufacturing and emplacement of buffer material around waste packages, emplacement of waste packages, and backfilling and sealing of drifts.

The four concerned geological repository concepts are:

- Horizontal disposal of waste packages in Opalinus clay formation (Mont Terri, Switzerland), by NAGRA;
- Horizontal disposal of waste packages in Callovo-Oxfordian clay formation (Bure, France), by ANDRA;
- Horizontal disposal of waste packages in crystalline hard rock (Äspö, Sweden), by SKB;
- Vertical disposal of waste packages in crystalline hard rock (Onkalo, Finland), by POSIVA.

1.1 LUCOEX Project organisation

The LUCOEX Project consists of six Work Packages (WPs) that are led respectively by the organisation indicated in brackets:

- Work Package 1 (WP1) - Coordination and integration (SKB),
- Work Package 2 (WP2) - Full Scale Emplacement Experiment (FE) Mont Terri (NAGRA),
- Work Package 3 (WP3) - Full Scale Emplacement Experiment (ALC) at Bure (ANDRA),
- Work package 4 (WP4) - KBS-3H Multi-purpose Test (MPT) at Äspö (SKB),
- Work Package 5 (WP5) - KBS-3V Emplacement Test in Onkalo (POSIVA),
- Work Package 6 (WP6) - Management and dissemination (SKB).

The Project is managed by a Steering Committee consisting of representatives of all involved institutions and chaired by SKB, which is also acting as the LUCOEX Project Coordinator vis-à-vis the European Commission (EC).

To support the Project implementation, an Expert Group (EG) has been appointed in the period late 2011 – early 2012; the EG comprises eight members: four individual representatives of the four involved institutions (these representatives are not directly engaged in the activities of the LUCOEX Project), and four external (also called independent) experts.

The scheme of the LUCOEX Project organisation is shown in Figure 1.

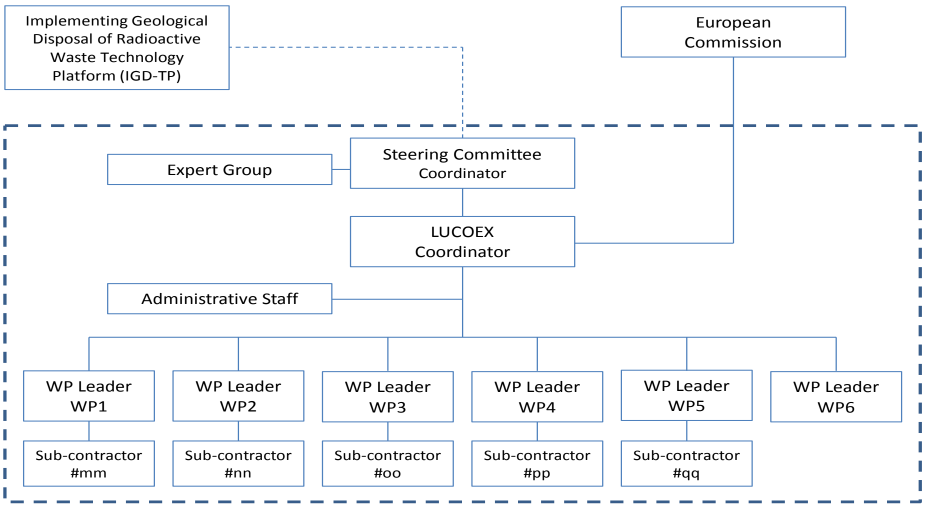

Figure 1: LUCOEX Project organisation

1.2 Expert Group Work Organization

1.2.1 Organization

The Expert Group reports to the LUCOEX Steering Committee (via its Project Coordinator), and consists of the following eight members (the four last persons being the external Experts):

- Jean-Michel Bosgiraud (ANDRA - Chair),
- Thomas Fries (NAGRA),
- Stig Pettersson (SKB),
- Hannu Pihlainen (POSIVA),
- Wilhelm Bollingerfehr (DBE-TECHNOLOGY),
- Alan Hooper (Consultant, UK),
- Lumir Nachmilner (Consultant, Czech Republic),
- Jan Verstricht (SCK/CEN), replacing Geert Volckaert on 25 March 2013.

1.2.2 Meetings

As per the Experts' Letter of Mission, the Expert Group meets at the request of its Chair or of the Steering Committee (the Project Coordinator), and as a minimum meets to discuss findings and to formulate assessments, recommendations and advice on the three occasions when EG Reports are required to be prepared.

1.2.3 Responsibilities

The Expert Group serves the LUCOEX Project with reviews, cross-Work Package (WP) examinations and recommendations and advice related to risk management, technical plans, achievements and dissemination activities. In particular, it considers:

- The added value generated through the technical and scientific integration in LUCOEX during progress of the project;
- The soundness and relevance of the technical approach;
- The scientific and engineering standard of the work carried out; and
- The progress of the technical/scientific work reached at the end of the Project and the fulfilment of the posted objectives,
- The level of dissemination reached.

For this purpose, the Expert Group has the responsibility to:

- Perform a critical cross-WP examination of technical work plans at the time of the EG Reports scheduled during the project, i.e. after approximately 1.5 years and 3 years (provided the work plans are updated and transmitted to the EG by the concerned participants),
- Perform a cross-WP examination and analysis of technical achievements on three occasions during implementation of the LUCOEX project: after approximately 1.5 years, 3 years and on the completion of Project activities,
- Carry out a technical review of the Final Project Technical Reports, including an assessment of the added-value reached in terms of scientific and technical integration, soundness and relevance of the technical choices made and the adequacy of the scientific and engineering standard of the work carried out.
- Advise on the technical relevance of the other reports submitted to them and intended for publication on the LUCOEX website with respect to objectives and obtained technical facts,
- Produce three EG reports (Deliverables) to document its findings on three occasions: around Month 18^{+}, Month 36^{+} and Month 46^{+}, and
- More generally make relevant suggestions/recommendations, based on the review findings, related to the LUCOEX Project work, either as a group or as individual members.

1.2.4 Deliverables

The Expert Group must deliver to the LUCOEX Steering Committee three Expert Group Reports to be posted on the public website of the LUCOEX project as Project Deliverables (D1.7, D1.11 and D1.14). These 3 reports have a "Public" (PU) Dissemination level and are later posted on the EC SESAM site, following their approval by the Steering Committee and their acceptance by the EC.

The first EG Report (D1.7) was issued in its final (and later accepted) version B on 01 July 2014. In this new document (version B), the Expert Group provides its second Deliverable: EG Report (D1.11) which covers the LUCOEX activities and outcomes over the period between mid-March 2013 and mid-October 2014.

2 Expert Group activities linked to the issue of EG Report D1.7 (version B) and of EG Report D1.11 (version B)

The Expert Group held one internal meeting in Andra's premises, on 25 June 2014 (six experts out of eight attended), in order to:

- Fine tune the editing of the version B (final version) of the first EG Report (D1.7), sent on 01 July 2014 to the Coordinator (SKB) for approval by the LUCOEX Steering Committee.
- Comment and assess the content of the documents (listed thereafter in Chapter 4) made available to them by the four Work Package leaders (i.e. from WP2 to WP5).
- Evaluate the general work progress reached after some 36^{+} months of LUCOEX activities.

Previously, three of the EG members had attended a LUCOEX work progress meeting, held in Aspö (SKB's premises) on 13 May 2014, and followed the next day by a workshop organized by SKB on "Repository Closure". On this occasion, a visit of the Aspö Hard Rock Laboratory (HRL) took place, with the focus being on the KBS-3H emplacement machine, as positioned in its test drift chamber.

More recently, five of the EG members attended (on 14 October 2014) a presentation made by POSIVA, at Onkalo site, of its buffer emplacement system (KBS-3V) operated inside a sub-surface hole mock-up. This presentation was combined with a visit of the Onkalo underground facilities (where the future emplacement test deposition hole is now being excavated) and was followed by a technical discussion lead by POSIVA's representatives.

The EG Report D1.11 (version B) integrates the Experts' findings, at the end of these various meetings and visits. Their critical review and recommendations come in Chapters 4 and 5.

The EG Report D1.11 also deals in Chapter 3 with the way their initial recommendations / observations contained in the first EG Report D1.7 have been answered by the concerned Work Package leaders.

3 WP leaders responses to the EG recommendations contained in D1.7

The first EG Report D1.7 contains a certain number of recommendations, transmitted to the WP1 to WP5 leaders. Some of these recommendations are reproduced below along with the associated response(s) by the relevant WP leader.

i) Work Package 1- Coordination and integration (SKB) – WP1 leader Jan Gugala (replacing Christer Svemar):

- EG recommendation(s):

"Even though the LUCOEX Project structure in "Project-Place" has improved since the delivery of the first Expert Group recommendations (in April 2012), there is room for further improvement. The Expert Group in particular (the reader in general) should be informed when final (only) documents or deliveries are downloaded to make their work easier… The names of the files must be improved and should be built up in a standardised way and show the expected content of the document (in short a self-explanatory title would help). Under folder "working document", some improvements could be made by adding additional folders, e.g. the different sub-projects or work packages clearly identified to make perusing easier.

Concerning the structure of the "Expert Group" folder, some additional sub-folders could be created: "Programme and agenda", "Minutes of meeting", "Presentations" and "Other documents". In the future it is likely that the number of documents associated with a specific meeting will increase and additional folders would help the Experts to find and file documents".

- WP1 leader response(s):

The LUCOEX Steering committee and coordinator have taken the active decision not to police how the individual work packages are sharing documents within the Project as long as deliverables are saved in the appropriate folder and that they inform the Coordinator and Steering committee. It is up to the EG to create its internal folder structure that suites its needs.

- EG final comment(s):

At time of writing the EG maintains its statement on the poor "user-friendly" nature of "Project-Place" as a tool for LUCOEX documentation sharing.

However, the Experts understand that a new arborescence of the different EC funded project documents (lodged in "Project-Place", under the umbrella of IGD-TP) should take place in the months to come. This should help browsing the different projects' contents, for occasional users (such as the EG members) of the "Project-Place" site.

ii) Work Package 2 - Full Scale Emplacement Experiment (FE) at Mont Terri (NAGRA) - WP2 leader Hanspeter Weber:

- EG recommendation(s):

"Monitoring strategy ***inside*** *LUCOEX (technical feasibility of implementation) and* ***outside*** *LUCOEX (THM behaviour) should be clarified in terms of expected outcomes. The FE overall schedule should also be scrutinized to check its compatibility with the LUCOEX general schedule".*

- WP2 leader response(s):

The tight work schedule was perceived by NAGRA as a risk from the very beginning of the project. NAGRA is still in good hope to finish the FE work at Mont Terri just at the end of 2014. But of course there will be a need for additional time to produce a serious reporting… The final LUCOEX Conference should happen around mid-2015, which leaves the possibility of presenting actual real results at that period.

- EG final comment(s):

The work schedule issue is well understood by all the concerned partners and also shared with the European Commission. The EG was recently informed about the negotiation ongoing (between the EC and the LUCOEX Coordinator) to provide an extension to the initial official Project deadline. More generally, the relevance of the initially posted work schedules is discussed again (from a project managerial point of view) in Chapter 5. Clarification on monitoring issues is still required. The strategy explanation could also be elaborated.

iii) Work Package 3- Full Scale Emplacement Experiment (ALC) at Bure (ANDRA) – WP3 leader Jacques Morel:

- EG recommendation(s):

"ANDRA should clarify the role of the cell head plug in terms of sealing performance. Andra should state how the far field is affected by the thermal interference between two horizontal disposal cells and how this phenomenon is taken into account in modelling (as far as this issue is not included in the ALC experiment). Andra should also specify if a thermal interference test between two thermal cells is planned at a later stage in the Bure URL (and at which scale)".

- WP3 leader response(s):

The precise design of the HLW cell head is still in the conception phase. One main question is the relative importance (and thus the necessity) of a sealing at the head of a HLW cell, which is about 70 cm in diameter, with respect to the sealing of the drifts (that will be several meters in diameter). This is why the terminology "HLW cell closure" is used rather than "cell sealing".

The diffusion of temperature through the surrounding rock mass generates an increase in the pore pressure with amplitude that depends on the distance to the HLW cell wall, as well as the permeability of the rock mass. Small scale experiments, respecting the geometrical proportions (diameter/distance between 2 cells for example) of HLW storage (but at a reduced scale) have been previously carried out in the URL to study this thermal interference effect. Combining the results from these smaller scale experiments with the scale 1:1 ALC demonstrator will help in understanding the interference effect at the scale 1:1 in the future repository (Cigéo).

Moreover, modelling considering this interference effect has been done for the storage concept. The specific modelling that will be carried out for the scale 1:1 demonstrator will be analyzed also in regards to these former modelling data. A thermal interference test between 2 or more demonstrator cells is not planned at this stage. However as mentioned before, lower scale thermal interference experiments were carried out, so that combining the results from these smaller scale experiments with the scale 1:1 ALC demonstrator will help in understanding the interface effect at scale 1:1.

- EG final comment(s):

The EG takes notice of Andra's responses which clarify the purpose and limitations of the ALC experiment and indicate how its results will be combined with other activities (other past or future experiments and modelling/simulation activities) to provide robustness and confidence in the design of the geological repository. More generally, these responses raise the question of demonstration strategies, which is further discussed in Chapter 5.

iv) Work package 4 - KBS-3H Multi-purpose Test (MPT) at Äspö (SKB) - WP4 leader Magnus Kronberg:

- EG recommendation(s):

"SKB should clarify how the potential buffer erosion phenomenon can be handled or mitigated over a significant time lapse, i.e. the time needed for emplacing the real super-containers and the buffer material over a disposal drift up to 300 metres in length if the environmental conditions are demanding (e.g. will the injection of silica-fume based grout in water-producing fractures be a sufficient solution?)".

- WP4 leader response(s):

Regarding the recommendations made specifically to WP4, SKB has to some extent been working on these issues. An internal document was produced on emplacement speed where a preliminary time of 10 days is needed to install the inner compartment of a KBS-3H repository. This figure gives an estimate on the time period during which the components have to be stable and not erode.

Methods planned to avoid dripping or spraying include first of all (as mentioned in the EG recommendation) post grouting using the "Mega-Packer". A secondary protection consists of the so called "drip shields" that are planned to be used to collect water that sprays (or drips) from the drift top and flows underneath the components (here it can be noticed that the components are standing on feet and thus do not soak in the water).

SKB also looked at redesigning the sliding plate to allow for higher leakages from the drift to pass under the deposition machine (these large mechanical changes were not implemented within the frame of the LUCOEX Project).

- EG final comments:

The responses provided by SKB are clear and convincing. However, a complete underground test remains necessary to check that all these mitigation solutions are effective and sufficient to move forward a future certification of the system.

v) Work Package 5 - KBS-3V Emplacement tests in Onkalo (POSIVA) – WP5 leader Keijo Haapala:

- EG recommendation(s):

“Pressing of bentonite blocks: The use of an isostatic press for such a set of big rings is deemed a major technical and contractual challenge. A “plan B” should be considered (e.g. mobilization of a uniaxial press) for the production of rings, in order not to impair the rest of the WP5 test plan. The overall KBS-3V Emplacement Test schedule should also be scrutinized to check its compatibility with the LUCOEX general schedule”.

- WP leader response(s):

For POSIVA, the pressing of isostatic blocks is not a part of WP5 main objective (WP5 is only focused on the mechanical aspects of buffer blocks installation). The reason is that the pressing issue was taken out of POSIVA's WP5 scope in the early phase of the project negotiation with the EC (thus there is a discrepancy between the text of the LUCOEX Scope of Work and the effective POSIVA’s work plan).

Besides, the pressing of buffer blocks by isostatic method has been Posiva's reference and the related development has been going on at the same time as the WP5 mechanical development. The purpose was effectively to use the bentonite buffer blocks in the installation tests even if the pressing of blocks was not part of the LUCOEX project. In practice POSIVA could not obtain the isostatically pressed blocks during this autumn 2014 and then purchased some uniaxially made bentonite blocks for use in the buffer installation test (just after the successful completion of the first phase of the test campaign, when concrete blocks are used as dummy).

- EG final comments:

The Experts take notice of POSIVA’s clarifications on the pressing (of bentonite blocks) not being a part of LUCOEX. The EG is also informed that “Plan B” was effectively implemented to allow for effective emplacement testing with uniaxially pressed bentonite blocks. The Experts still consider that the rationale for using isostatically pressed bentonite blocks instead of uniaxially pressed blocks should be elaborated (e.g. costs vs. benefits analysis); this would help the reader to understand better why this technical alternative (to the equivalent SKB reference design for KBS-3V) is being explored by POSIVA, even if some good experience in isostatic pressing is available.

4 Expert Group new recommendations and findings after 36^{+} months

4.1 Preamble

In order to carry out the expected critical review for its second report D1.11, the LUCOEX Expert Group (EG) requested that the information best representing the status, at mid-2014, of the four technical Work Packages (WP2, WP3, WP4 and WP5) should be made available.

The information provided in response to this request, which formed the basis for the review, is identified under the respective sections for each of the concerned Work Packages. The large-scale experiments (and their objectives) comprising each of the Work Packages were technically described in the first EG Report (Deliverable D1.7) and are not reproduced in this second report; a few graphs or pictures only are included to illustrate the comments.

4.2 WP2 - Nagra- Full Scale Emplacement (FE) Experiment at Mont Terri

Information provided by NAGRA:

a) PowerPoint Presentation to Bentonite Meeting (Berne, 12 June 2014), entitled “From raw bentonite to full-scale emplacement tests in the frame of the FE-Experiment”,
b) Deliverable D2. 2 entitled “Report on the construction of the emplacement tunnel” (issued 28 May 2014),
c) Power Point Presentation (made during the Aspö 13 May 2014 meeting), entitled “FE LUCOEX Experiment Mont Terri - Progress of WP 2 - Bentonite backfilling”.

The PowerPoint Presentation (a) dealt with aspects of production of bentonite blocks (bricks) to form the pedestal supporting a waste package and the production of bentonite pellets to backfill the space around the pedestal and waste package inside the emplacement tunnel (drift).

The reasoning behind the selection of the aspects that are dealt with in the presentation, and the omission of other aspects, is not always explained. However, the information does demonstrate the successful use of industrial scale machinery and testing procedures to manufacture blocks and granular (pelletized) backfill from raw bentonite material according to certain quality requirements. In contrast to equivalent work on fabricated bentonite engineered barrier components as described in WPs 4 and 5 of the LUCOEX Project, no quantified quality assurance parameters are stated (even though they are existing). Rather, a qualitative statement is given that the “fabricated products meet the requirements” associated with their use.

Expert Group Recommendation(s) 1/3:
The Experts recommend that quantified requirements should be defined and justified by NAGRA for the relevant parameters of the produced bentonite materials. This information is worth sharing within the frame of the integration work (WP1).

The particular aspects explored in relation to bentonite block production were water content and compaction pressure, where it is stated that optimum parameters have been determined. However, other characteristics identified as important (mineralogy, grain-size distribution and compaction pressure cycling) are not covered in this document (however information is given in Power Presentation (c) showing that further work was carried out before a truly optimised set of characteristics could be identified).

From a more general point of view, no indication is given of the expected swelling pressure developed by the emplaced material at the time of its water saturation in the repository (this value depending on the effective emplaced dry density of the bentonite material).

The presentation also provided a small amount of information concerning the transport and storage of bentonite blocks prior to their emplacement. In particular it was shown that the maintenance of a relative humidity of 70% in the storage area in Mont Terri is in equilibrium with the “optimised” 18 weight % water content of the bentonite blocks, thereby ensuring an absence of instability effects from drying out or further water uptake. So far no information was made available to the EG members on any experiences and observation carried out on bentonite blocks and bentonite pellets behaviour over time under in situ conditions.

The pedestal mechanical resistance (compressive strength) issue is well illustrated in the photo below provided by NAGRA, showing how the blocks forming the pedestal are tested.

Figure 1: NAGRA - FE - Test of pedestal blocks compressive strength

Expert Group Recommendation(s) 2/3:

As pointed out in the first EG Report, those bentonite material aspects are highly relevant to work also carried out in WPs 4 and 5 and it is recommended that integration of findings on bentonite material processing, qualification and conditioning should occur within the LUCOEX Project WP1.

The report on the construction of the emplacement tunnel (b) dealt with work carried out in the period March-October 2012. This work was reported in detail to the EG at its meeting held at Mont Terri on 24/25 September 2012, shortly after the final stage of slab replacement in the emplacement tunnel. All relevant comments have already been made in the first EG report. The NAGRA report contains considerable detail of the project management aspects on the construction of the emplacement tunnel, leading to its acceptance by the project manager on 09 October 2012. In particular it shows how the rupture of the initial tunnel structure was remediated and how lessons were learnt to ensure a stable tunnel structure in accordance with specifications suitable for emplacement of the experiment.

The PowerPoint Presentation (c) provides a significant amount of data on how NAGRA has investigated in details the problems linked to the fabrication of bentonite materials (blocks forming the pedestals and "pellets-powder" granulate mixture). This presentation gives also some information on how the pedestal will be assembled underground.

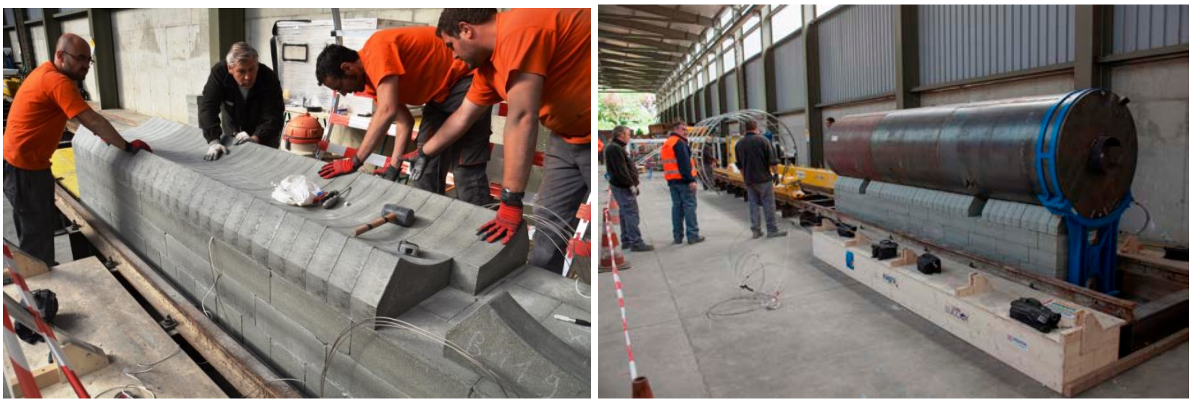

Figure 2: NAGRA – FE - Construction of pedestal made of bentonite blocks in Grono

Additional information was also provided (by E-mail) this summer by NAGRA to the EG members on the construction & commissioning of the backfilling machine to be used in the FE experiment. The photo below shows the auger type conveying system considered for bentonite pellets emplacement around the canister, after preliminary positioning on the pedestal.

Figure 3: NAGRA - FE - Commissioning of bentonite backfilling machine at Wirtech factory

A challenge was the design and construction of a prototype machine for backfilling horizontal tunnels with highly compacted Granular Bentonite Material (GBM) as dense and homogenous as possible. The machine fits into the small diameter FE tunnel and will transport, emplace and compress the GBM using five auger conveyors simultaneously. All relevant parameters such as the backfilling speed and the backfilling pressure can be controlled. The prototype machine was successfully tested in two full-scale pre-tests in May and August 2014 in Grono and will be used to backfill the FE tunnel in autumn / winter 2014.

In another late E-mail NAGRA elaborated further about its bentonite blocks and pellets production strategy:

"*After re-assessing the range of possibilities for backfilling materials only natural (non-activated) sodium bentonite from Wyoming was used for the FE/LUCOEX experiment. Approx. 3'000 highly compacted bentonite blocks, each block with a weight of 25 kg, a dry density of 1.8 g/cm3 and a water content of 19 %, were produced for filling a full 2 m long section in the back end of the emplacement tunnel and for the pedestals below the three heaters. Additionally 350 tons of highly compacted and granulated bentonite mixture was produced. With several pre- and mock-up tests it was possible to prove that with highly compacted bentonite granules ("pellets") with an average dry "pellet" density of 2.18 g/cm3 and with a very broad "pellet" size distribution, a so-called Fuller-type distribution, an overall bulk dry emplacement density of at least 1'450 kg/m3, corresponding to a swelling pressure of 3 to 4 MPa, as targeted in the Swiss concept, can be achieved".*

At this stage of work progress, on the basis of the information provided, the EG members see no particular potential problem likely to impair a successful performance of the FE experiment by NAGRA. The planned visit to Mont-Terri in December 2014 (see Chapter 5) should help the Experts to form a final assessment on the results of the FE test campaign and assess the extent to which the developed methods are relevant to industrial scale implementation (from a mining and nuclear point of view). Clarification could also be made onsite on the monitoring issues raised previously by the EG members (see Chapter3).

4.3 WP3- Andra- Full Scale Emplacement (ALC) Experiment at Bure

Information provided by ANDRA:

d) Report entitled "WP3 ALC Full-scale Emplacement Experiment Test Plan",
e) Report entitled "WP3 ALC Full-scale Emplacement Experiment Cell Excavation and Emplacement Report".

The Test Plan Report (d) was available to the EG to inform its review in 2012. All relevant comments have already been made in the first EG report.

The Cell Excavation and Emplacement Report (e) partly comprises information on experimental design and borehole instrumentation that was also presented to the EG at its first meeting held in Andra Offices on 28 March 2012. All relevant comments on that information have already been made in the EG's first report. New information concerns the excavation of the test cell, including measured responses of the rock mass, and the conduct of the low-power (33 watts/ metre) preliminary heating test.

Although some minor difficulties were experienced, the excavation and low-power heating test were considered successful such that the main heating test was commenced on 18 April

2013 at a power of 220 watts/ metre, which should lead to a temperature of 90°C on the liner wall after some two years. The drilling of the test cell was blocked just short of its target depth and improvised methods of extending the cell still fell slightly short (by 20cm) of target. Particularly given that the cell as planned was already at a scale reduced from that in ANDRA’s disposal concept, this problem merits further analysis to assess its impact on the representativeness of the experiment.

The measured evolution of the rock mass in response to excavation of the cell was stated to be in line with previous observations following excavations of cells with the same orientation in the same area of the Bure URL. It would build further confidence if a more scientific rationale for the evolution behaviour could be provided in the last LUCOEX report, in addition to this somewhat “preliminary” observation.

A small number of sensor failures have occurred and it would be valuable if there could be an analysis of the failure modes and prospects of improving reliability (i.e. bench marking of sensors, redundancy of sensors…). Explanations are suggested for some of the observed deviations from expected behaviour, for example the presence of rubble in the liner/ rock interface affecting convergence but for other deviations no such possible explanations are offered. The graphs below show the temperature evolution (with time) of various sleeve elements since the heating phase started (the temperature reached in April 2013 was 73°C). It is further indicated that some 2 additional years are needed to reach the maximum expected temperature of 90°C.

At this stage of the test, the EG has a good confidence in Andra’s capacity to reach the initially posted ALC experiment objectives.

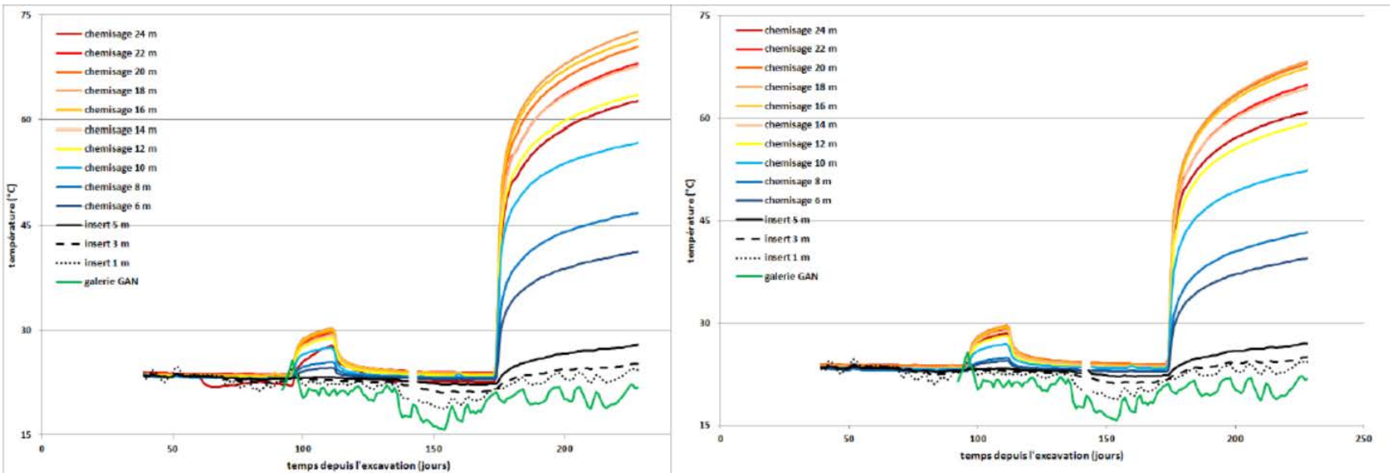

Figure 4: ANDRA - Evolution of ALC sleeve temperature with time (left: top, right: lateral)

<u>Expert Group Recommendation(s) 3/3:</u>

It is recommended that by the conclusion of the ALC experiment, particularly after larger THM responses have been obtained as a result of heating, explanations of the likely causal phenomena should be provided more thoroughly. This should be possible and made public by the date of the planned LUCOEX Conference (mid-2015).

4.4 WP4 – SKB – KBS-3H Multipurpose Test (MPT) at Aspö:

Information provided:

f) Deliverable D 4.01 entitled "Report on Manufacturing of buffer and filling components for the Multi -Purpose Test" (issued 20 May 2014),
g) Deliverable D 4.02 entitled "Report on Deposition machine upgrades during the Multi- Purpose Test" (issued 20 May 2014).

The report on manufacturing of buffer & filling components for the Multi-Purpose Test (f) largely comprises the application of established, standard quality assurance tests on new batches of bentonite material procured for the fabrication of components for use in the MPT. Reproduced descriptions of the standard test procedures themselves occupy a high proportion of the report. In the view of the EG, this information should have been dealt simply by references to the relevant procedures, although the EG of course accepts the importance of quality assurance in respect of engineered barrier components.

The report touches on aspects of the manufacture, transport and handling of bentonite components that are relevant also to WPs 2 and 5, in particular compaction technology and parameters to produce a dry density according to a specification.

Expert Group Recommendation(s) 4/3: It is recommended that integration of findings on bentonite material production, qualification, conditioning should occur within the LUCOEX Project WP1 (see also Recommendation 2/3 above).

The testing of fabricated blocks focused on water content and dry density. It was found that the fabrication and machining techniques that were used produced a variability of these characteristics between blocks that resulted in some blocks being outside the relevant specification for the components when applied as engineered barriers. The report states that nonetheless the blocks are considered suitable for use in the MPT. While the EG can envisage why this might be the case, it considers that an explanation should be provided to justify this statement.

Expert Group Recommendation(s) 5/3: Given the importance of these components in the engineered barrier system for the KBS-3H disposal concept, it is recommended that the causes of the observed variability should be investigated and remedial measures proposed for any future fabrication of these components. Alternatively the tolerances on dimensions (deemed acceptable by SKB) should be elaborated and justified more thoroughly.

The report on deposition machine upgrades during the Multi-Purpose Test (g) focused on the outcomes of an investigation of the control system for the horizontal deposition machine.

This investigation was carried out to assess the work required in order to correct the difficulty of the system to fully balance the load, requiring a significant degree of manual intervention in the control system. Based on tests on the resulting improved system design, the machine was considered sufficiently reliable and adequate for the deposition tasks in the MPT experiment, given that this is by definition a prototype. Further improvements are identified as being required before the system could be considered suitable for routine industrial application. The EG members questioned whether the implementation of the identified improvements provided a prerequisite for the application in a real repository or formed a prerequisite for a license (i.e. in repository conditions). However the EG agreed with both the content of the analysis that identifies further improvements and with the statement that these would be achievable, given the appropriate commitment of time and resources.

During the May 2014 meeting in Aspö, a Power Point presentation on the installation of the various MPT components was made, showing in particular pictures of the emplacement operations (inside the Deposition Drift) concerning the distance block and the Super-Container.

The EG members attending the presentation had the feeling that the main MPT objectives (*"Test the system components in full scale and in combination with each other, … carry out installation… and monitor the initial state…"*) **were satisfactorily met so far** (without prejudice with respect to the issue of the speed at which any evolution could be monitored).

However various pictures showed that cracks have appeared either on the rings surrounding the containers or on the discs forming the distance block (see photo below). It would be of particular interest to know more about these cracks:

- When have they appeared or have been noticed first?
- Where did they first develop: during the production process (pressing and stripping), their temporary storage, and the assembly operations on surface, in the transport tube or during the final deposition activities?
- Have they evolved with time, are they a deep (penetrating) or "surface only" phenomenon?
- Hence, are they likely to incidentally impair the deposition process if sudden rupture appears?

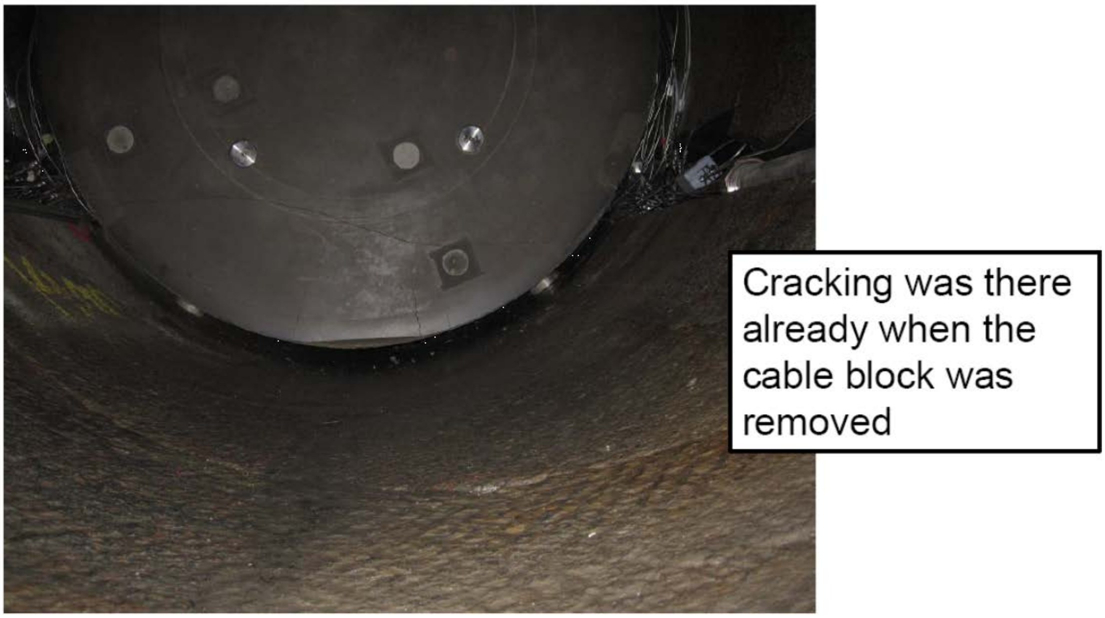

Figure 5: SKB KBS-3H - MPT- Cracks on top of Distance Block

Expert Group Recommendation(s) 6/3:

The EG members recommend that the cracks appearing on blocks be investigated in terms of origin, extension / magnitude, and mainly risks (local breakage) to deposition operations. More generally, the EG should like to know **about remedial actions considered, should such a type of event (local breakage) occur inside the deposition drift** (cf. also Chapter 4.5 on bentonite block problem handling issues in POSIVA's experiment). This aspect is of significance, when operating in nuclear conditions.

4.4 WP5 – Posiva –Buffer Block Emplacement at Onkalo:

Information provided:

h) Deliverable D 5.1 entitled " Detailed Project Plan Appendix 1 – Report on WP5 buffer installation process" (issued 23 May 2013),
i) Deliverable D 5.05 entitled "Report on quality assurance and problem handling during buffer emplacement" (issued 10 October 2012),
j) PowerPoint Presentation to LUCOEX Progress Meeting (14 May 2014) entitled "Quality Control of Buffer Installation in KBS-3V",
k) PowerPoint Presentation to LUCOEX Progress Meeting (14 May 2014) entitled "Problem handling tools for buffer installation in KBS-3V".

There is understandable overlap between the Reports (h) and (i). The technical work reported briefly in Appendix 1 to the Detailed Project Plan that is not replicated in Report (h), concerning buffer manufacturing, handling and emplacement, was presented in detail at the second EG meeting on 24/25 September 2012. All relevant comments on these aspects have already been made in the first EG report. As noted in that report, the results from the work on manufacture, handling and transport of bentonite material, in its various forms, are relevant to the equivalent parts of WP 2 and WP4.

Expert Group Recommendation(s) 8/3:

It is recommended that integration with WPs 2 and 4 of the relevant findings on bentonite material should occur as part of the LUCOEX Project (see previous recommendations on this issue).

The two PowerPoint presentations (j) and (k) deal with the two main technical areas covered by Report (i), so they will be covered by review comments on Report (i) rather than by separate comments.

The report on quality assurance & problem handling during buffer emplacement (i) deals with:

- The selection of measurement technology to monitor the achievement of quality assurance requirements for buffer emplacement (essentially geometric in nature),
- And the selection of technologies to deal with the removal of bentonite debris and reinstatement of deposition holes following a fault situation.

The quantified quality assurance requirements for buffer emplacement are clearly very challenging, given the mass and size of the buffer components that have to be handled in restricted working conditions. A major objective of WP5 is to test whether these requirements can be achieved under realistic industrial conditions. The evaluation of measurement technologies has been carried out in a comprehensive and systematic manner. The EG supports the analysis that has been presented and is now awaiting with interest the testing of the selected technologies under realistic conditions (underground in Onkalo).

However, the rationale for the very demanding geometric tolerance required is still not known by the Experts, hence the relevancy of such a strict technical target cannot be assessed.

Expert Group Recommendation(s) 9/3:

The demanding geometrical tolerance objectives set by POSIVA in the fabrication and positioning of the bentonite blocks inside the deposition hole could be more clearly justified, in particular the reasons why they differ from the “original” design and experiment (previously carried-out in Aspö by SKB) could be explicated (the EG members were told the geometrical tolerances come from a POSIVA’s buffer design report, not made available to them).

Coming back to the “uniaxial block pressing” versus “isostatic pressing” issue, the EG members should like to know more on the rationale for such a choice, which differs from SKB original approach (POSIVA responded to this question, previously raised in the first EG Report D1.7 by saying that comparison between the 2 technologies is the motive of the work).

The evaluation of fault situations (i.e. when blocks are partly broken or jammed during their deposition down the hole) has also been comprehensive and systematic. However, the report is not sufficiently clear about the motivation for some recovery situations, especially after the spent fuel container has been emplaced. The situation is potentially further confused by unclear definition of what situations are excluded from evaluation in the LUCOEX Project but remain of importance in the KBS-3V disposal concept.

Expert Group Recommendation(s) 10/3:

Particularly given the societal interest in monitoring and retrievability (or reversibility), the EG recommends that the conceptual approach and project context for this area of WP5 should be explained and motivated more clearly. The EG members understood that fault situation remediation tests are not a part of the work within LUCOEX.

Technical visit at Onkalo, on 14 October 2014:

Five (5) of the EG members attended the demonstration made by POSIVA, at Onkalo site, of its buffer emplacement system operated inside a sub-surface hole mock-up. This presentation was combined with a visit of the Onkalo underground facilities (where the future buffer emplacement test site is now being excavated) and was followed by a technical discussion lead by POSIVA's representatives and those from their main subcontractor (which developed and manufactured the various pieces of equipment forming the emplacement system).

POSIVA (and its subcontractor) must be thanked for granting the Experts full access to the test facility and for the transparency and openness in the technical exchange which took place at that time.

The Experts' findings and comments, following this visit and the technical exchange, are as follows:

- The only emplacement system component operated in front of the Experts was the Buffer Installation Machine (BIM), while the Buffer Transfer Device (BTD) was idle in the vicinity. The operation of the BTD (and its docking to the BIM, followed by the transfer of the block assembly from the BTD to the BIM) could not be checked, neither the preliminary positioning of the BIM over the deposition hole mock-up.
- The BIM was remote operated, while already positioned above the sub-surface polycarbonate deposition mock-up. The Experts could watch the block lifting device swiftly moved up and down, with a 7 ton dummy load (assembly of concrete blocks).
- From a mechanical point of view (stricto sensu), the EG members took note that the system developed by Posiva managed to lower down the hole (i.e. inside the tube made of polycarbonate folios) the block assembly with a very good accuracy (even though the centering jacks could not be operated due to the lack of stiffness of the polycarbonate folios). Two sets of dummy blocks were stacked above each other (with little decentering of the first set vis-à-vis the other set), and later also removed very easily.
- The EG members were told the BIM operations would be reiterated in the weeks to come with the real bentonite blocks and that later a complete cycle including the use of BTD would be carried out. The Experts were also informed that similar operations (including a complete transfer and deposition cycle combining BTD and BIM) would be later implemented (most likely in December 2014) in situ (one of the future test holes was still being excavated during the EG visit underground, hence previously excavated holes were shown to the EG members).

- The photos below illustrate the BIM machine positioned above the deposition hole and the dummy blocks lowered down the polycarbonate tube (mock-up).

Figure 5: POSIVA - BIM machine pre-positioned above the deposition hole (mock-up)

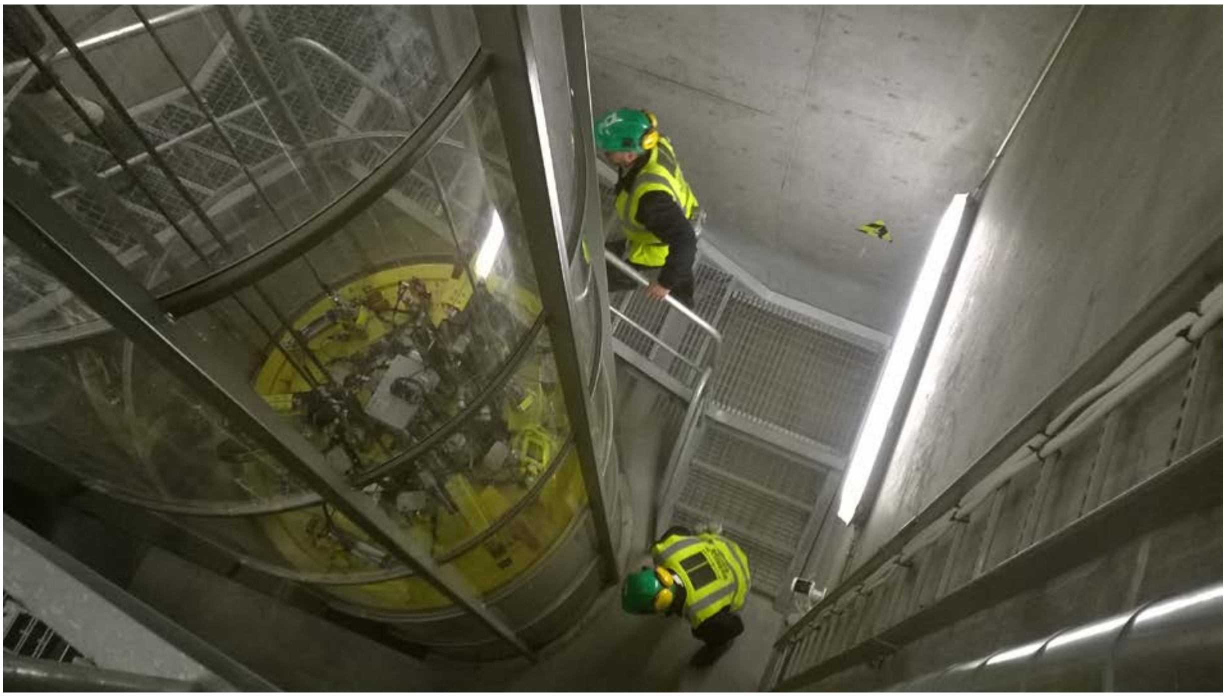

Figure 6: POSIVA - Dummy blocks lowered down the deposition hole (mock-up)

The EG members have a good opinion of the mechanical development made by POSIVA (and its subcontractor) concerning the emplacement system as built for the deposition of bentonite blocks, at this stage of work progress. There is also a reasonable confidence in the technical capacity to successfully complete **underground** the cycle of planned operations forming the demonstration program, even if the **work schedule still looks quite tight** to finalize the complete cycle underground by the end of December 2014.

Now when looking at the design basis, the related justifications and the general purpose of the demonstration, the EG members think there **is still room for technical improvements** and **clarification**:

- The EG members were told that so far no redundancy means (e.g. retractable mechanical grippers coming on top of suction-cups to secure the bentonite block lifting, as in SKB's design) or fail-safe approach had been incorporated in the design and its subsequent development: this phase of development will come later.
- Similarly, remediation situations have not been investigated so far and no particular dispositions have been considered or developed for intervention in case of stoppage at any stage of the deposition cycle (this could be critical if limited access is provided, either because of the very narrow space surrounding the BIM or when the canister is already installed): this phase of development will also come later.
- The problem handling tools shown to the Experts are not at this stage sufficiently developed for assessment and the rationale and circumstances for their use ("fishing operations") still need clarification. POSIVA indicated however the relevant tests are planned within the frame of LUCOEX.
- When looking at the bottom aspect of the previously excavated deposition hole, the planarity and horizontality criteria mentioned (around 1 mm) are far from being granted. Even if this "mining objective" is out of scope of the mechanical demonstration carried out by POSIVA in LUCOEX, this interface issue raises a certain degree of concern on the relevance of the geometrical criteria set out for the stacking of the blocks inside the deposition hole.

> Expert Group Recommendation(s) 11/3:
>
> The EG members recommend to POSIVA to further clarify in its final WP5 Technical Report the demonstration limitations of the mechanical components now tested and how this development fits with the next phases anticipated for integration of "nuclear and mining needs" in order to reach some type of certification, prior to an effective use in the repository.
>
> It would also help the reader's understanding, by learning more about the "mining commissioning" of the deposition hole and how the geometrical criteria set up for this object are commensurate and coherent with the geometrical accuracy required at time of bentonite blocks positioning and stacking inside the deposition hole.

5 Expert Group general recommendations

Based on its findings, the Expert Group provides two categories of general recommendations on Project Management issues, and on Integration issues.

5.1 Managerial recommendations:

a) Lessons learnt so far from the implementation of the LUCOEX technical WPs

Expert Group Recommendation(s) 12/3:

The information provided by the WP leaders (with the exception of WP3 - ALC experiment, which is now in a “passive mode”) indicates certain delays in the implementation of particular tasks having different background, such as various technical problems, missing software, changes in design of handling equipment, optimisation of experiment design. These delays (which are of concern in a vast amount of projects, whatever their type) have precluded achievement of complete project results by the initially planned end of the LUCOEX Project.

The Expert Group would appreciate analysis of problems encountered by particular teams while launching their experiments and identification of the lessons learnt which may be applicable in managing future, large, underground experiments and / or construction of a disposal facility…

More generally, the risk management plans should have a focus on the delay issue, and a “significant free float” should be systematically integrated in the construction of the individual WPs and general Project Work Schedules, to allow for potential deviations without prejudice to the main Project deadline.

Since the delay issues are, by essence, encountered in other EC funded projects, and more generally in all technically complex projects, and since the delay risk is quite often commensurate with budget and contractual issues, it would be wise to spend more time on the EC Project Work Schedules and to “double check” their relevance at time of preparation of the “Description of Work”.

b) Demonstration Strategy

When assessing the work carried out in the technical WPs, the Experts have often experienced some difficulties in understanding the general context and the (sensible) technical limitations of the demonstrations / experiments concerned… some time (and some useless questions raised or irrelevant comments made by the Experts) could be saved if the demonstration strategy of each participant were made available as a matter of good practice at the early stage of the EG work.

Expert Group Recommendation(s) 13/3:

To improve the EG work and assessment in future EC projects, it would be good practice to provide the Experts, at an early stage of their mission, with the following data (on top of the technical information already contained in the Project Description of Work):

i) Repository concept (for the phenomenology studied or the technology developed) with respect to its rationale and justification, and the related state of the art (if any),

ii) Objectives of the demonstration tests in order to fill gaps which are needed to be closed with regard to repository implementation but are not state of the art technology today,

iii) Design basis of the experiment concerned **with its limitations** and how it fits (in time, scale and progressive complexity) with the more general demonstration to be submitted to nuclear licensing authorities and decision makers,

iv) Work plans and Risk Management plans that deal with project-specific issues.

5.2 Recommendation on Integration

Expert Group Recommendation(s) 14/3:

The integration between the various Work Packages is, still to date, marginal, due to the unique nature of the respective programmes. In these circumstances, the participants should look for (and make explicit) what they can put in common or intrinsically have in common (e.g. KBS-3V and KBS-3H concepts for SKB and POSIVA, host rock THM for ANDRA & NAGRA, formulation of bentonite admixtures for blocks and pellets) and specify the likely benefits / inputs to their own programme which are generated by the test outcomes (e.g. cooperative critical review of the respective lifting devices used respectively by SKB and POSIVA for installing bentonite rings down the vertical deposition holes).

Another possible common issue is how to manage the difficulty and risks of fabricating and emplacing large, heavy bentonite blocks to small tolerances (typically mm), as is the issue of how to protect finished blocks during storage and transport from damage caused by possible fluctuating temperature and humidity or from shocks during handling and transportation.

The Expert Group considers that the subject of the management of tolerances could be an element for integration on its own, covering not only the tolerances on the design and specification of bentonite blocks (e.g. size of blocks, water content, density) but also boreholes, drifts, emplacement machinery, any element of the engineered barrier system and how all these have to fit together.

Another important issue with regard to integration could be a debate about the role of the different geotechnical barriers (bentonite blocks, bentonite pellets, plugs etc.) in the safety concept and the importance of functioning of the barriers. This of course tackles a very sensitive point in the Safety Case but has to be taken into account when setting up demonstration tests and related requirements to the different barrier components.

6 Expert Group objectives and planned activities for the next period

The LUCOEX Project technical WPs have by now reached a mature state. The Expert Group considers **there are no major identified technical issues at this stage likely to impair the successful completion of the various experiments / tests** engaged in the technical WPs (even if incidents may always occur and if there is still some potential need for trouble-shooting in certain cases).

The main challenge remaining is the **tight Work Schedule** allocated to finalize the tasks and analyse the monitoring data made available by Project end. **Time is also short to produce all the WPs technical reports** (including the final summary reports) within the initial Project Schedule.

The EG members were recently informed by the LUCOEX Coordinator (SKB) that the EC should grant the Partners with a Project deadline extension and could also accept a revised Scope of Work concerning SKB's activities... Assessment of SKB's achievements will be revised (in the 3rd and final EG Report, scheduled by mid-2015) on the basis of that revised scope and on the technical outcomes made available.

The Expert Group will focus its activities for the next period on the following items:

- Attending the NAGRA - FE backfilling operations (December 2014) at Mont-Terri,
- Staying in close touch with POSIVA's WP Leader to learn more on how the BIM demonstration is ongoing (and can in particular be completed underground with the bentonite rings). Data on "problem handling tool" will also be of interest;
- Staying in close touch also with SKB's WP Leader to follow the outcomes of the new scope of activities and interpret the results obtained (the need for a potential additional site visit will be debated);
- Having again a close look on Andra's ALC test in spring 2015;
- Participating in the planned LUCOEX Conference in June and by doing so covering the final status of all WPs (including WP6 – Dissemination).

By spring 2015 , the Expert Group should also like to receive the final technical WP information needed to discharge its responsibilities for overall assessment of performance and achievement, in particular the most relevant reports available on integration and dissemination (those two aspects of the Project have not been examined as such, so far).

The main reports on Integration (WP1) and Dissemination (WP6) are also expected by that time.

Finally, the Expert Group also expects that by spring 2015 the LUCOEX Experiment leaders will formally respond to the recommendations that it has made in this report D1.11 so that the treatment of the relevant issues may be considered in the final EG report.