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TRANSCRIPT

Spring 2018 BOARD MEETING

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NWTRB BOARD MEMBERS

Jean M. Bahr, Ph.D.
Steven M. Becker, Ph.D.
Susan L. Brantley, Ph.D.
Allen G. Croff, Nuclear Engineer, M.B.A.
Efi Foufoula-Georgiou, Ph.D.
Tissa H. Illangasekare, Ph.D., P.E.
Linda K. Nozick, Ph.D.
Kenneth Lee Peddicord, Ph.D., P.E.
Paul J. Turinsky, Ph.D.
Mary Lou Zoback, Ph.D.

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I N D E X

P R O C E E D I N G S

BAHR: Okay. Well, good morning with the traditional intro music. Welcome to the U.S. Nuclear Waste Technical Review Board's Spring Meeting of 2018. Today's presentations and discussions will focus on the operational and performance confirmation monitoring of a geologic repository for disposal of high-level radioactive waste and spent nuclear fuel, and the retrievability of emplaced waste. I am Jean Bahr. I'm the Chair of the Board. And I'm going to introduce the other Board members in a moment, but first I want to briefly describe the Board and tell you why we're holding this meeting and what we plan to accomplish.

As many of you know, the Board is an independent agency of the Executive Branch. It's not part of the Department of Energy or of any other federal organization. The Board was created in the 1987 Amendment to the Nuclear Waste Policy Act to perform objective ongoing evaluations of technical and scientific validity and DOE activities related to implementing the Nuclear Waste Policy Act.

The 11 Board members are all appointed by the President from a list of nominees submitted by the National Academy of Sciences. We are mandated by statute to report Board findings, conclusions, and recommendations to Congress and the Secretary of Energy. The Board also provides objective technical information to Congress and the Administration, DOE, government and non-governmental organizations, and the public on a wide variety of issues related to spent nuclear fuel and high-level waste disposition.

We put out a number of reports, and copies of some of those can be found on the document table at the entrance to the meeting room, and they're also all available on the Board's website for download at www.nwtrb.gov.

A lot of effort went into planning this meeting and arranging the presentations, and I want to thank, first of all, our speakers, most of whom traveled from abroad to make presentations at our meeting today. And I also want to thank ~~doctors~~ Drs. Efi Foufoula-Georgiou and Tissa Illangasekare who acted as the Board leads and who coordinated with the Board staff to put this meeting together.

So, I’m going to now introduce the Board members and tell you a little bit about the schedule for the meeting. First, the introductions. I’d ask that as I say the names of Board members that you raise your hands so that you can be identified. I’ll begin. I am Jean Bahr, the Board Chair. All of the Board members serve part time, so we also have other jobs on top of our Board appointments. In my case, I’m a Professor of Hydrogeology at the University of Wisconsin, Madison. Dr. Steve Becker is a Professor of Community and Environmental Health in the College of Health Sciences at Old Dominion University in Virginia. Dr. Susan Brantley is a Distinguished Professor of Geosciences and is the Director of the Earth and Environmental Systems Institute at the Penn State University. Mr. Allen Croff is a nuclear engineer and adjunct professor in the Department of Civil and Environmental Engineering at Vanderbilt University. Dr. Efi Foufoula-Georgiou is Distinguished Professor in the Department of Civil and Environmental Engineering at the Henry Samueli School of Engineering at the University of California, Irvine. Dr. Tissa Illangasekare is the AMAX Endowed Distinguished Chair of Civil and Environmental

Engineering and the director of the Center for the Experimental Study of Subsurface Environmental Processes at Colorado School of Mines. Dr. Lee Peddicord, who will be joining us a little bit later this morning and is currently a vacant seat at the table, is the Director of the Nuclear Power Institute and Professor of Nuclear Engineering at Texas A&M University. And Dr. Paul Turinsky is a professor of Nuclear Engineering at North Carolina State University.

So, I've just introduced seven Board members, in addition to myself. Due to other commitments, Dr. Linda Nozick and Dr. Mary Lou Zoback are unable to join us today. Dr. Nozick is a professor in the School of Civil and Environmental Engineering and Director of the ~~college~~ College ~~program~~ Program on Systems Engineering at Cornell University. And Dr. Zoback is a consulting professor of Geophysics at Stanford University. The Board currently has one vacant position.

As I usually do at Board meetings, I want to make clear that the views expressed by the Board members are their own, not necessarily Board positions. Our official positions can be found in our reports and letters which are available on the Board’s website. If you’d like to know more about the Board, a one-page handout summarizing the Board’s mission – let’s see, I think I -- I’m not sure if I’m at the right – okay, the Board’s mission and presenting a list of the Board members can be found on the document table at the entrance to the room, and you can also visit the Board’s website, www.nwtrb.gov. All reports from the Board, correspondence, testimony, and meeting materials are available there. I should mention that we have relatively recently updated our website and there’s some materials that are still being uploaded to that, but all of the recent materials are certainly there.

During this meeting there are going to be two opportunities for members of the public to make comments, before the lunch break this morning and at the end of the day. We ask that if you want to make a comment you add your name to the sign-up sheet that is at the registration table outside of this room. And written comments and any other written materials may also be submitted by providing the material to one of the staff members today or by sending the material by mail or email to the points of contact we noted in the press release for this meeting. And the press release is posted on our website. Documents that are submitted to the Board by the public will become part of the meeting record and will be posted on the Board's website along with the transcript of the meeting and the presentations.

If you want to make a comment during the meeting, because this is being webcast, we'd appreciate it if you would use the microphones and please state your name and affiliation first so that you will be identified correctly for the transcript.

We want you to be aware, as I mentioned, that this meeting is being webcast live. You will see cameras around the room. Depending on where you are sitting, you might be part of the webcast. I also want to request that the presenters speak loudly enough so that those in the back of the room can hear. And it would be helpful to those who are watching the webcast if the presenters will summarize any questions before answering them, particularly if they're questions that come from the public.

The webcast will be archived after a few days, and after that it will be available on our website so you can watch it over and over and over again, to your heart’s delight. The meeting agenda is already posted on the website. And the presentations will also be posted and be available for download. The presentations will also be part of the webcast today.

So, now I’d like to provide you a little background on the topic of today’s meeting and outline today’s agenda. Worldwide, there’s a strong consensus of the value of a stepwise and phased approach to repository licensing and development. So, this is this kind of stepwise process where you go in various directions and you can come backwards.

In this process, the implementer and the regulator periodically assess whether the proposed disposal concept and the associated repository design can meet socially acceptable health safety and environmental standards and rules. Many consider this type of iterative and centralized process important because it preserves the ability of future generations to modify or even reverse decisions that were taken during the implementation of a disposal system. And so this is, again, sort of illustrating this idea of decisions to either follow the reference path, to modify the path, or to reevaluate. And you want to do this taking into account information that's obtained during the implementation process.

So, this depends on two things. One is an effective monitoring strategy for the repository environment, including both its component engineered and natural barriers. And this monitoring is the primary method used to generate data that are required to make decisions about whether to go forward or to change course. The other is retaining the option to retrieve the emplaced waste, if necessary. The option of retrieval is dependent upon, among other things, the geology of the host rock, the engineered barrier concepts that are used. And as illustrated down here, this from the NEA program, the cost as well as the ease of retrievability changes as the repository progresses.

A study of national programs conducted by the NEA, which is based in Paris, showed that reversibility and/or retrievability are important aspects of policy or legislation in many countries. And there are a wide variety of approaches to reversibility or retrievability in national policy and legislation because social, legal, and technical environments vary from country to country, and these environments can also change with time.

In the United States, the Nuclear Waste Policy Act of 1982 requires that any repository shall be designed and constructed to permit the retrieval of any spent nuclear fuel placed in such a repository. The Nuclear Regulatory Commission has requirements pertaining to high-level waste and spent nuclear fuel retrievability. It also has requirements for monitoring to confirm that subsurface conditions are within the assumed limits for the licensing review, and that natural and engineered barriers are functioning as intended and anticipated. So, this monitoring program is referred to as performance confirmation. And the requirements are given in Title 10 of the Code of Regulations, Parts 60 and 63.

So, using, as an example, the DOE license application for the Yucca Mountain Repository, DOE described in the license application its plans for waste retrieval and its performance confirmation program. This is an outline of sort of a schedule once a decision to retrieve waste is made of the timeframe of different activities.

DOE identified 20 performance confirmation activities that it planned to conduct to evaluate whether the repository is working as expected and within the acceptable safety margin, and to confirm that the waste retrieval option is preserved during repository implementation.

Two of the performance confirmation monitoring activities the DOE plans or planned for Yucca Mountain are seepage monitoring and waste package corrosion, and that’s because water seepage into the emplacement drips and corrosion of the waste package are two of the key factors related to repository safety in the DOE license application. Seepage monitoring would evaluate the spatial and temporal distribution of seepage flux for ambient and thermallyperturbed conditions, as well as analyzing the chemistry of collected waters. And waste package monitoring includes remote monitoring of external corrosion on the packages.

So, there are three overarching questions that we’re going to try to address today. The first is what are the requirements for undertaking operational and performance confirmation monitoring and retrievability? What are the technical and institutional challenges involved in carrying out those activities? And finally, I think most importantly, what we hope to get out of this meeting is what lessons can be learned from international programs that can be applied to the U.S. Geologic Repository Program.

So, in order to accomplish that, we’ve invited a number of speakers to help us address these questions. This morning, Dr. Claudio Pescatore, who’s formerly with the Nuclear Energy Agency of the Organization of Economic Cooperation and Development, will tell us about work that the Nuclear Energy Agency has done over the past 20 years on retrievability and reversibility.

Next, Dr. Patrick Landais of Andra, which is the French National Radioactive Waste Management Agency, will give a presentation on governance and technical approaches to reversibility and retrievability in France. He’ll be followed by Dr. Piet Zuidema, formerly with the National Cooperative for the Disposal of Radioactive Waste, better known as Nagra, which is the implementer of the Radioactive Waste Geologic Disposal concept in Switzerland. Dr. Zuidema will describe the role of monitoring in the Swiss Geologic Disposal Program.

Then, in the final presentation of this morning, we’ll hear from Dr. Maarten van Geet of the Belgian Agency for Radioactive Waste and Enriched Fissile Materials, ONDRAF/NIRAS, who will tell us about the research development and design work being conducted for monitoring and retrieving waste in a geological disposal facility in Belgium.

After the lunch break, Dr. Horst Geckeis of the Karlsruhe Institute of Technology in Germany will give a presentation on the experiences and the challenges involved in retrieving waste from the Asse Salt Mine in Germany, which was used for disposal of low-level radioactive waste. He’ll be followed by Dr. Dani Or of the Swiss Federal Institute of Technology in Zurich, in Switzerland, who will discuss sensors and technologies for monitoring subsurface water seepage in a geologic repository. And then Dr. Raul Rebak of G.E. Global Research will give us a presentation on sensors and technologies for monitoring waste package corrosion in a geological repository.

And after all of these presentations, we’re going to invite the speakers up for a panel discussion on various aspects of repository monitoring and waste retrievability, and we look forward to that summary panel.

So, we’re about to start. If I could ask you all to please mute your cell phones and let’s begin with what I think is going to be a very interesting and productive meeting. And it’s my pleasure now to turn over the podium to Dr. Pescatore who will get the meeting started.

We are taking care of a few technical things.

PESCATORE: So, good morning, Madame Chair, colleagues from the Board, ladies and gentlemen. So, as Chair was saying, I was invited to talk about the projects we did at the NEA on the reversibility and retrievability, but the background of the presentation, first I would like to thank the Board for the honor they are making me to come on this invitation, but also for the possibility I had, in fact, to go back and to think about what we did because, in the end, the second of the two international project I managed was end in 2011. So, since then, a few things have happened. In fact, after 2011 was natural that I worked on monitoring, memory preservation, and radiological standards. And I believe in this context that new thinking was made that perhaps put into perspective the work that we did in reversibility/retrievability. And the title and the messages in this presentation will affect all of this. So, we go beyond just the NEA project.

And the plan of my presentation is that, first, I will, in fact, talk about my post-2011 findings and thinking, and then I will talk specifically about the latest of the two NEA projects. Then I'll provide conclusions.

The title of my presentation comes from a song from Tom Lehrer, for the older of us that may remember this. And the song went "When the rocket's up, who cares when it comes down? It's not my department," says "Wernher von Braun." And so this quote is basically ~~light motif~~leitmotif in my presentation. Basically, it says that there are two departments, so there's the receivers and the makers. And, well, they better talk to one another, especially in a friendly setting.

And also the question arises would we say anything like this for a repository today? Who is willing to say a similar thing for a waste repository? And the answer is very simple, nobody; okay? Nobody is willing to say this. Perhaps in the eighties, yes, people were willing to say these things, in the seventies, yes, but nobody today. Nobody today is willing to say we walk away. And very importantly, nobody's even thinking about saying, "The nuclear materials in this r~~d~~epository are below regulatory concern." So, this is when we walk out of these materials.

In fact, I find out that all raise hope a possibility for care taking. There are four possible interventions, and eventually even retrieval, after closure. And these suggestions, internationally, go from subliminal to totally assumed, and I will give you some examples.

The subliminal part to me in the U.S. is when you have the 10,000 years Land Withdrawal Act, basically telling people, "Well, you know, we'll be there for 10,000 years." So, perhaps that gives us a chance also to go back and to modify, to retrieve. The markers are required. They are called "passive institutional controls." In fact, passive matter is not controlled at all. And it's not even institutional; perhaps it was institutional when it was conceived, but, you know, saying it's institutional means there are institutions. So, in this sense, it's subliminal.

But it's also assumed because we have this "stewardship" concept in environmental remediation area, especially in the nuclear waste side, where there's even an agency within the DOE or department or whatever section, Legacy Management, to do this. So, at Savannah River, they will look at this, we build reactors forever, for instance. And retrievability is a requirement for WIPP. It was used in the WIPP. In fact, the WIPP had to demonstrate technology for retrieval before they could get certification.

Now, if you look at the Joint Convention, now the Joint Convention has been signed by 100 governments, amongst which the United States government, and this convention belongs to the government, it does not belong to the ~~international~~ International ~~atomic~~ Atomic ~~agencies~~Energy Agency. It belongs to the governments. The agency in Vienna --- I was secretary for ~~[inaudible] for~~ this convention. And probably this convention applies also to the NWTRB because it is your government. And the convention says, well, after the disposal is closed, you have to keep records and ~~[inaudible]~~inventory, we have to preserve it. So, and one of the questions is why you preserve this stuff. Well, perhaps you have to carry out institution controls and monitoring and access restriction, if required. This, if required, is something to get out of. But really it needs to be present. And the other one is if during any period of institutional control an unplanned release of the radioactive material takes place, perhaps you must be able to intervene. So, in this sense, caretaking is suggested.

The IAEA guidance is very subliminal because we really have to go into it and dig into it and understand that basically the word “control” every time in the IAEA guidance, regulatory guidance, it’s used, it really means – implies that there are people and there is knowledge.

The ICRP is clearly saying that the closed repositories should be seen as a functioning nuclear facility. It is basically absorbing a function, which is that of isolating the waste. Although even if the repository should be designed and built to be safe without intervention of man, there ought to be no intention to relinquish oversight of the closure. Now, there is also the object of reason about this, and I will come back to that.

The concept of oversight includes not only institutions but also the involvement of society, the local, for instance, communities, or the state. And this has also surveillance of the closed facility should continue for the longest practicable.

We look at the NEA, there is a collective statement which says, well, we agree with what the ICRP is saying.

The KBS-3 concept was the first one -- well, now I hear about the NWPA, the quote I did not really remember, but in the eighties, in the early eighties, 1983, there was the position by the KBS-3 concept on retrievability. It was basically it is the future generations' responsibility, if they do any action like retrieving, we will make sure, though, to preserve the information. And the information is just to allow them perhaps to retrieve the copper or the spent fuel. It's not about safety, either.

And then they realized over time that it was probably not good enough in the Swedish situation. And in the 2000s, SKB in particular demonstrated the technology for the retrieval can be developed. They showed technology can be developed and deployed. However, they still don’t claim retrievability. Basically the position is this, this is not irretrievable; okay? Maintaining information capabilities for retrieval is not their concern. Same position for Finland now.

In Switzerland and Germany, it is totally assumed, therefore it’s subject to licensing. So, they have a concept, and Piet I’m sure will talk about, it is called Long-term Monitored Retrieval Deposition or Disposal. And in Germany, the containers should be suitable for retrieval for 500 years. I’m not talking about France because I’m not sure we have a good – a defined position for after closure in France, but Patrick Landais will talk about that.

So, overall, I would say that those communities do not want the repository to be left unattended or forgotten, and nor do the technical folks. You’ve seen the quotes I gave you, but they’ve been really not so clear. It’s been difficult for them to be explicit about not forgetting and what it means to retrievability. The issue of memory comes up, of course, because everybody wants this memory to be kept. But no strategy's really been defined yet, and it's not an easy subject. And it came up, in fact, during the latest licensing hearings from the Environmental Court in Sweden. It was last December, as I recall. And basically says the Swedes said – the Environmental Court said this memory part is very important, and it is important also for licensing in the end. The strategy has to be identified.

Now, coming back to the radiological reasons, I never hear this but it's very evident if you work in a radiological area that basically the reason for continued attention, continued oversight is that the radiological standard that's used, the 0.3 millisieverts per year, or something similar, it basically applies only when the radiological situation is managed, when you have control over the source or you have intention to control the source, if you're around the source and you can do something about it. But if not, then the radiological standards are different. Then if it is for free release below regulatory concern, then you have much stricter standards. And, of course, this is not standards that can be applied to a repository. And if we have intervention conditions, it can be much larger. So, this is, to me, is a very important reason to keep oversight from a technical reason.

Now I will talk briefly about the R&R project of the NEA and put them in perspective. Basically, as I mentioned two projects, one in the early 2000’s. At that time, the Swiss had just articulated a new position about retrievability and reversibility. The Swedish industry was saying this is not in my department but we are doing something about it, developing the technologies I mentioned. The French were debating reversible/non-reversible disposal at that time. The Finns suddenly had a legally-imposed reversibility requirement with the so-called decision ~~and~~ in principle in the year 2000. And so the more advanced programs were under pressure, some from the local communities. Certainly France was an issue. And so we started this project around the year 2000. And I believe at that point it was important that we distinguish between two concepts, reversibility and retrievability. They’re two separate concepts, and it’s important to keep it separate. I’ll give you other quotes later on. So, up to now, I’ve been using them fairly loosely.

The second project was in 2008-2011, and was started by Andra. They wanted to see that we could establish an international retrievability scale. We did establish it, and Jean Bahr showed it, in fact, on the presentation she gave. And we went farther as well, and I mentioned this. And the ICRP-122 that I mentioned earlier is informed, in fact, by this project, very much so. You can see some of the pictures from our projects in the ICRP document.

This project is very well-documented. I point out the bibliographic database that we developed. The report on the history and status of R&R in the NEA member countries; the last international conference in this topic, fairly voluminous and with a large representation; the final report; the final brochure; and also this scale that I was mentioning earlier.

So, the bibliography is interesting because it starts by saying – this is the first sentence of the bibliography says

"These concepts are not new concepts," and they give in two examples from the United States. The first one is the report to Congress by the U.S. National Academy of Sciences that says, "The reversibility of an action should be counted as a major benefit; its irreversibility, a major cost." It is interesting that the word "reversibility" is associated to the word "action," okay? I believe this is the right way to present it.

And this document NUREG-0300 of 1978, one of the authors is Daniel Metlay, a member of the staff of your Board, says, "If wastes are disposed on earth, their retrievability -- assuming technology as advanced as present -- should not be precluded." So, these are early quotes. You can see reversibility's associated with an action, whereas retrievability is associated with a thing; you retrieve a thing, you reverse an action. I believe these are important things to keep in mind – distinction to keep in mind.

The report on status and issues, I suggest you have a look at it, it is a factual collection of the replies from 14 countries, and through this debating, and this is something that we could do as NEA, that is really have the country write what they thought, what they thought was their official position, and you'll find the official position under definition, historical developments, communicating with stakeholders, regulatory issues, so you can see what each country will say.

Now some of the messages. I went back to my presentation, in fact, for the REMS Conference in 2010. I took my presentation there and I'm giving you some of those main messages. The first message, is there is the will, there is the means. That is if you want to go back, you can always go back. You have to build another repository basically to get your waste back. This is the situation. And this is the situation -- this is an actual situation because this is the mining back of the Cigar Lake~~. You're in the~~ uranium deposit. You can see that that to build the repository to get out the waste. It looks very much – it is the negative of a repository; okay? And the depths are 500 meters, just like many other repositories around the world. And it is even a more difficult situation because it's under a lake.

So, this can be done. It’s only a matter of having the means and the will.

The other message was, if possible once, probably is likely always possible, that is saying it’s impossible is not really very credible. There’s a quote here from the Nirex report that says, “Well, you know, we found that we could deliver what was asked for in terms of technical visibility, and without compromising safety, which, of course, is one of the big questions.”

The other message says, “Okay, you can do this, but the ease of retrieval will change with time, you have to accept this.” And this is the international scale which was shown by Jean. You can see the six steps of the lifetime of our waste package, from basically ~~the~~ storage until it degrades, the cost of retrieval will go up in time, the ease of retrieval, of course, will go down, but hopefully the safety assurance will be still all the time up. This is also another message [inaudible].

Which technical measures that can boost reversibility? Well, there are two important aspects. One is providing easier access to the waste packages, and this can be done by enhancing the stability of openings, by delaying backfilling, more easily removal buffer materials, delaying the final sealing, for instance, and/or providing improved capability to handle the waste packages. So, hopefully, if you have longer-lasting containers and more durable waste forms, this also improves the reversibility and also retrievability.

But reversibility is of an action, as I mentioned, so it’s also important there are no technical measures to allow that action to take place. A decision-making system that is inclusive and that proceeds in stages, so before the end of the stage you can ask yourself is there a good reason to go back and modify what was done? It’s good to ask this question each time one wants to move on. And, of course, important is to preserve at least maintaining records and memory, but keeping records up to date and usable over time is a challenge even by itself and needs to be looked at.

The cost for supporting reversibility and retrievability, they can range from no cost if the options are “built in,” like Sweden, Finland, France. I don’t think you can ask them how much more it will cost you in France, and they will say, “Well, this is part of the concept.” The full cost of the national program, if, at one point, a stronger commitment was wanted, ~~[inaudible]~~ vice versa, I believe that in Switzerland if they do not deliver what was decided upon in terms of retrievability, the problem would be scrapped. So, it’s the full cost.

Other messages are that basically disposal, of course, is carried out without the intention to retrieve. It should be safe by itself if were left alone, but, however, it’s not a good idea to reduce retrievability unnecessarily. It is a good idea to apply reversibility. The types or degree of reversibility must be negotiated, whether it will change from place to place. And, of course, the ease of retrieval must be balanced against some technological considerations. However, we should be reminded that it's easier to scale down than scale up.

In terms of reversibility, as I mentioned, again, it’s a characteristic of an action, so it’s the process of repository – it applies to~~a price of~~ the process of repository development – this is the implementer and the regulator together – and national decision-making, which is about, again, regulator probably political system. Reversibility is the best available technique in terms of management approach that values flexibility. During the development of the design, this realization, the implementer asks himself the question can we undo this action, are we placing unneeded obstacles to potentially reversing this action. And I would think that Patrick Landais will talk about this. And also reversibility is a feature of the staged decision-making. It’s important to basically yourself the question should we go back or not each time? If, for instance, the regulator asks these questions and says, black and white, you know, “Yes, we discussed this question the first time, then the second time, then the third time, but the tenth time it comes, this is a big decision to close the repository.”

So, in conclusion, I would say that walking off a high-level waste repository site is not in the spirit of our time. Today’s relevant questions are how do we keep an eye on the repository for as long as practicable, what does it entail, who would do that, and what is the connection to retrievability. It seems to me that for advancing disposal programs, forms of retrievability are needed post-closure. Pre-closure retrievability, to me, seems obvious. So, three approaches, it seems to me, have emerged. One is the facilitated access for repair or retrieval. Then the other one is non-facilitated access but not irretrievable disposal, meaning that retrieval technology is demonstrated. Or non-facilitated access but whole containers must be sufficiently intact for potential retrieval over a mandated period of time. And, all over, applying reversibility while developing the repository, I believe, is a very good thing to do, and would pay. Thank you.

BAHR: Thank you very much, Claudio. You mentioned that reversibility and retrievability are two distinct things, but I don’t think you actually defined that distinction. So, could you amplify on that for us?

PESCATORE: Well, retrievability, as I mentioned, is, first of all, it’s a reaction. And so it’s preparing – pardon, reversibility is of an action, so allows you to prepare for retrieval. So, all the decision-making you do, all the technical decisions even, okay, are how you place your container, in which directions or the kind of buffer you put in. You always ask yourself the question, “Well, what about if I had to go back and undo this action?” So, this is an intellectual challenge.

Retrieval is of a thing, so in order to be able to retrieve this thing, perhaps you should ask yourself will it be corroded? You cannot reverse corrosion. So, will it be corroded? Will the waste form be basically destroyed? So, it’s more with the thing. And then perhaps you invent also the machinery to be able to retrieve the thing, once you’ve undone ~~; why should you even do~~ these actions. ~~?~~ So, to me, that is the big distinction. And reversibility would apply also to the regulator. They would ask themselves can we go back on this.

BAHR: Are there other questions from Board members? Paul Turinsky.

TURINSKY: From the cartoons, it looks like the cost benefit changes with time, where it becomes less favorable with time as one looks out. Has any regulatory body basically built that into their decision of whether a repository's design is adequate or not?

PESCATORE: In terms of what? In terms of?

TURINSKY: In cost benefit.

PESCATORE: Cost benefits, I don't --.

TURINSKY: Yeah, as you go out in time, that's going to change probably --.

PESCATORE: Yes. No, I'm not aware of that. I know that there are -- perhaps there were -- certainly in Finland there was an expectation that the implementer would also give an idea how much it would cost to retrieve, and probably Switzerland they have something similar, but I’m not sure it’s from the regulatory -- it’s not in terms of benefits either. I believe it’s for future societies to decide.

TURINSKY: Is that fair?

PESCATORE: If there is -- no, is it a benefit to us, then we shell out the money, but we know how much it costs, more or less. It’s not based on this -- on the contemporaneous decision-maker or regulator to make a decision based on benefits of cost abilities. Just the idea, it must provide the future generation the idea how much, more or less, it will cost, but not about the benefits.

TURINSKY: Okay, but, I mean, when we regulate nuclear reactors and decide do we have to do a back-fit, we always do a cost-benefit analysis to decide --.

PESCATORE: Yeah, but the nuclear reactor is 40 years and this thing is thousands of years. So, that is, I believe, the big difference is really the time scales.

TURINSKY: Well, I mean, the uncertainties are going to be larger, but I don’t see where time scale comes in.

PESCATORE: But I’m not aware the regulators regulate on this. I’m not aware.

BAHR: Steve Becker had a question.

BECKER: Becker, Board. Thank you for that opening presentation. I think you did an excellent job framing the issues for us. You mentioned that an inclusive decision-making system is an important factor that boosts reversibility. Could you say a little bit more about that, including the kinds of things that need to be part of that?

PESCATORE: Inclusive today is basically what the ~~[inaudible]~~Blue Ribbon [Commission on America’s Nuclear Future] said, defined in America as being consent-based ~~c~~siting, and so consent-based technology, even development. So, it’s really this dialogue. And reversibility can be, in fact, one of the basis for dialogue with society at large, not only the local community. So, it is this concept that basically we listen to everybody.

BECKER: Thank you.

BAHR: Efi Foufoula.

FOUFOULA: Efi Foufoula, Board. I really like your presentation and the metaphors you use, but I also was noting down words like “should,” “good idea,” “may,” “reversibilities in action,” “reversibilities in future,” and so forth. So, my question is, for such a very highly technical problem, and also you mentioned control, which means information, so, for such a technical, high technical problem, what is your opinion, if we were to just do it and do a cost-benefit analysis or put down all the technical factors, leaving alone institutional ones or perception or consent-based, et cetera, technically, are we more advanced than we were in 15 or 20 years ago, to say that, yes, we have complete reversibility if we wish so, and we can design it as part of the disposal, not as an afterthought?

PESCATORE: As I mentioned earlier, it’s a matter of degree that you want to build into the system, and then you certainly have to decide, with the rest of society, the kind of degree you want it to be. You can do it because you can retrieve even a repository that it is already built is not really built with reversibility in mind. I mean, I showed Cigar Lake, it’s a lot of money, but, you know, we can do it.

And I showed you that there are three ways that people think that they can do it. The Swedes, they do it. They say it’s not irretrievable, but, in fact, it is retrievable because they’ve shown the technology. So, they show it is possible. And it is a particular design. It’s a copper container. It’s a certain cost and so on. It is their own way of doing it, but the Swiss, they have this facility to access for as long as practicable. It’s different kind of costs. So, it’s really negotiated nationally. It’s the result of negotiation, it seems to me. It can be done. The quote I gave from Nirex says, you know, because Nirex probably was saying before when people were asking, “Why we cannot do this,” it was the classical response from technical people, “Oh, you cannot do this.” But then Nirex went around and says, “Well, eventually we did it.” So, you can do it.

I have an interesting quote from my old director general. He was really a hard-nosed type of technical person, and we were together at a conference, I believe it was Las Vegas, many, many years ago. Some person from the audience said, “You know, people want retrievability but they really don’t know what they’re talking about. This is going to be done.” And I thought my director general would say, “Yes, you’re right. I mean, it really doesn’t make sense.” But no, he responded, saying, “Look, I cannot even tell my son, he’s an adolescent or a young man, what he should be doing, how can I tell people in 50 years what they should be doing? So, you really should give them the possibility of going back.” So, and this is possible. I believe this is possible.

BAHR: Other questions from Board members? Do we have questions from staff? Dan Metlay.

METLAY: Dan Metlay, Board staff. Claudio, a two-phased question.

PESCATORE: Like the rocket.

METLAY: Yes. Question number one, I'd like to hear your thoughts further on the question of retrievability just for pre-closure versus retrievability both for pre-closure and post-closure, number one. And I'll wait for the second question.

PESCATORE: The retrievability for pre-closure, it's something that needs to be defined. Oh, or perhaps, I'm not sure whether you want to be normative about this, but the position how we are going to be able to do this all the time. And it was not written in any regulation that you should be able to retrieve pre~~-~~closure. So, it's a difficult thing. On one hand, people say, "We are going to be able to do this." On the other hand, there are no, as far as I'm aware, at least when I was running this project, one of the issues we found was the regulators would not wet their feet on this retrievability requirement before closure. In fact, the regulators don't like to talk about retrievability because it's not necessarily a safety concern. So, what they talk about safety, and retrievability is not about basically safety. You can claim that retrievability during the repository development is a safety issue, in fact, but there was a need to discuss this further, and there was a big hole I find. But I could agree also that technically people should be able to do this.

I will say something more. If you use the concept of reversibility, somehow where you develop your concept, and you think “Can I go back if I do this,” then, of course, you go a long way to be able to retrieve if accident happened or for other reasons during your repository development.

METLAY: So, the second part is a little different. What makes a retrievability plan credible? So, for example, as Jean talked about it in the U.S. case, there’s certain requirements for laying out “a plan to retrieve.” And if you look at that, either in the regulations or in the DOE’s license application, it’s a fairly straight forward and pretty undemanding requirement. So, the question is if you’re talking about this as being something that we should anticipate, or at least create the conditions under which retrievability would be facilitated, what makes a credible plan to do so?

PESCATORE: Well, I would think it’s the usual things, which is the plan cannot be just words, it also must also be some sort of demonstration, so technology development demonstration, and it should be also a plan that you show that you revise from time to time to see and to update and see what you have learned. So, you have to show history of learning and eventually technology which have been shown to be applicable, factual, the two.

BAHR: Bobby Pabalan.

PABALAN: Roberto Pabalan, Board staff. Claudio, you mentioned that different national programs, the concept of reversibility and retrievability range from subliminal to assumed. And in the case of Switzerland and Germany, both countries have assumed and subjected to licensing retrievability and reversibility after closure. My question is in two parts. Can you say something as to why, in Switzerland and Germany, they came to make it subject to licensing R&R after closure. And secondly, do you think it will help in terms of public acceptance or a community's acceptance to be a host site for a geologic repository if retrievability and reversibility after closure is subject to licensing, given that you gave some examples that the technology has been demonstrated to work or to be able to be done?

PESCATORE: Okay, the first part of your question I would defer to Piet Zuidema and also to Horst Geckeis. They come from Switzerland and Germany respectively. They can give you more precise answers. Perhaps they can respond right now. I'm not sure how you're running the meeting.

As for retrievability, yes, I -- it is interesting if you look at this 2010 status report, people wriggle away from responding to your question, but I believe that clearly it's -- simply France is particularly, and I can say this, it would be a bonus. People would be much more, say, prone to acceptance. Yeah, retrievability clearly keeps this continuing to be able to keep an eye and not abandoning. It's something, you know, that everything wants. But, as I mentioned, even the technical people want it, only they do not have the courage to say it.

BAHR: Nigel.

MOTE: Nigel Mote, Board staff. Would you make a comment about security with respect to the availability to fissile materials? You'll know a number of countries have looked at borehole disposal of spent fuel. One of the claims made for boreholes is that the fissile materials are not easily recoverable. As you move from that to retrievability and then to reversibility, there is implicitly more access to those materials over timeframes that we need to be concerned about. You gave the example that in Germany the containers must be suitable for retrieval over 500 years. And in most democracies, if you wind the clock back by 500 years, there's been a number of changes, which in political terms gives cause for concern. Would you comment about how this plays into plans for retrievability and reversibility?

PESCATORE: Okay. If you wind back the clock 500 years, it's true that things have changed a lot, and in 500 years from now things are going to change a lot. But in the case, for instance, certainly of Germany and Sweden that I mentioned, since the repository will be closed, it’s not really an easy access for a repository. So, from the point of view of security, it’s not a big issue, it seems to me. Perhaps it’s more an issue in the case of the Swiss, and again, you should ask this question to Piet, he would be able to talk about that.

Regarding borehole versus mined repository at a certain repository horizon level or depth, it is clearly more accept -- even if it is closed, it is clearly more, say, retrievable, the repository, than the borehole. But this is, in fact, used to the advantage of the repository in Sweden, and I would say also in other countries, and also because of all these subliminal messages that you’ve heard about. In Sweden, it is clearly written down. I mean, if you go to the borehole thing, this would not be retrievable. So, retrievability is used in Sweden as an argument, in fact, for the mined repository. So, this is all the information I have. So, clearly people have to reply this question, but, in fact, the only quote I can give you, perhaps in other countries they can give you the same one, is that I’m sure the Swedes, they say, you know, because this is a mined repository, it’s not boreholes, this can be retrieved.

BAHR: Bret.

LESLIE: Bret Leslie, Board staff. Following up the answer to Dan’s second question, which is credibility, you said two things, must include demonstration, and revise and update. For the first one, is it the demonstration of just the retrieval technology, or is it also the demonstration that the monitoring necessary to make the decision is part of that demonstration?

PESCATORE: Again, probably this should be -- it’s part of the concept that you want to sell about retrievability, yeah, it’s part of the concept. I don’t think the WIPP, they had this concept of showing the monitoring -- no, they have the land withdrawal, they have the markers on top, but I’m not aware that they had a program of monitoring so that we could prepare. So, it depends on the -- on the other hand, you know, I’m sure the Swedes will have a monitoring program, but they’re not selling the retrievability either. So, it’s really a matter of national negotiations, how people feel about the credibility of this organization or that organization. We must allow that this is a societal project. It’s not a hard-nosed technical project. We must keep this in mind. So, there must be this adjustment. Keeping, in the end, this concept of safety in the absence of man, if that comes to pass, to be the first goal.

LESLIE: So, the second part of my question is the revise and update part of your response. For a long period, let’s say the pre-closure operational period is 50 to 100 years, do you envision that you would update your monitoring capability after the waste is already emplaced, or can you explain a little bit more about the revise and update? Because, you know, the technological advances that might come about over that timeframe could inform your decision, but unless you can do it all remotely, there’s obviously a safety cost of trying to put in new machinery.

PESCATORE: It’s a difficult question. I’m not sure I’m able to respond. First of all, I think this concept of reversibility will allow you to this because perhaps this will allow you, for instance, to close the holes or the galleries and then the position areas at a later period that it would normally do. So, this will buy you time because the concept if no make it this -- not, say, rushing it is part of this reversibility concept. So, but, of course, at one point, there is a, say, a compromise you have to do. And, again, reversibility, that helps because you can say, look, this is what we did and in this time, this is why we closed, let’s say, this area, and the technology at the time was this one, and it wasn’t good enough; okay? So, we cannot go back and every time update. So, this concept of reversibility and being able to discuss when you do closing decisions I think is very important for that as well because it allows you not to say each time you have to go. What is important is each time you took a decision, you used “best available technology” at the time.

BAHR: I think we have time for maybe one more question. Is there a pressing question from the staff, or is there one pressing question from the audience? Okay, well, thank you, Claudio. We’ll move on to the next speaker.

So, now we have Patrick Landais from Andra in France, who’s going to be talking about “Reversibility and Retrievability: Governance and Technical Approaches.” And are you going to use -- do you have the microphone?

LANDAIS: Thank you. Good morning. First, I would like to thank the commission for inviting me here. I am really used to speaking in front of our national evaluation commission, which is the similar commission to yours. And so I will try to discuss about this title, which is reversibility and retrievability, and mainly the two points which are the governance, which is set up in France, and the technical approach we are dealing with.

When you are discussing about reversibility and retrievability, and Claudio said that really well, you can deal with quite a lot of discussions. You can deal about knowledge management. You can deal about memory. You can deal about ethics and how you consider the progress of science for the future, and is it one of the ways you have to deal with reversibility, what is the impact of reversibility on the decision-making progress, is it the main factor on the way you are dealing with your operating conditions and so on, and is it the main driver for your project management? So, you can speak for hours on reversibility and retrievability. So, I will try to focus on several points.

This is my first slide that could be the last slide, but, anyway, this is the general framework of Cigéo, which will be the future repository for the French high-level and intermediate-level waste that will be located in the East of France, in the clay formation, which is 500 meters deep, which is of Callovo-Oxfordian ~~[inaudible]~~ age. And as you can see here, we have different parts of this underground facility and surface facility. The surface facilities, the waste transfer and service ramps here, and here the construction and support facility with the ventilation and service shaft. And in the underground facility, two main parts, the intermediate-level waste disposal and the high-level waste disposal, and this is a view of reversibility. This is a scheme of the underground facility which has been made probably one-year-and-a-half ago. And I can tell you that the new one is not the same. This is clearly reversibility. This is clearly step-by-step progress. As soon as you are optimizing the cos~~as~~t, the safety, the progresses made by science and technology, you are changing your mind, you are changing your progress, and you make it evolve with time. And then this is typically an example of reversibility. This is a pre-pre-deposit reversibility stage.

Well, some history of the reversibility in France because it’s quite a long history and since the very beginning of the work we have done at Andra with the safety authority and with the government. Very early, as soon as the first law, which was passed in ’91, there was a request for the study of a repository, reversible or irreversible. So, we have the two choices to be made and the two ways of dealing with the repository.

From the beginning of the studies, which started after the law of ’91, we had to search site for the implementation of an underground laboratory first. And during this period, when discussing with public and at that time dealing with public acceptance -- I would say that “public acceptance” is not really the good word to take into account, it’s something else -- but at this stage there was a very important issue for public to have the reversibility included in the political decision-making process. So, during this year, during which we are siting our future laboratory, there was already some discussion with the public. After the visibility of the repository was demonstrated in 2005, we got in 2006 a law for the sustainable management of radioactive materials and waste, and the law states that the disposal, in this case, must be reversible, and the reversibility period will not be less than 100 years. So, it will be roughly similar to the operating phase. And a future law will define the condition of reversibility which was done in 2016. So, just after the public debate of 2005, the law which was passed in 2006 explicitly included the term of “reversibility” for the future repository in France.

During the years after this law was passed, in 26 to 22, there were exchanges with the local stakeholders to know their expectation about reversibility, exchanges also with the scientific community, with different symposiums and different conferences about the subject, and mainly involving -- and also involving people of social sciences in order to understand about the research, about the ~~economic~~ academic research, what could be the drivers for the reversibility. And at the end of those reflections during this stage, the emergence of two notions of different reversibility of decisions and recoverability of waste, which is close by Claudio said that we'll have two things, reversibility of decisions, which is a main thing, and within that retrievability of waste packages which is recoverability of the waste.

Well, in 2012 to 2013, and then going all the way at the public debate about Cigéo, it was not a real public debate, anyway, it was not possible to set it, but we had to decline the concept of reversibility in the form of different tools. We'll come back on tools a little bit later. And the law was passed in July 25, 2016, about the reversibility.

I come back a little bit about the public debate which took place in 2013 and 2014, which was followed by different

Andra’s proposal. We have to take the decision which commits the society for more than four generations, which is huge. And take a final decision is not reasonable for those future generations. So, we have to make the decision progressive in order to make it possible. So, this is clearly the output of the reflection since 1991 to 2016. Just to take into account that this type of thing, four generations, implied that the decision should be progressive.

So, the concept of reversibility is more and more moving towards a governance approach for which technology only provides tools to facilitate the step-by-step governance of the project over four or maybe five generations, I don’t know. So, it becomes possible to allow a learning phase because we all know that we will learn during the step-by-step implementation of the repository to give way to technical progress, because I am sure that the concepts we are designing right now will not be the concept we will implement in 70 years, for example, for the high-level waste. I’m quite sure that we will not use steel anymore in 50 years, but anyway. To enable the next generation to redirect the choices which were made before and to go back.

So, that means that every generation decides for itself, leaving open the option for the following.

So, this is the very classical scheme which has been already shown by Claudio. And here I have this definition of the reversibility capacity for successive generation, either to continue the construction and then the exploitation of the successive phases of a disposal, or to reevaluate the choice previously defined and to modify the management solutions. Whatever society will decide, even at this stage, we know that the implementation of Cigéo will be a step-by-step process and that it will be reevaluated by the safety authorities and by the government at different steps, probably each five years or each ten years. So, that there will be a gradual control implementation of the repository. There could be alternative waste management options to be chosen if relevant.

I will give you another example of pre-operational phase reversibility. Maybe you have learned that one of the main decisions of the safety authority following the safety option ~~[inaudible]~~ dossier ~~on reversibility~~ submitted in

2016 was to reevaluate the potential disposal of bituminized waste. So, we have to make something like reversibility of our [inaudible] and just to think if there could be another option concerning the future disposal and management of bituminized waste, and it’s 80 percent of the 80,000 cubic meters of intermediate-level waste we will have to dispose of in Cigéo. So, at this stage, we have to think over do we store -- dispose the bituminized waste directly, as we saw that to now, or do we modify our system of management of this type of waste packages and, for example, do we have alternative waste management options such as pretreatment.

In case of an undesired repository evolution there could be corrective action to be implemented, and if waste becomes a resource, it may be retrieved, which is not really the case in France, as far as you know. We don’t store spent fuel -- we don’t dispose spent fuel, but vitrified waste.

To do that, the main thing is to have a good knowledge, an updated knowledge of the way you think the disposal will behave during the operational phase and during the post-closure phase. It is why, since I would say 1992, 1993, in

France, we have developed what we call the PARS, which is the Phenomenological Analysis of Repository Situations. This is a tool to describe the phenomenological evolution of the disposal and the environment. So, this is also a tool which is clearly related to the way we should evaluate the necessity to change the things during the operation of the repository.

So, the objectives to describe the evolution of the phenomenological processes, which are affecting in space and time the waste disposal and its environment, so, this is dealing with many components, materials, interface, coupled processes. We have to manage six orders of magnitude in time if you are considering the post-closure evaluation and seven orders of magnitude in space. So, it’s huge. And so this is why we developed this tool, to fulfill the objective of the traced and step-by-step implemented tool for evaluating the phenomenological evaluation for a system.

And this PARS is clearly associated with -- oh, there’s something wrong here. It’s clearly associated with the assessment and the safety assessment. So, we are starting by the PARS with the detailed quantification of the thermal, hydraulic, mechanical, chemical and radiological evolution of the disposal in the geological environment, including the uncertainties, going through a preliminary assessment and then going to the safety assessment, including the safety reports. And doing that and having a quite clear vision of the evolution with time and space of the phenomenological evolution of the repository where we have the ability of defining what should be monitored and what are the main issues concerning reversibility during the operational phase.

As I told you, this reversibility is now considered in France as the enhancement of the possibilities given to the future generations to reconsider the decisions which were taken by us, and the range of choices open to the future generation. And then really we have a set of governance and technical tools, and I will come back on some of them. In terms of governance, continuous improvement of knowledge, R&D and monitoring. In terms of tools, incremental development, the progressivity of the construction, the flexibility of operations and relating time schedules, the adaptability of the different installation, the retrievability of waste packages. In terms of governance, the transparency and transmission of knowledge over time, the involvement of the society during all the process of the development of Cigéo, and the control by the state, and also the reviewer and the safety authority under the supervision of the Parliament. So, these are the main tools, both technically and on governance of what should be reversibility of over time.

Retrievability, for us, it’s only one of the tools for -- retrievability is only one of the tools for the reversibility. It has been discussed after the first talk by Claudio, but retrievability cannot demonstrate it indefinitely. You can expect that you will retrieve. The example of Cigar Lake is interesting, but Cigar Lake was flooded. So, you have to think about what will be the evolution of your geological environment in, I don’t know, 1,000 years or more in order to really evaluate what will be the mining process to put in place in order to retrieve the waste and to retrieve the waste packages, or I don’t know if it will be waste packages in 10,000 years, for example, because of corrosion and transformation with time. So, retrievability is only a tool for reversibility; it’s not an objective by itself. You are not building an underground disposal by just keeping in mind that you will retrieve the waste packages. If you do that, just use a surface storage and that’s it, and you can do that. We have to say that the real meaning of having an underground disposal is to have a permanent structure in order to manage, over time, this type of waste.

There was also discussion about cost, and the retrievability does not imply high cost if it’s considered in the design phase. If you consider within the design phase, which is in the law in France, you have to include into the design phase all what is related to reversibility. Well, it’s within the cost, and I could not tell you which is the part of the cost of Cigéo which is strictly related to reversibility or retrievability. We have to take into account the retrievability from the very early stage of the evaluation and, well, it’s few percent of the total cost. So, it’s two to ten million Euros. The cost for retrieving will have to be supported by the generation, which we’ll make the decision for. And it does not need to be provisioned by the present generation, which is also an important thing.

The retrievability also, as I told you, there is no intended use of the waste which will be disposed of in Cigéo. Most of this waste comes from spent fuel recovery operation, and the recoverable part has already been extracted. Our generation plans to dispose waste in Cigéo without the intention to retrieve it later. This is associated with European directive from 2011. Cigéo is designed to be closed, with the dismantling of equipment, with backfilling, with seals. And the closing operation, obviously they will naturally increase the level of the effort to be made in order to go back and to remove waste packages. Then the recoverability, so withdrawing the packages, is not viewed as an end by itself, it only makes sense when associated with other tools of reversibility and when it contributes to it. For the flexibility offered to the operator, and also for an improved knowledge and ability to redirect all or part of the waste to another management facility. I don’t know why, for example, for treatment of [inaudible] waste as I discussed already for the bituminized waste.

Obviously, there are some impacts on the disposal concepts from retrievability and reversibility. This is a commitment, as I told you, of Andra following the public debate of 2013 and then the law of 2016. And the main design option on which retrievability is based are the robustness and the durability of containers, cells, equipment left in place in the cells. Of the monitoring of retrieval condition, availability of functional clearances, monitoring condition in the cell, and the different components of the cell. The performance of the equipment for retrieval operation on design basis and also on evaluation of this retrieval operation in penalizing condition and the ability to deconstruct Cigéo partial closure equipment, design ability to deconstruct closure structures, and to reequip later the installation. So, all this these occurrences are studied by Andra because it will be part of the licensing files to be provided to the safety authority in 2019.

There are also incorporation in the design of Cigéo some preventive provisions, reservation of space in the handling cells to install specific equipment dedicated to retrievability, reservation of areas on the surface for the construction of building possibly necessary for hypothetical scenarios of retrieval, and specific and necessary operation on the assumption of possible retrieval, training staff, specific controls, information management such as cartography and so on, and the periodic reevaluation of retrieval conditions. For example, here, we are preparing a material library for the future in order to have the zero state of the material we are using in Cigéo for the future generations if they would like to know what was initial material which was used to construct several components of the Cigéo.

So, for example, these are the different location on the surface facility which are dedicated to retrievability. And these are some of the operation -- I will not go into detail -- on the technical operation and the equipment, waste packages, disposal cells which allow to facilitate package retrieval. What we intend to do is to use the same system which allow the waste packages to be inserted in the cell for retrieving it and, for example, to transfer it back to the surface.

For example, in the high-level waste cell, which are here, which will be probably 150 meters long, the liner, which is here, maintains a gap around the waste packages, making the retrieval easily if decided. And, for example, we have made a surface demonstration in a system which is very close by the system we used in the underground. And just using saline mist in order to provoke very fast corrosion of the waste packages and also of the liner, and then, after this very extensive corrosion, tried to remove the waste packages, and we were able to do it with the same equipment that was used to put it in place. And we made a small movie of that. It was really impressive to see the amount of corroded steel which was removed from that, but, anyway, we were able to retrieve the waste package. And then also, in order to limit the corrosion of the waste packages but also of the liner, there are specific studies, features and studies to tie the assembly of the liner and to try to have a low chance of ~~the~~that after waste emplacement.

We need also some ~~study~~ stability within an evolving environment. The development of the project is very progressive, as will be the construction. And this progressivity implies the concept of reversibility, providing the possibility to retrieve already disposed radioactive waste packages and allowing a gradual and controlled implementation of the repository. It also offers opportunity for adaptability, optimization, technical and cost optimization, flexibility, for example, one way or another, the policy in France is to stop the nuclear production of electricity, and then probably we will have to dispose of directly some spent fuel which will not be re-treated in ~~the [inaudible]~~La Hague. Testing at scale one, we will have an industr~~y~~ial pilot phase at Andra which will last probably ten years. The ten first years are for the exploitation and the operation. Obviously, monitoring, and implying next generation in the decision process, letting them a burden with already available solution but also with the freedom to develop their own solution, and also making funds available.

Well, when you offer all those opportunities, we are facing some issues, and at least one issue. The opponents tell us okay, you know that you will have to optimize, you'll want to be flexible, you know that there will be scientific and technical progresses in the next 20, 30, 40 years. Why are you in a hurry to develop a repository? Just let the future generations think over, just let the future progressions of science provide you more efficient, more safe solutions, and wait for that. Just have a surface storage for all the waste that is produced and then let the future generation decide with the progresses. We are not in a hurry. So, when you are developing the governance of reversibility of quite a long term, you are facing this type of opposition. And technical is not that easy to understand, and it's mainly a political decision at that stage.

We are to prepare the decisions together and to organize the link between generations. So, the geological disposal will be under the control of society, with a regular review of the operation. There will be appointments with all actors, the residents, the community, the reviewers, the State. There will be consultations on the basis of safety reviews, on monitoring, on technical development, and probably the first meeting point will be proposed ten years after the commissioning of the repository.

There are some implications of reversibility. The monitoring of the disposal, cell, and waste package behavior, and the long-term memory-keeping. There are also technical requirements on the operational life of the repository and the minimization of additional cost. But there are opportunities for the flexibility of future policies, for example, as I told you, stopping the production of nuclear electricity in France, and the integration of new technical development. So, as I talked previously, is it an end of a contradictory debate between surface storage and underground disposal?

So, these are the main objectives of the monitoring of Cigéo. We have to check that the installation remains in the nominal operating range, and we have to identify any possible change in the installation likely to bring the installation out of its nominal operating range. So, we have two aspects, the classical monitoring of a nuclear facility for the worker safety and also the specific monitoring which is associated to radwaste disposal specificities. They have to support the retrievability of radwaste. They have to support the assessment of the consistency of disposal of system state, the different components during the operation, with what we expect from the post-closure functions.

So, for our licensing ~~slides~~files, which will be provided in the end of 2019, we have to define a preliminary monitoring plan and to assess the capability of the monitoring system to fulfill its functions. So, as I told you, we will have an industrial pilot phase around 2025, maybe a little bit later, it will depend on the decision process, which will be the first type of Cigéo before the authorization of progressive and complete operating. And as you can see, during this stage, there will be a very large monitoring process that will measure all the parameters, and the monitoring, which will rely on part of the components of the underground installation.

So, for example, here, this is the monitoring we are expecting and we have already put in place on the disposal cell for high-level waste to check that the favorable properties of the Callovo-Oxfordian formation are preserved in terms of temperature, pore water pressure, stress, strain in boreholes and around the disposal cell. We have also ~~put~~ to check the evolution of the metallic sleeve in order of functional clearance and corrosion progressive, and also to check that the post-closure safety function to protect the waste from water are preserved. So, we will have to measure the mass loss of metallic ~~compounds~~coupons, the gas composition into the disposal cell, and mainly the production of hydrogen, the temperature and the hygrometry and the liquid water flow.

So, these are different monitoring techniques we will have to use, Lidar, for example; robots for viewing the underground infrastructures and waste packages, and, again, trying to evaluate the different aspects of the evolution of the repository.

As well, there is something really important. Most of the countries which are involved in the disposal project, they have operated for several years and maybe more than 20 or 30 years, in ~~work~~ our case~~s~~ it's more than 50 years, URL, this is the layout of the French URL in ~~Meuse~~Bure, and we have 25 different technologies which are imposed in the URL. There are a lot of physical parameters which are monitoring. We have more than 10,000 operating sensors ~~cells~~ in June 2017, 1.6 billion of data recorded every day in the database, and three billion of data already recorded in the database. So, keep in mind that when we are starting, all of us all over the world, when we are starting a repository, we have also the experience of a very small repository without any waste in, but with a lot of experiments which are the URL, and they are providing you a lot of data on the efficiency of monitoring, the necessity of monitoring for your future repository.

So, summary, the ethical concerns for reversibility originate in the time scale required to manage the most harmful radioactive waste and especially for Cigéo the century-long service life. The cost of technical measures taken to ensure reversibility is factored into the project already, meaning the current generation are providing future generation with Cigéo option for acting on the disposal process. But should future generation decide to exercise this option, for example, to modify the repository to allow the emplacement of a new type of waste, for example, spent fuel, or remove waste packages, they will have to take the responsibility of their decision, and also in terms of cost.

The “incremental development” of Cigéo gives future generations the possibility to accelerate or delay the construction and the operation of Cigéo, and it promotes the inclusion of future phases of construction and all improvements made possible throughout the scientific progresses. And more particularly, the optimization opportunities that have already been identified but which have not yet been included because they don’t reach a sufficient degree of technology will be provided in the license application. And if the licensing is granted, they will be integrated later into subsequent stages of the project.

So, as I told you, step by step, the operational flexibility gives to generations the possibility to delay or accelerate. The adaptability of Cigéo and its specific designs mean that it can be adapted to the spent fuel waste disposal. And the retrievability gives future generations the possibility to consider the decision to use the deep geological disposal as a way of managing all or part of their waste packages. Thank you very much.

BAHR: This is Jean Bahr from the Board. You mentioned at the very beginning that the diagram that you showed of the Cigéo was already outdated and that there have been modifications to the design. What are some of the things that you have learned that led to the recent modifications?

LANDAIS: Well, for example, we have shown that for optimizing the cost, the use of a tunnel boring machine, the more extensive use of a tunnel boring machine will be really helpful. And then we have modified a little bit the way of excavating the intermediate-level waste zone in order to be able to have more extensive use of the tunnel boring machine, which is associated with also the liners to be put on the Callovo-Oxfordian formation and which will be much more easy for the future.

The other thing is also that to know the lengths of the high-level waste cells was 120 meters, and we were able to expand this len~~s~~gth to 150 meters. That meant that you reduce the number of cells where you have to dispose of the vitrified waste packages. So, those are two examples. There are others that make the -- well, the overall thing is the same, but when you are coming into details, there are step-by-step optimization, which have already been done.

BAHR: And then the second question, you did a nice job describing the variety of monitoring that’s going on and that you anticipate, have you talked much about what observations during monitoring might actually trigger a decision that you need to retrieve the waste, or is that left to the future generations who are going to have to make that decision?

LANDAIS: Up to now, we have some variation which are allowed below or above the reference evolution of the repository. For example, if the corrosion ~~e gene~~rate of the steel waste packages is higher than expected, you will measure a higher production of hydrogen because it’s anoxic corrosion. So, for example, just an example, this type of monitoring is very important because it can provide you data which allow you to define if the evolution of a major component of your system is the same as you were expecting, or if there is a deviation compared to the expected evolution of your system. It’s also the same with the evolution of the EDZ around the main excavation. And if you can see that the creeping rate is not what you were expecting or what you have measured in years and years in the URL, so there will be something important that can make -- that can impose an evolution of your design, yes.

BAHR: So, how do you make use of those observations if, for example, you see that there’s a higher level of hydrogen production or a greater creep rate? Does that then go back into your safety assessment model?

LANDAIS: Yes. Yes, that will be the case. It’s why the safety evaluation will be reprocessed every five years. It’s already what we are doing right now. It’s what we will do later.

BAHR: Thank you. Other questions? Efi?

FOUFOULA: Efi Foufoula, Board. I wanted to follow on the same question. I mean, the billions of data that you mentioned, this is impressive. You mentioned six orders of magnitude and in space, seven in time, or the other way around. So, in terms of using this data with information technology, I don't know what, in the last 15 years a lot has been done in extracting knowledge from data. So, are you happy or you see more potential or need to develop that part of the whole process?

LANDAIS: Okay. I would say we are happy, but I am sure that there are a lot of improvements to be made, for example, for the sensors, and we are quite confident with that. If you are going back 20 or 30 years ago, about the size of the sensors to measure something, and if you are looking at the size of the sensors which are available right now, that are efficient operating sensors, there is a factor of ten, and sometimes a factor 100. The sensitivity of the factor has expanded. So, there are a lot of progresses which are done right now with very robust sensors which allow us to have a more distributed measurement of what we need, for example, around optic fibers, and a less intrusive effect of our monitoring system, which is a very important thing in the whole aspect.

For example, there is something extremely important we deduced from the experiments which were conducted during 15 years in the URL, it is a creeping rate. We have measured that the creeping rate is quite high during one year, and then it is very low, and now we are even not able to measure it with the valuable sensors. And the second thing is that the creeping rate is not related to the size of the excavation you are making. That means that you have not different processes which are involved when you are excavating a small borehole, a larger cell, and a big cell of nine meters in diameter, for example. The processes are the same. The rates are the same, that allow you to have a good confidence on the way you will be excavating the different infrastructures for Cigéo, which can be 89 square meters in section. So, these are two things which are extracted from those billions of data that which are important. For example also, you can say that for the diffusion, which is quite a simple phenomenon in clay minerals and clay formation, where all of the experiments we have made on small samples and larger samples, they are all consistent that you could say, okay, we have the diffusion coefficient, that's it. Well, we did it in situ for years, and the data we have extracted from those diffusion experiments, they are perfectly confirming the data which were obtained from data samples. And what is interesting, and I don't know if ~~people~~ Piet will say that, is that the data which were obtained in Swiss in their URL and on their samples are also the same. So, both what we are doing at different scales and what doing our colleagues at different scales are absolutely consistent. And for a major process such as diffusion, it's very helpful.

FOUFOULA: Okay, just to clarify, so you are merging this data or ~~coupled~~ coupling this data with a modeling exercise?

LANDAIS: Yes. Yes.

FOUFOULA: Of course, and you use them at diagnostic tools for the things that you mentioned there in other also conditions outside the ones -- so, what I try to understand is, of course, I have a system A and I monitor, I know my processes, I do my physics-based modeling, I have my data, and I learn about that system, but are you able also to extrapolate, as you said, that there's suppose the size of the containers was different, excavation, et cetera, so you are doing scenario outside the current condition based on the data that you learned?

LANDAIS: Yes. For ~~more~~ most of the component of the future repository, we were able to test it at scale one within the URL. So, we are very close from the very realistic things. But, for example, for the seals that will be made in bentonite, we have just a small -- I would say small seals in the URL, and we will have to build a real-size seal as soon as the pilot phase in Cigéo in order to test it and in order to prove that we're able to build it and around.

FOUFOULA: Thank you.

BAHR: Other questions from the Board? Question? Paul.

TURINSKY: Turinsky, Board. I'm not sure I know how exactly to phrase this question, so it could be hard for you to answer if I can’t figure out how to ask it. What are the implications of an approach where one has a long-term operation of a URL gathering data, characterizing the media, characterizing operations that are required, and equipment, versus one very short operation of a URL, and then learning, as one is actually filling, doing placements in the repository?

LANDAIS: I think it’s two things that are working together. I think you cannot oppose what we are doing in the URL and what we will do step by step into the Cigéo project. There is one thing we will do. We have to know the authorization, to operate the laboratory until 2030. I don’t know if we will be authorized on a financial standpoint and technical standpoint, and I don’t know to operate the URL during 30 years again ‘til 2060 or so, I don’t know, but we are really expecting to be able to do that because we really think that the URL will be forever an excellent tool to help you defining the optimization you will have to implement in Cigéo for the future. Let’s say for example I’m quite sure that we will not use a steel, not for the waste package, but, for example, for the liners, and maybe we will have composite material in the future that will be highly resistant, highly efficient, non-corrodible, which will have no interaction with bacteria or no reducing properties or oxidizing properties with the geological medium. And I'm quite sure we will not test those type of new sleeves and new liners into Cigéo without testing them first into the future URL. So, I really think that progressing together with a URL for a scale one or scale 50 percent of the different components together with monitoring the real equipment of components of Cigéo have two excellent tools to go further around and to test the technological progresses we could make in the future.

BAHR: You mentioned --.

LANDAIS: And the other thing -- excuse me, last thing. With the URL, you can have the public; in Cigéo, no.

BAHR: You mentioned that you I guess currently have authorization to continue operating the URL through 2030, is that correct?

LANDAIS: Mm-hm.

BAHR: So, the funding and the stability of that research program is independent from the decisions that are made every five years on whether to continue, is that correct?

LANDAIS: One day ~~When the~~ [inaudible] it will be linked, but, at this stage, no. We have the authorization until 2030.

BAHR: Do you anticipate, at the point that you start operating on the sort of every-five-year decision process, that that could interrupt monitoring or development activities associated with the URL? Is that something to be concerned about?

LANDAIS: I have no answer to that. As a scientist, as a researcher, I would say no, we will have the URL all along the operation of Cigéo. But I think that one of the things we're trying to do for the future is to open the URL to other purposes than the one repository of waste packages, and to open it more widely to science in general. So, it's what we are trying to do. Already our URL is a training center. So, we expect also that the actual URL will become, step by step, a quite large scientific facility which could be open to quite a large number of purposes, besides our direct purpose.

BAHR: I think I saw Sue ready to ask a question.

BRANTLEY: Sue Brantley, Board. I’m thinking about all these sensors that you have running, which is really impressive, and all the data that it’s generating, which is impressive. And then I’m thinking into the future, you know, if you actually got this repository running and all the sensors and all the data. And then I’m thinking about, you know, I work with the state in Pennsylvania where we have fracking going on, and all the public demand for data, and all the data that’s being produced, and then the difficulties the state has in getting that data not only out to the scientists but also out to the public because the formatting can be different in those two cases. You know, the scientists want big volumes of data; the citizen, they don’t really know what they want sometimes, but they need access in a different way. Have you thought about what you'll do in terms of getting data for the public, how much of the data will be public, how can you build things for the public to access data and think about data versus science? It just seems like a really hard task to me. It that something that you've thought about?

LANDAIS: It's already on our task because --.

BRANTLEY: Already what?

LANDAIS: It's already on our task because the data we are producing right now should be public, all of them, because we are a public body, and our technical data should be available. So, and the public -- well, some organization asked us to make our different data available for everybody. Besides this, what I show on the phenomenological analysis of repository situation is quite a good way for integrating the large amount of data we are producing. The thing is that we have to integrate those data into models and to provide to the public the models by themselves. So, very simple models just to show them that we are able to manage the scientific results, to use these scientific results into the models and to demonstrate the safety. So, it’s a step-by-step change, the data, the qualified data, then the data used for the modeling and the phenomenological modeling, and then the safety evaluation, which is a more simplified model than the phenomenological model, and all that based on experimentation. This is the overall thing that helps us to have a communication to all the public and to be able to explain to the public what we are doing, but it’s not an easy task anyway because the demand of the public is already progressing on all these environmental aspects of our society, and the nuclear waste is a major one. So, we are working a lot on that. We have a surface observatory of the environment, and it’s very important to be able to take the public, to make them visit while what we are measuring in the environment that is safe to have a zero state of the environment of the future Cigéo, and just show us what we are measuring and why we are measuring those types of data. The “why” is maybe more important than the result by itself. We have to demonstrate that what we are doing is a good thing and that we are able to explain why we are doing that and why we are not doing something else.

BAHR: Tissa.

ILLANGASEKARE: Illangasekare, Board. So, you mentioned that you are measuring the diffusion -- it’s more of a technical detail question, you have mentioned the diffusion coefficient and the diffusion coefficient you’re measuring in the lab, and t~~w~~hat matches with your measures in the field. But when you look at the system, eventually you have to look at the whole system operation as a whole system. So, are there any ~~of the~~ measurements you had to make ~~and~~ that operate in the larger system -- so, for example, you mentioned fiber optics which can get distributed sensing. So, are there any other measurements you had to make in the larger system w~~e~~hich may not necessarily upscale from your lab -- your pilot~~rior~~ scale?

LANDAIS: Well, you know that the lab -- in the lab, you have an underground surface of something like four square kilometer, and the Cigéo will be an underground layout of something like 20 square kilometer, which is just a factor of ten. It’s nothing. So, for example, the THM behavior of the clay formation which have been experiment in -- well, let’s say mini cells comparable to high-level waste cell, there is just a factor of ten in size, which is nothing. So, I think that the data we are obtaining at this scale in the URL will be extrapolated quite easily to the real scale of Cigéo.

BAHR: Any other questions from the Board? We have about time for one question, if we have a pressing one from the staff. Bobby.

PABALAN: Roberto Pabalan, Board staff. The sensors that you have used for the URLs, can these be applied also to a repository for spent nuclear fuel when the temperatures and radiation is going to be much higher?

LANDAIS: Yes. Well, the first goal of the monitoring system we are operating into the URL is to demonstrate that those sensors will be applied to the overall situation in Cigéo. And for the temperature measurement, yes, we have sensor which can measure higher temperature than the temperature which are expected. But, well, whatever we are disposing into the future Cigéo, for example, spent fuel, we have a limit in terms of temperature, which is 90 degrees at the contact of the Callovo-Oxfordian formation. So, whatever the future waste packages will be, including spent fuel, we will have to respect the 90 degrees Celsius parameter.

BAHR: Okay, well, we’re right on time. We’re scheduled at this point to have a 15-minute break, so we’ll reassemble at ten minutes after 10:00. Thank you.

BAHR: Okay. Well, welcome back. I’m trying to keep us on schedule because we do have a very full day. Our next presenter will be Piet Zuidema, formerly of Nagra, the Swiss implementer agency, and he’s going to be talking about “The Role of Monitoring in the Swiss Disposal Program.”

ZUIDEMA: So, thanks a lot, Madame Chair, ladies and gentlemen. I’m happy that I can talk to you about the role of monitoring in the Swiss program. So, these are the questions that have been asked to me. I will address all of them in my presentation, and starting with this one. So, the relation of monitoring to safety and repository implementation, so, monitoring is a real key source of information for the safety case. And the safety case is a key element for the stepwise decision-making in the Swiss disposal program. So, in that sense, one can say monitoring plays an important role in all phases of the disposal program.

So, monitoring is used in the early phases to get regional information to assess geological stability for site selection. It’s part of RD&D; that means it’s used in long-term experiments in URL, in the lab, and that also includes experiments to evaluate host rock suitability. Then it will be used as part of site characterization in the in situ URL, and then it will be part of surveillance of the performance of the repository system once it’s implemented, looking at the site, the disposal rooms, but also specific long-term experiments at the site and elsewhere.

I think it’s very important, so, monitoring results need interpretation, and results of that interpretation may require action. And that means you have to have flexibility and have to have options to act, and retrieval is one of the options, besides other.

So, I'll now go quickly through all the different elements. Let's start with long-term stability. And I think here you have to be aware where Switzerland is. Switzerland is in the middle of Europe. We have a wonderful landscape, the Alps, and there are good reasons for that, that's the geological setting, that means we are at the interface between the Eurasian plate and the African plate. There's the so-called Adriatic indenter that pushes into the side of Switzerland, and that has led to the formation of the Alps. And that means we have tectonic movements, uplift, erosion, and then we have differences in the tectonic activity, and you see it here, uplift. If you go from north to south, you see differences. And if you look at [inaudible] you see differences. And that means that we also do monitoring. This is uplift. And here, what you see is the result of measuring series for more than 100 years with regional high-level precision leveling that supports other geological information that really shows that uplift in the Alps is bigger, or, even more important, that uplift in the northern part of Switzerland where we will put the high-level waste is small.

Similarly, with looking at seismicity, there we have historic information, but then we have the measuring series. And also by monitoring and looking at it, we can confirm that actually the siting regions we envisage in Northern Switzerland have the quality we want.

Now we move to RD&D, monitoring and RD&D, and there we have heard it from Patrick Landais, our URLs play a very important role. This is from the very early phases when we still looked at ~~crest~~ crystalline, you see migration experiments. So, we have a well-characterized feature, a structure with injection holes, obstruction holes. And there we did a long-term experiment. And what ~~we~~ one did monitor was the breakthrough of tracers, and that was the news by models, blind predictions to see if we actually can capture that. And you can see here we can very well capture that. So, again, monitoring used to get information.

And I want just to point out a few things. If you only make a single measurement, for example here, they don’t fit. And if you only would have that one instead of the whole series, then you would be wrong. So, I think it’s very important, monitoring has its reasons why you do it. You really see does it fit into the overall picture or is it an artifact.

We have done several things like that. For example, for our clay host rocks, so the question of cells, sealing of the excavation-damaged zone, again, a series of measurements. I’m not going to go into details here.

Then also for corrosion, as an example, and here you see, again, the same. If you wouldn’t do monitoring, that means that you have a long series of measurements. You would just look at the individual points would be really misleading. So, I think it’s very important that you take the series of measurements because you always have outliers due to artifacts in your measuring devices. So, I think that’s an important point to recognize.

One of the experiments we have started to implement or implemented a few years ago is a one-to-one representation of the disposal tunnels for our high-level waste repository in the rock laboratory of Mont Terri. So, it's a one-to-one replicate. It's not real waste in our heaters, but this gives us an indication what you actually can measure in situ.

It's heavily instrumented. I'm not going to go through all the parameters, but I just can say we have instruments for whatever, more or less, you want. And that includes, for example, also fiber optics, et cetera, where you have here~~tier~~ one example where you see the temperature evolution as a function of time.

Okay, with that, I want now to move to the major part of the talk of today. So, monitoring is part of repository surveillance. And I think here you have to be aware of the background. So, what we have seen in Switzerland, and I think that was worldwide, there were very early on already proposals for alternative concepts to geological disposal. Started already in the seventies if you look into the literature, and that means that concepts where the main emphasis was on ~~the~~ monitoring and retrievability, and that ~~it~~ did lead at that time to concept with much more reliance on societal control. Keyword would be “nuclear guardianship.” That was pretty prominent for a while.

In Switzerland, these concepts, at that time, found some support by some of the NGOs, and then when, in the middle of the 1990’s, we had to start preparation of a new energy act. Then an energy dialogue working group with pro- and anti-nuclear representatives were put together, and they had also to address these fundamental aspects of nuclear waste management. This group did not reach any conclusion. There is a report by it, but anyway, we couldn’t agree. And then the government decided to implement an expert group on disposal concepts for radioactive waste called EKRA. And EKRA got the job to compare different concepts and then to come up with proposals. And in their mandate, the question was that they had to address safety, active safety, passive safety, monitoring, and control, and retrievability. And EKRA’s basic ideas were then afterwards implemented in the law, and you will hear about that now.

So, this is a scheme with the broad concepts evaluated by EKRA. So, the starting point for all concept is interim storage, and then one thing is you keep it at the surface, that's what the nuclear guardianship people would like, or you can go deep underground, and you have a whole range of options. And I'm not going to go through them in all detail, but it's important, so EKRA took a broad view. And as I said, they looked at it and assessed it with respect to active and passive safety. Passive safety means that if nobody looks after, it's no hazard to the environment, whereas if you have active safety and active measures stop, then you will have a safety problem. Then monitoring and control, retrievability. And the result they came up with, you should just combine them, have passive safety with reversibility or retrievability.

And the concept proposed by EKRA has the following key elements. First of all, retrieval should be feasible without undue effort up to the final closure of the repository. Measures should be taken that allow control and surveillance during operation and the observation phase. ~~Its s~~Specific measures and the measure that they then proposed was the so-called pilot facility, but, on the other hand, they felt that it’s very important to have immediate passive safety by backfilling and sealing the so-called main facility where nearly all the waste is in. So, this is the basic concept, and that went also into the law. And you see here the major point of it. So, it says that monitoring of the repository during operation and an observation phase must be implemented. Retrieval should be possible without undue effort until the end of the observation phase. But very important, the measures we take for monitoring and retrievability, they should not compromise passive, long-term safety.

So, the elements of the repository, now four, a main facility with a high level of passive safety and nearly all of the waste is in that main facility. A very, very small amount goes into the pilot facility. So, the main facility is where the waste is. And you get this high level of passive safety because you continuously backfill and seal the disposal rooms. No specific monitoring measurements there. And actually we have also assessed that, so if you abandon the repository with closed disposal rooms, you have already a significant level of safety, actually it would meet the safety criteria. Then we have a test facility, you could also call it an in situ URL, to further investigate safety-relevant properties of the host rock and technology before start of operation, but also during operation you can investigate further issues, for example, related to closure.

The pilot facility is the instrument for in situ monitoring of the real facility. It monitors the behavior and performance of the waste, the backfill, and the host rock during operation and the observation phase. And the data that are collected in the pilot facility should support the safety case for closure of the repository. And that, however, means that transferability of the information of the final pilot facility to the main facility has to be insured, and that means that the layout of the pilot facility has to be comparable with the main facility and that also representative wastes have to be put into that pilot facility. However, it’s also said that we can do additional monitoring in other places in the repository, but also elsewhere, and that for sure also includes continuation of regional monitoring of the geologically mined.

Then it’s clear that we also have the option to use the test facility for dedicated long-term experiments that are complementary to the pilot facility, and the reason for that you will see in a minute.

A good example of such a pilot facility is, as I mentioned, the so-called FE experiments that we implemented in the rock laboratory in Mont Terri, and there we have now the possibility to check how that works. One should say operation of the Swiss high-level waste repository is only expected to start in the year 2060. So, looking at this for 30, 40, 50 years, we have even more data than Patrick Landais. So, in that sense, we will compete with one another.

Okay, now let’s go to monitoring in a bit more depth, and this is really for the Swiss situation in Switzerland, but I think that applies also to the others. Monitoring, or we say in a way “control,” “have it under control,” that consists of technical and societal components. On societal, you could also say it’s our institutional components. And the technical one is more what can be measured, whereas the institutional or societal one is more who is involved in the measurements, in the interpretation, and in the decisions on potential actions.

Measurements in the pilot facility must be meaningful as indicators for system performance, and there we see the limitations. That means the parameters must be measureable and directly or indirectly be relevant for safety. And you will see it later, unfortunately, there are not many of them, and that means that parameters that would be relevant but cannot be measured in the pilot facility, that we should do experiments somewhere else. Now, measureable in the pilot facility, what are the key factors? First of all, when is this relevant phenomena occurring? And that you can derive from physics and chemistry. Then the next thing is can you really measure it with the sensor, is the performance of the sensor adequate to actually capture it. And then we have phenomena, but actually they become only safety relevant after breaching of the canister, that means the earlier transients are not that important, it's irrelevant at that point, and that's often pretty close to steady state, but that is ~~for~~ far in the future. So, in that sense, it's not so easy.

Now, relevance, what is relevance? That is derived from safety. It's very similar to what Patrick Landais said, that comes from a phenomenological description analysis but that is also complemented by modeling tools as analytical instruments to check what is important, what's not. So, by means of sensitivity analysis, we find out what is actually decisive for overall performance of the repository.

Now, if we looked at the phenomena that we happen in the nearfield of a high-level waste repository, you see in blue that are the ones that we have a potential to measure, that means we will see the immediate effects from excavation. We will thermal loading. We will see something about desaturation and resaturation; then that affects the bentonite, if it resaturates, it starts to swell. And probably, probably we will see somewhere some start of corrosion of the canister on the surfaces, but that is even less likely. And you see it here the temporal evolution. So, in green is what happens due to operating the repository. So, it’s construction, waste emplacement, monitoring, and then sealing. In Switzerland, it’s not really defined how long it goes, but the current thinking is it’s about a hundred years, probably slightly more, probably slightly less. We don’t know.

We will, for sure, see the formation of the EDZ. We will see initially that we have oxidizing conditions. Probably towards the end we see that they become more reducing. We, for sure, see temperature increase due emplacement of the high-level waste spent fuel. We will see something about changing in water content, but real sealing will only be much later when you have full saturation. Corrosion might start, but until you really get breaching of the canisters, that will be very, very far in the future, probably even much longer, depends upon what material you’re going to use. And that means movement of any radionuclides out from the waste form into the bentonite or even further into the host rock, that will be very far away in the future. And so the conclusion is, with respect to overall system performance, not that much can be measured. If, let’s say, overall system performance cares about how nuclides move or don’t move, then we won’t see too much, or nothing at all.

Okay, so that means monitoring of the overall repository performance in a direct manner is not possible, and only a few relevant phenomena can be captured by monitoring. And the reason is that the time needed for resaturation of the emplacement rooms for canister corrosion and canister breaching for the start of waste matrix dissolution and the release of nuclides into the bentonite, out of the bentonite, into the geosphere is by far too long. And actually if you talk to society, they are interested in all these nuclides, they want to prove that they don’t move. And if nothing happens, you know, that’s a bit disappointing. And one also has to say that for the conditions you have, so it’s the steady-state conditions that are normally relevant for safety, and they’re also not reached within these timescales that allow monitoring the pilot facility. However, we will see strong transients and they can be captured, and that’s at least something. So, in that sense, the conclusion is, from the scientific point of view, if you want to monitor phenomena that really capture containment, retention, slow release of radionuclides, there is a need for additional specific experiments, and they can be done in first generation URLs, so independent of the site, for example in our case in Mont Terri, or dedicated experiments at the site.

Retrieval, I think retrieval during operation is just good engineering practice that you have to have. You know you will have deviations in emplacement process that can happen. You have to take corrective actions then or you find out later on that the production something was not right or whatever makes it necessary. So, during operation, that was always foreseen. In the observation phase, we are asked to get there. The reasons can be monitoring something, somewhere, or changes in the external environment. I think, for example, new findings in science and technology, nothing to do with our URL or with our site, but it’s just progress in science, or society wants to have something different. So, there are many reasons why one could think about that.

We also see that, after closure, it’s still possible. We have heard that although this morning the effort will just increase because you have to have access, et cetera.

So, to summarize, it’s possible to retrieve the waste if this is decided to be necessary. And then, in Switzerland, we really came to the conclusion the reason and the justification to retrieve, that’s not up to us today; it’s up to those that take the decision. And we came also to conclusions that, in that sense, we do not, today, have to find the reasons why to retrieve. So, I think we should just be open-minded. We should give the possibility if it’s used. That’s not our decision.

This you have seen before. So, it’s the different stages, and also our interpretation is pretty the same, but I anyway repeat it. So, I think, first of all, the effort for retrieval will go up the further you close the repository. That’s the bad news. But the good news is the level of passive safety increases the further you go with closure. And also the further you close it, the less is the burden on future generations. And there I think one has to watch out.

You know, we see it, people lose interest. People lose the capability to do something. So, if you leave it open, there is a risk that final closure will not have the quality what we want because people just are not interested. For example, in Switzerland, we have no mining history, nothing at all, so, you know, the specialists will be gone. And so, in that sense, I think it’s really important to find the balance between, you know, how much, how far down the road do we want to get now with people that know it, and how much do we want to postpone and give to future generations. Then the next thing is how much passive safety do we want to have, and then the third question is how much effort is acceptable for retrieval.

Now, as we heard this morning, what is very clear, planning for retrieval makes actual retrieval much easier. And very simple things can help, just good packaging, thinking about space, et cetera. I think the real implementation we see differences, but it’s very clear it helps a lot if you think in detail about how you have to do it. And actually, in Switzerland, to get an operation license, we have to have the equipment and we have to demonstrate how it works. So, it’s not paper job, it’s a real job. And actually that work is complemented by a cost assessment, what it would mean if you have to do it. In that sense, you see if it’s really practical.

Okay, now society and monitoring and retrievability. A very brief summary. I think, you know, will the repository be safe for the required timespan? That we only can answer by arguments, and that includes modeling. By monitoring alone we cannot get the answer to that question. But, nevertheless, the question is always there. I think you measure what the models predicted, and so, in that sense, we have to make sure that we have performance indicators that are relevant for that, the question, and that can be reliably monitored. So, they have to be relevant for safety and monitorable, and that leads to dedicated experiments. But, on the other hand, I think you should be honest, society must be aware of what can be done and what not. There are strengths of monitoring, but there are also inherent limitations.

Retrieval, I think that's what we see, at least in Switzerland. In a way, it's found to be good engineering practice, and, you know to know that disposal is not irreversible really gives a good feeling. People say, "Okay, at least, you know, they are not overconfident. They're humble," et cetera. So, they at least say about if it will be needed, it could. And I think it's also clearly a consequence of monitoring that we are able to act. But I think it's also very important that we are very clear about the robustness of the system, and I think we should design for robustness. So, even if there is a small deviation, that does not mean that we have to retrieve it. And I think that's a thing we have to make very clear first on. You know, we are going to build a repository that can live with deviations because it cannot predict everything perfectly, but we should clearly say what is the margin where we can safely operate.

So, our conclusion is that one should start the dialogue on monitoring and retrievability with society very early on. That's what we have done. And then also be clear about the decision-making process. And actually one can say, in the broad sense, with the current legal framework, we could handle that, although it’s not explicitly addressed, but we could handle that.

Okay, so what can monitoring do? It can provide specific information for the implementation of a geological disposal facility, operational aspects for site selection, for choosing your concept, including the engineered barriers. Then during construction, operation, and closure, you will just check, confirm, and, if necessary, make corrective actions. And you can monitor for a restricted number of phenomena.

It is very important for RD&D. It helps us to figure out long-term stability, host rock performance, performance of engineered barriers, et cetera. And then I think very important, it’s a platform to help the interaction between technical experts and society, to enhance mutual understanding. That’s at least what we see in Switzerland. It’s important that you know human beings are behind it, our faces, and if you have something to interact on, that helps. So, see and understand each other’s view.

But monitoring cannot, and I think it’s very important, cannot be a part of the system to ensure long-term safety. That’s against what we want. We want to have a system with passive barriers that is safe without monitoring. And in that sense, surface monitoring after closure is possible, but, technically speaking, it’s not so clear what will be done. Nothing has been fixed. And I think it’s very important to distinguish between monitoring and institutional control. So, we think institutional control is very important, and in how far that needs monitoring and what type of monitoring, that’s an open thing.

Then monitoring cannot prove directly that the overall system works. As I said, we cannot look at what the nuclides actually do. It cannot provide meaningful measurements for all parameters with high accuracy and resolution wherever you want for as long as you want. That’s not possible. Some of the things can be done, but not everything. A range of limitations are listed below.

So, with that, I come to my last overhead. So, monitoring is very important for repository implementation. It helps in all phases, from site selection through RD&D, site characterization, and operation, closure, and surveillance of the repository. Monitoring actually addresses technical and non-technical expectations, but, then again, we have to be aware there are inherent limitations on what can be achieved by monitoring regarding demonstration of performance of the overall repository system, and there are also still some technical challenges.

The evolution over the last 40 years, I would say monitoring has always been good engineering practice since the start of engineering. That’s what one does as an engineer. One never builds something, and if you can, you always monitor, at least in Switzerland that’s what we learned. And in that sense, one has to say monitoring has always been essential in repository development, but with moderate expectations with respect to the overall demonstration. And over the last 25 years, this overall demonstration became more a need. One can say society was very much interested in that is these in situ demonstrations, but I think it’s important we also were able to make clear to society what we can do and what not. And finally, I think the collection of data is only half of the story, but the interpretation and our very important well-balanced input to the evaluations and decisions are equally important. So, again, I think one has to watch out that you give well-balanced input, you know, that you are aware of the robustness of the system, otherwise it could have endless stories of small [inaudible] that are completely irrelevant. And with that, I would like to close and show how wonderful Switzerland is.

BAHR: Thank you. You mentioned that there’s a requirement that retrievability be easily accomplished during the operational phase, and it seems to me that your pilot facility, the waste that’s disposed there is clearly readily retrievable. It’s not so clear to me that the waste in the main part of the facility where you’re going to be backfilling as you go is really easily or readily retrievable.

ZUIDEMA: Well, I think it’s, again, a question of definition, what is -- it says without undue effort. And then the question what's this undue effort. And, as I said, you know, we had, in an interim phase, we had concepts where we wouldn't backfill and wouldn't seal. That would be very easy to retrieve, but then the conclusion was -- and that's now in the law -- that is not the way to go because the compromise with respect to long-term safety is too much. So, there is an effort to retrieve it, it should not be undue, but by having a certain enhanced effort, we get safety as back. And so the decision was we backfill it, we seal it, but then -- and that's what I said, you know, we took some measures. For example, we have decided or we know that our bentonite, you can pretty easily remove it. And in that sense, we take big tunnels in our case, three-meter diameters at least, that we easily can remove this backfill around the canister to get it out, and that means it's something like without undue effort. And undue would be that you roughly can compare it to the cost emplaced.

BAHR: Okay, thank you for that clarification. Are there questions from other Board members? Tissa.

ILLANGASEKARE: So, you made a very important point at the beginning, the points of getting continuous data. So, then you made, at the end, you made the point that you can obviously monitor the surface but you cannot monitor deep. Is that what you meant? So, that means that the system will never come to steady state. So, I'm suddenly confused by your first point that you had to monitor long-term, continuous, then when you are -- later, you said that you don't need to rely on the monitoring system later, but then that assumes that the system is either steady or, is that what you meant?

ZUIDEMA: Well, I have to expound on that; you know? Again, in Switzerland, we have some things we are really happy about, and one of those things is we have a host rock that has a very low permeability, below and above it has other confining units, clay-rich, and there we have a long-term experiment by nature. Up and below these tight rocks, we have aquifers, and these aquifers were slightly more than one million years ago saline. And then due to erosion, they were flushed by fresh water. So, about one million years ago, a long-term diffusion experiment started. And we can monitor today what we see. We see a diffusion profile. And this profile, you can only get if your analytical tools of modeling, where you say no advection, only diffusion. And we have that in several places in Switzerland. And in that sense, we do not have to worry about the performance of the host rock because nature has made experiments that have a duration of more than one million years. So, in that sense, we are humble and say, you know, we can now make an experiment for 100 years, we make these experiments, you know, these diffusion experiments for example, in Mont Terri, but the key thing is this real long-term experiment. And I have to say, in certain aspects, you have made the selection today of countries that have an easy life, I say, because they have these tight clay host rocks. And if you wouldn't have that, you know, you would have to rely on engineered materials, that story is a different point. But then again, there are a few things we have to watch out for, it's stability. So, it's not the barrier function, but it's stability, and that's where we do as much as we can, but that is more the regional monitoring. So, also in Switzerland, the scientists, there is a significant number of scientists that have some reservations for the pilot facility. They say it just makes no sense. You know, we are in that sense -- or I am personally more open, you know. You know, often you make -- you measure things you never expected. So, I think it still makes sense, but I'm not sure that it will really contribute that much, but I think, in that sense, it's good. And there we say, you know, we go on for let's say for a hundred years or something like that, but at a certain stage, at least, you know, six people are normally pragmatic. If after more than 100 years you're still not sure if you want to put the waste down or get it up again, I think that's very unlikely for a Swiss person that is not able to decide after more than a hundred years if this is a good thing or not, but, you know, that's my personal view, knowing Swiss people after a certain period of time, you just say yes, that's it.

BAHR: Sue.

BRANTLEY: Sue Brantley, Board. I have a couple of questions. So, I like this idea of a natural experiment, what you just described, a diffusion experiment because, to me, one of the biggest problems is we can measure something now, but predicting it geological time into the future is hard, but we’ve spent a lot of time interpreting geologic time. So, that’s what you’re talking about. I like that. The problem, though, is, as I’m sure you know, you know, in this place, you can have one set of parameters, and then the heterogeneities that are always present in real systems can mean that, very close by, that you would have a different set of conditions. So, talk about that. What about all the heterogeneities that you have in Switzerland, and how do you take those into account?

ZUIDEMA: Yes. Well, again, you’re absolutely right. Now, the nice thing is these sediments, you know, they are, in the lateral sense, pretty homogenous. Vertically, there is some heterogeneity, but, you know, these isotope profiles, that’s something we do in all [inaudible] but in several boreholes, so it’s not a unique observation. It’s something we do. And, you know, once we have really set the final site, we build, look at that in several boreholes that are in the order of one to two kilometers away from one another. And now we even see if they’re very far away from one another, we exactly get the same picture. So, this Opalinus clay, it’s a real nice thing; you know? You should check it if you have something in the U.S. It’s really astonishing.

BRANTLEY: Have you seen any heterogeneities? Have you seen any fractures or any places that it didn’t operate homogeneously?

ZUIDEMA: No, we have discontinuities, but, you know, this is a plastic clay, so you have excellent self-sealing. And so we haven’t seen any wiggles in it where you see there must have been some of the -- that there has been a reaction that had any impact on this. Nothing also in the measurements, nothing.

BRANTLEY: So then a different question, as far as I understood your talk, you said you’re not going to measure gas, you’re not going to measure aqueous concentrations, and I think the argument was the changes wouldn’t happen fast enough to warrant putting a sensor down there to measure those things. So, that’s obviously predicated on an assumption that your modeling is correct.

ZUIDEMA: Well, I would say it differently. What we will do is, as I said, you know, we have two things we look at. The pilot facility is the overall performance of the nearfield, you can say. But what we do in parallel is that we make dedicated experiments, for example, also migration, you know, diffusion experiments, we do that. They do that already now. They run probably for a hundred years or so. We do, for example, very long-term tests where we look at the effect of gas on bentonite and clay, but that are dedicated experiments because there we actually can make them such that we see something in these hundred years. Whereas with the one-to-one representation of the repository, you know, nuclides, there won't come any nuclides out. So, we have to do something else. An experiment where the nuclide is already in the rock starting with, and not only after ten thousands of years, and that's what I mean. So, we do make experiments, but they are very specific for specific phenomena. And we do that already now, as Patrick Landais said, in our rock laboratory, but that's a research rock laboratory.

BRANTLEY: Okay. So then one final question. You have some breakthrough curves in your talk, in the beginning, and you call those predictions. And a prediction means to me, you know, you've got a blindfold on and you pick all your parameters out of the literature, and you run your model, and then it's a prediction.

ZUIDEMA: Well, that was what was, more or less, done. It's obviously not from the literature, but, you know, first of all, this was crystalline rock, so it's not the rock I talked about.

BRANTLEY: That's another point I was wondering about.

ZUIDEMA: That's fine. But then what we did do, we did do a hydraulic characterization. That's what the modelers got. But then there is something else. You know, in these fractured rocks, the so-called matrix diffusion is pretty important phenomena. And they got the diffusion coefficients that were measured on small cores and sorption ~~from~~ on crushed material. And I must say, at that time, there was a real worry that one could actually transfer data from the lab to in situ. And so the modelers didn’t get the break zone curves [ph]. They had to with the diffusion coefficients measured in the lab on small slices of rock, and the~~y~~ sorption ~~from ow~~on crushed rock, that was the ~~problems~~ parameters they got, they had to make the prediction. They didn’t see the curves beforehand.

BRANTLEY: So, there was nothing measured in the field that was used -- or there was no knob in the model --.

ZUIDEMA: No, no, no, no fitting. No.

BRANTLEY: That’s pretty impressive.

ZUIDEMA: And, you know, at that time, and that continuous thing, you know, in how far or, you know, things, experiments on these small sample’s meaningful for something large. And that was at that time, and we are still happy that we did do that. So, that was, you know.

BAHR: Steve Becker, and then Efi.

BECKER: Becker, Board. We heard earlier from Patrick about monitoring data being public~~al~~ly available. I'm wondering what Switzerland's plans are with respect to monitoring data and the public.

ZUIDEMA: Well, that's the same; you know? In principle, everything is public here. It is such that we have, for example, in the rock laboratory in Mont Terri, it's an international project, and I think probably Maarten knows the number exactly. I think we've got about nine countries and 16 organizations, lots of scientists. And what is very clear, that those that did do the experiment have then the possibility to publish it before everything is distributed to everybody. But after it's published, you know, everybody can have these things.

BECKER: With respect to the actual operation of the repository?

ZUIDEMA: Well, that has not been decided, but I'm convinced it will be the same. For example, if we do field experiments or in situ characterizations, site selection, all the data, it’s all open. But one has to say, you know, that is an interesting thing that, actually, interest in it is rather limited, but people just want to be sure it’s there in case. And so everything is open, yeah.

BAHR: Efi.

FOUFOULA: Efi Foufoula, Board. So, you mentioned that the system is robust and small deviations do not require retrieval. Now, small deviations is, you know, is a loaded word because you have to interpret within the system. And at the same time, we’ve been talking about diffusion, diffusion and the migration experiments. Help me a little. In your plot, which is, I don’t know, slide ten, I mean, nothing to me suggests diffusion there. I mean, these are --.

ZUIDEMA: No, no, that’s what I said. You know, I didn’t talk about the whole story of Switzerland, that would be really interesting, but this was in the early phases; you know? We started in the late seventies in Switzerland. And at that time -- this one -- at that time, you know, about the underground, not too much was known because nobody did go there. So, this is crystalline fractured rock, and this is -- has nothing to do with the Opalinus clay we look at now.

FOUFOULA: Okay, because you scared me.

ZUIDEMA: Yeah, no, this is -- no, no, this is highly heterogeneous and complex.

FOUFOULA: Okay.

ZUIDEMA: Yes.

FOUFOULA: I was trying to calculate this log there, log, log [inaudible].

ZUIDEMA: Yeah, yeah, this is -- no, no, this has nothing to do with what I said before. Those are two different stories.

FOUFOULA: Thank you.

ZUIDEMA: Yes.

BAHR: Other questions from the Board? Any questions from staff? Do we have any questions from the audience? Please come up to the microphone.

WELLS: Follow your format and state my last name?

BAHR: Yes, please.

WELLS: Wells, Southern States Energy Board. My question is you talked about the energy dialogue working group and then EKRA.

ZUIDEMA: Yep.

WELLS: One was not able to come to resolution, the other did. Is there a difference in the background of the members and does EKRA still exist today?

ZUIDEMA: Well, there was a clear difference also in the mandate. You know, EKRA was by elected people; it was not -- you know, the energy dialogue was, you know, the NGOs were able to send somebody, et cetera, but they were not -- the dialogue group did not have the job to come to a recommendation. You know, they had to discuss, whereas EKRA had the job to make recommendations. So, it's already the mandate was different. And then I would say in Switzerland, you know, sometimes NGOs in our case have, you know, the problem is that we see that disposal, it's one way to put the question mark for nuclear energy. And so it's not necessarily disposal~~e of~~ that is at debate, but it is the question about nuclear energy. And that makes it sometimes difficult. So, in that sense, one has to say this energy dialogue, it was much more heterogeneous and had less emphasis that they really had to come up with a conclusion. Whereas EKRA, it was also mixed, you know, people that are not in favor at all of nuclear energy but are aware that one has to do something. So, the second part is EKRA has been dissolved in the meantime. It's not anymore there.

BAHR: Any other questions? Okay, well, thank you. So, our next speaker is Maarten van Geet from ONDRAF/NIRAS in Belgium. And he's going to tell us the Belgium story.

VAN GEET: Good morning everyone. Thanks for this invitation. And indeed I will try to inform you a little bit on the Belgian situation. So, for that, I will first introduce a little bit the context in Belgium. Then I will talk about these issues of reversibility and retrievability, the definitions that we use in Belgium, the update of the disposal concept we did in the early 2000's, and an update of the layout of the disposal facility that we did recently and concluded last year. And then I will go on some issues of monitoring, definitions again, methodological aspects, societal aspects, and technical aspects, and then end with some conclusions.

So, in Belgium, we have three types of waste. We have this low- and intermediate-level waste with only traces of long-lived radionuclides, which we call the category A waste, for which we developed a surface disposal facility. Actually, it was already in the 1980 that it was a law that allowed us to develop a solution that should be progressive, flexible, and reversible. So, at that time already, we had in law something about reversibility for the low-level waste. And we developed the surface disposal facility and submitted the license in 2013, which was really an integrated approach with a lot of societal involvement with local communities, and even some kind of co-designing of this surface disposal facility. So, we have some context with society in that respect.

However, for the other types of waste, category B waste, which is low- and intermediate-level waste with long-lived radionuclides, and high-level waste, we have currently no institutional decision ~~over~~ on the long-term management. So, there's even no decision on geological disposal for these types of waste. But, of course, NIRAS/ONDRAF recommends geological disposal.

So, if you look on this -- on a timescale, it's already in the mid-seventies that we started to research on geological disposal for this high-level waste. In the early eighties, we developed our underground research laboratory dedicated for these studies with several extensions. And lately we started a large-scale heater experiment. So, there's quite some research that was ongoing for geological disposal, but at the political level, we are lacking some decisions. So, end of the eighties, we published the Safety and Feasibility Interim Report. We did the second one early 2000's, SAFIR2. Conclusions were that, from a technical point of view, the host rock that we were studying in our underground laboratory was certainly -- had good characteristics and had the potential to be a good host rock for geological disposal, but that we should start the societal dialogue and it was time to have political decisions. That's why we started, in 2010/2011, several public consultations. This was concluded with a waste plan that we submitted to the government in order to take a decision and principle on geological disposal, but ever since we did not yet receive this decision. However, in 2014, the EC directive that Patrick Landais was also mentioning was transposed in Belgian law, and this has an important impact because there reversibility/retrievability is popping up again, although there is no decision on the long-term management of these types of waste. So, that's a contradictory situation in Belgium with respect to long-lived and high-level waste.

So, that's concluding the situation in Belgium. Maybe also inform that there is no full and fixed regulation in Belgium available for geological disposal. So, also there are a lot of uncertainties remain for the time being. This does not mean that we do not continue our research. We do continue RD&D on geological disposal with currently still a focus on these poorly indurated clays in which we have an underground laboratory.

Why do we do this? We want to guarantee continuity on our knowledge. We want to be able to continue this -- to transfer all this knowledge to coming up generations. We also have to do updates of cost assessments. We are phasing out nuclear energy by 2025. So, if we have to update costs, we still have a few years in front of us to update costs. And, of course, we iteratively want to integrate the available knowledge and the return of experience of research.

So, let’s go to this reversibility and retrievability issue. First of all, some definitions. So, as mentioned, there was a law in June, 2014, which stipulates that national policies and future national policies must contain methods for reversibility and retrievability, taking into account the need to ensure the safety of the repository. However, it was not defined what is reversibility and retrievability. So, both words are used without definitions. Now, the Belgian regulator was present at the NEA conference in 2010 on reversibility and retrievability, and in one of their papers they proposed these definitions. Reversibility is taking back the waste during the operational phase, before the backfilling or sealing, with similar means as by which the waste was emplaced. And this is mandatory for the regulator. Retrievability, on the other hand, is taking back the waste after partial backfilling and sealing, and probably involving other means than those needed to emplace the waste. This is not requested from the regulator, but might be by society. And it’s clear that attributes of retrievability should not endanger the long-term safety. And the retrieval of the waste will be subject to a specific license not included in the construction & operational license of a geological facility. So, for the time being, those are the definitions we use today in Belgium. So, they differ a little bit from what was said in France or even at an international level NEA.

Now, our SAFIR 2 report in the early 2000’s said that the geological disposal in poorly indurated clays was -- had good prospects to continue on it, however it also stated that the concept that we proposed at that time had some flaws, and that’s why we did a reevaluation of a disposal concept. And we incorporated several elements to make such an update. First of all, we wanted full containment during the thermal phase for the high-level waste. We did not want to unduly disturb the host rock. We had a preference for materials and implementation procedures for which a broad experience and knowledge existed. And we had a preference for permanent shielding of the waste, and the minimization of operations in the underground. The last one was a return of experience from an underground laboratory. It’s not that easy to work underground and make large operations in such conditions.

So, we had a full approach to come up with a new concept. It was a structured, step-by-step approach. It was a multidisciplinary working group that developed this. We had a consultation of internationally-recognized experts and the whole procedures were fully documented. We came up with three major possibilities, a supercontainer, which means that we, on surface, contained the waste with a kind of supercontainer, several engineered barriers; another option was a sleeve, so that we develop some engineered barriers in the underground already and that we insert the waste in the underground; and finally, a direct contact, I would say, with the waste and the host rock with a lesser accent on the engineered barriers.

Now we worked with a multi-criteria analysis, so several criteria were defined, scores were given. We had a reference weighting but also alternative weighting, and this led us to final conclusions. Now, the weight factors that we used are listed here. I will not go into all the details, but important is that we included already flexibility and specifically retrievability. Although, I want to remind you, this was in 2006, so before the law of 2014 that stipulated reversibility. So, we have included it already at that time. However, you can see that the overall rate or weight was rather limited and was only three percent compared to the other elements.

The result of this multi-criteria analysis led us to one specific design that came out as the best for all the different alternative weightings, which is this supercontainer with Ordinary Portland Cement. And this is how it looks like. So, for the high-level waste, it’s the spent fuel or two canisters of vitrified waste that will be surrounded by a three-centimeter thick carbon steel overpack, which will be inserted in a big concrete matrix, which surrounds these overpacks with about 70 centimeters of concrete. And optionally can have stainless steel envelope surrounding these supercontainers. The major items for choosing the supercontainer was the watertight containment and the ability to characterize all the materials. That was the major driver at that time for the choice of the super container.

Now, I mentioned in 2014 there’s this new law that states that reversibility/retrievability is needed. So, we reevaluated the supercontainer design and checked if this is still in line with this new law. First of all, we found out that this permanent shielding that the supercontainer would provide would rather be positive with respect to reversibility and retrievability.

Secondly, this outer stainless steel envelope that was optional at the time became mandatory after this law of 2014 because we believe it will enhance the reversibility and retrievability issues. And finally, up to now, we did not find major arguments to put into question the supercontainer design, with respect to reversibility and retrievability.

Now, next to that, we also reevaluated the delay out of the repository that we started in 2015. It was, of course, based on peer review but also on a HAZard IDentification we performed. Major weaknesses with the former design, which is illustrated here, which consisted of several shafts, one major access gallery, and perpendicular to it disposal galleries of up to one-kilometer length. It seems that operational safety issues were not fully included in this design, and that the X-crossings, so the disposal galleries, one on the other side of this access gallery was difficult to construct in these poorly indurated place. And, as we did it after the law of 2014, we also wanted to make sure that reversibility and retrievability aspects would be included in the new layout.

So, several alternatives were evaluated. First of all, similar to the former design but limiting the disposal gallery length to about 400 meters to be aligned with tunnel regulation and German mining regulation for the escape of personnel in case of accidents. Then we considered the possibility of having double access galleries to have more escape routes and to avoid these X-crossings. So, we only have one crossing here, a T-crossing between a disposal gallery and the access gallery. And then we also have an alternative to maximize reversibility because, as in Switzerland, we also considered that backfilling should be done immediately after emplacement. In practice, it seemed only feasible to do backfill about 50 meters. So, if you want to maximize the reversibility so that you don’t need other means to retrieve the waste, then we should have disposal galleries of about 50 meters, and then we can backfill only at the end of the operational phase after several decades, for instance.

This led to several variants of these different alternatives that we had. So, here you see, for instance, if you would draw the scheme with increased reversibility issues, then you get, of course, a very big surface or area compared to the other designs that we had. So, there's certainly some tradeoff that needs to be made in this. Again, we have some kind of multi-criteria analysis. Reversibility/retrievability is, again, included, but this time it has a weighting factor of up to 15 percent, and this led us to one specific layout that was chosen and which is illustrated here. So, you see here, two access galleries with a collecting gallery, perpendicular to it the access galleries, and perpendicular to them these disposal galleries of 400-meter lengths for the disposal of the B waste and the disposal of the high-level waste and C waste.

So, retrievability was included, but it's 400 meters length, not the 50 meters. That's the tradeoff we had to make with respect to operational safety and retrievability. The backfill material that we will use will be something that is easily retrievable, so that can be easily removed after emplacement so to enhance the retrievability afterwards.

Let’s go to monitoring and monitoring aspects. First of all, again, these definitions. During the public consultation in 2010, it was clearly highlighted that the social demand on “control” was very important. They used the word “control,” but within its context we have interpreted it as a demand for monitoring. Again, in this law of 2014, monitoring is mentioned as well, but, again, it is not defined. So, it doesn’t say what is really needed, and it stipulates that modalities needs to be defined later together with stakeholders, whoever the stakeholders might be. So, today, there is some uncertainty on what to monitor. So, we currently focus more on the monitoring strategy and the flexibility to incorporate monitoring aspects rather than to focus today already on monitoring techniques or devices. It’s too early in our program to develop these things we believe.

If you look at the monitoring strategy, it’s similar to our safety strategy actually. We believe that you have several boundary conditions that need to be fulfilled. Today, many of them are still uncertain for us, but, of course, we still have some outcomes from former programs, but basically you always have to check if all these boundary conditions can allow to protect man and the environment now and in the future to develop passive safety, make strategic choices, develop the concept, and then make detailed basic scientific aspects.

Now, with respect to the monitoring then, we can check which of these leads to a need for monitoring. So, similar as Piet has mentioned, we want to focus on the monitoring of elements that are relevant for the safety. So, then we can make up a parameter prioritization, identify the parameters, and check if you are able to measure them in situ or with other means. And then iteratively, we can make up a more advanced program with respect to monitoring. So, that’s the current monitoring strategy.

Today, we have already some dialogues with society. Actually, we have the luck to have these partnerships that developed with us these surface disposal facilities, and they allow us to discuss with them also on geological disposal. Although it’s rather generic, it’s not to discuss with them on geological disposal in their community, but rather to have ideas of what potential laypeople might demand.

Now, I did myself these interactions with those people, and, first of all, we asked them, without any context, what they expect from monitoring. And then there is a clear demand for measurements of leakage of radionuclides as close to the source as possible, and the full transparency of data to all members of the public. And I think this comes back to the presentation of Piet, it’s similar, they want to know if radionuclides will leak, and you have to measure it as close as possible to the source. However, afterwards, I gave some context on how a geological facility should work, how it works, how we developed it. And then monitoring becomes more nuanced for those people as well. And it can be considered very broad, including RD&D, long-term in situ experiments during the operation, not necessarily in the repository itself but, for instance, in an URL. They clearly said that, of course, it should not undermine long-term safety but that it should help in decision-making with respect to, for instance, partial closure. That there was a need of stepwise transparency. Instead of full transparency, giving all the data immediately on a website or something, available to everyone, they said, “Well, we have some educated members within the public that are able to see those data.” And that only a filtered transparency was probably needed to the larger public. This was based on data that I have shown from the underground laboratory where some sensors do fail after a certain time and come up to give very strange data, and that if they look at that and if all members of public would see those data, they would be frightened without good reason. So, that’s why they came up with this idea. And then, of course, they also said that if you do monitoring, it also demands for alarms to be set.

From a technical aspect, from a technical point of view, we currently only foresee the flexibility to incorporate monitoring, and actually we have heavily -- we were heavily inspired by the Swiss case. So, we do foresee a specific support zone, as we call it, where we can have several galleries where we could measure and could actually kind of prepare such a pilot facility like in the Swiss case with full measurements around real drums in order to avoid monitoring or too much monitoring in the real disposal galleries. That's the idea that we have incorporated up to now from a technical point of view.

So, this leads me to the conclusions with respect to the Belgian case. So, take into account that there is currently not yet a policy decision on the long-term management of long-lived and high-level waste in Belgium. In the early 2000's, we had an integration of our knowledge, and it was clear that these poorly indurated clays had good prospects to be a potential host rock but that an update of the concept was needed from a technical point of view. In 2010-2014, we had public consultations and eventually a law of 2014 making clear that reversibility, retrievability, and monitoring are very important aspects, although they are not fully defined yet. Then 2003-2006, we did a reevaluation of the concept and we developed the supercontainer concept. Reversibility and retrievability were already included in the evaluation, but it was not a major driver at that time. But the reevaluation in 2014 illustrated that we did not see major problems with this concept with respect to reversibility/retrievability. And then in 2015-2017, we did the development of a new repository layout. There reversibility/retrievability were explicitly considered. We had to make a tradeoff between operational safety and reversibility/retrievability issues. And we also included the flexibility to perform monitoring tasks. Thank you for your attention.

BAHR: So, thank you. You mentioned in the previous slide the I think public desire for there to be explicit alarms, and that means that you have to make some decisions about -- I guess it was a couple of slides -- alarms to be set, you have to make some decisions about what is an alarming situation. And so how -- do you have a strategy that you would expect to use to go about deciding what’s a trigger point?

VAN GEET: Well, this will strongly depend on safety case, of course, in which you -- I think it was mentioned by Piet as well -- you have some boundaries, and probably a lot of items you can have quite larger boundaries. For instance, the corrosion in our case as well, the clay itself, the host rock itself is such a good barrier that corrosions of the engineered barriers are not that important. I mean, if it’s several hundreds of years, several thousands of years or several tens of thousands of years, does not really impact the final safety of your repository system as a whole. So, probably we will have to define later on, based on the safety case, some margins that we can use, first of all, margins that we assume to be the nominal evolution of the system, but then also margins at which maybe a reevaluation is needed, and that’s probably the way forward that we have in mind today.

BAHR: Thank you. Other members of the board, questions? Tissa.

ILLANGASEKARE: Yeah, Illangasekare, Board. So, in your concept analysis, you look at the supercontainer with the OPC came out the highest, but one of the reasons is that possibly they are not natural material~~, even though~~ involved, you have concrete. My question is, actually I was in another panel, we looked at this issue of using concrete for capping, so ~~but~~what is~~n~~ the long-term behavior of concrete, in the context of you look at long periods, you know, ~~you~~ have you ~~n't~~ done anything on the integrity of the concrete as a manmade material?

VAN GEET: Okay, so, of course, since the design or since the choice of this supercontainer concept, we are working on this. Again, we are in a clay environment, so everything is diffusion-controlled, everything goes very, very slow. So, also this concrete will last quite a while. For some experts, it won’t change even after millions of years; I’m not sure that’s true, but. Everything goes very slow. The major objective of the Ordinary Portland Cement in the case of the supercontainer is just to maintain the high pH and, in such a way, decrease the corrosion rate of the overpack. And actually that will last very, very long, we’re talking years, certainly tens of thousands, maybe even hundreds of thousands of years. There certainly is some uncertainty still present today, but it goes well beyond the timeframes we had set ourselves of several thousands of years.

ILLANGASEKARE: So then during the handling, there is any possibility of stressors with produced fractures, micro-fractures?

VAN GEET: So, within this poorly indurated clay, the poorly indurated clay is self-sealing but very, very fast. So, if you drill a borehole, within several weeks, it's completely closed. Ten-centimeter borehole, it takes weeks. Even if we drill or excavate galleries, we have to emplace a lining immediately. We do an over-excavation of ten centimeters on a diameter of four meters, and then we have just enough time to emplace the lining, and then the clay is converging already to the wall. So, it goes very, very fast. So, in that respect, we have to emplace a lining which takes all the stresses. And with respect to reversibility/retrievability, we have designed our linings in such a way that they can take all the stresses from the overburden so that there is no transfer of stressors on the supercontainer itself. Everything is taken by the lining.

BAHR: Other questions from the Board? Dr. Peddicord, who has joined us now.

PEDDICORD: Peddicord from the Board. A question in terms of your programs in ONDRAF and the legal context of the national program and where it stands now when you're waiting for decisions, but is there anything that you are constrained from doing in your research program that you would want to be doing or like to do that at the moment you cannot carry out? I'm thinking of emplacing maybe radioactive sources in your underground research lab or whatever it might be, any comments on that?

VAN GEET: So, with that respect, from a technical point of view, we are not really limited. So, even in our underground laboratory, it's on the premises of the Belgian Research Center for Nuclear Energy. So, we can use tracers, we can really use radioactive sources within the underground laboratory, et cetera. From a technical point of view, that's not really an issue. The major issue for us is the societal issue. So, if we would like to look at other host rocks, which might be a possibility, then we probably have to go to communities and ask for the possibility to drill a hole over there, and to-date that's the major issue. All these communities are not really willing in having just a drill hole just for research. So, during this public debate or public consultation, one of the arguments used was there’s not enough research done, although there was 40 years of research, but anyhow. That’s one of the main items that came up. So, what we could do is to check other host rocks, but in order to do that you have to drill a borehole, and there it starts actually.

BAHR: Other questions? Paul.

TURINSKY: Turinsky, Board. When looking at monitoring, there’s sort of two timeframes involved. One is basically the lifetime of the equipment that’s put down there. T~~t~~he other one is the lifetime of the observer, and that is how long, you know, from a societal viewpoint, will there be an interest in actually looking at the signals that are coming out. And I would think you’d have to consider that in deciding how long that instrument should last also; you know? Thinking about things, you know, the only thing that’s lasted for several thousand years is probably religion at this point; everything else has changed; okay? So, have you thought about that, or your organization, about society itself and how long people will actually be interested in monitoring?

VAN GEET: This is more to do with transfer of knowledge, I think, and this is, of course, part of monitoring and reversibility, et cetera. So, it’s clear that for the in situ measurements and monitoring, we do consider it during the operational phase this will last about 100 years. As we are operating, we assume that at least someone will be interested in the monitoring results and the outcomes. So, there I don’t see a major problem.

Afterwards, it’s indeed transfer of knowledge. And actually during the public consultation rounds, and I didn’t mention it, but also in the law of 2014, it’s mentioned that we should transfer knowledge to future generations. Again, without the definition, again, not stating what it means, but it’s an awareness, I think, of the fact that the repository is there. And I think that’s more a social aspect, getting the society involved, and that’s what Claudio mentioned as well, getting the society involved. If I take the comparison again with the low-level waste, there I think it really works. We do have these partnerships locally. People are involved. They have -- there’s also a medium-term fund, so this kind of fund that allows those communities to develop things with this money for their community, but also with a link to the repository, knowing where the money is coming from, that it was related to the fact that they accepted to have to dispose of this low-level waste on their territory. There is also a communication center located there with the specific aim to inform people not only from the local communities but also attracts the surroundings, and even the whole of Belgium -- we're not that big -- to come over there and have a look on what has been done there and what's the impact of such a repository. And I think in that context it might be more -- some people might still be interested in having some idea, okay, we have this repository there and what's the impact now. I think this might be -- if the society is really involved, I think there might be an interest locally at least to have these results and see how this evolves with time.

BAHR: Other questions from the Board? Questions from staff? Bret.

LESLIE: Bret Leslie, Board staff. Unfortunately, I didn’t get a chance to visit the underground research lab, but, for monitoring, have you thought about what monitoring would be needed for the supercontainer concept, and can you scale that to the laboratory to just begin to think about what monitoring you’d need to be at full scale?

VAN GEET: So, as mentioned, this is not the focus today of our work because we think we are too far away from decisions, et cetera. But, for instance, the major objective of the supercontainer is to retain the radionuclides, at least during the thermal phase. So, that means that corrosion is the most important thing. So, I think that probably we would try to monitor the pH, because as long as the pH remains high, corrosion should be low. And next to that is the corrosion rate of this overpack and maybe the gas production rates in that time. But, again, we will try to limit it to a few amounts of supercontainers in a specific zone, not on every supercontainer. That’s not our major idea for the time being, but, again, this might change if there is interaction with different stakeholders, but today it’s not our major issue.

BAHR: Did I see another -- Dan Metlay.

METLAY: Dan Metlay, Board staff. So, I know I’m confused, and maybe others are confused about the fact that on the one hand you have transposed the European Directive, on the other hand you say no decision has been made. Could you say some more about that, or if it is too difficult, don’t say anything?

VAN GEET: I’m as confused as you are; you know? So we had this public consultation rounds in 2009, 2010, we had this waste plan 2011, and then came up in 2011 also this EC Directive which stated that actually each member state of the European Union needs a clear view on the long-term management of spent fuel and other types of radioactive waste. So, we assumed that this would be an additional trigger for politics to take a decision because we had, at the same time, submitted, we thought, all the information needed to be eligible to take a decision, and the commission somehow demanded for each member state to do so, but there are other political forces that play as well. So, at that time, we didn’t have a government for more than 500 years -- 500 days. That was really a [inaudible]. For more than 500 days, at least not a federal government. We still had local government, et cetera. So, Belgium did consist and did work and did function after all, but no political decision could be taken. The pity is that the government afterwards did not pick up these issues. And I think that the urgency of the EC Directive was gone a little bit, and so it all has to do about constellation at the specific moment, I think, and it was just bad timing I suppose to submit all these issues at the moment that other political issues were at stake in Belgium.

BAHR: Any other questions from Board staff? A Board member? Yeah.

ILLANGASEKARE: So, you mentioned in your monitoring strategy or planning, you are talking about the selected parameters to monitor, so that’s a good concept in my view, but the question is that when you look at very long-term monitoring, the parameters can change. So, I assume that you have some models of the system to make those determinations, or how do you -- you don’t plan it a priori, as the system develops, you then decide which parameter to monitor, is that what you meant?

VAN GEET: Well, you also have these boundary conditions next to it; you know? So, from our point of view, as scientists, we do have some ideas on what we would like to monitor. Probably the regulator has his ideas on what he wants to monitor, and we can develop these things. But there are other stakeholders that might have other ideas, and that’s less clear what they want, how they want it, and that’s maybe not -- well, of course models will be used to safety case as a whole, not only the models but all the phenomenological knowledge, all the arguments we have, and the models will be used certainly for what we want to measure to have an idea how to measure it, what to measure. But if stakeholders come with specific questions, then, of course, we will check also with this safety case and try to explain, but I’m not sure today that we will be able to convince them every time that some of the measurements they ask for are not relevant, for instance. So, maybe we’ll have to measure things that we, as a scientist, might consider not that relevant, but if they consider it very relevant, then we should have a look at it, I think, and try to check what are the possibilities. But, again, I do -- I did like the presentation of Piet who stated very clearly that we also should be very clear on what are the limitations. And actually that’s what I did in my -- it was during the EC project modern, I did have contact with these partnerships and informed them on the limits. I informed them. I gave them real values from the underground laboratory where, in some experiments, more than 50 percent of the sensors failed after a few years. This is what I explained to them. This is what I have shown them. And ~~if~~ with this context they have a whole different view on what monitoring would be for them and what it means, but you need to inform them. If you just ask them without any context, then demands or expectations might be very, very high, but you have to inform them and then they are more realistic. And they are realistic actually.

BAHR: Other questions from the front of the room? Any questions from the back of the room, or comments? Please come up.

WELLS: Christopher Wells, Southern States Energy Board. Your definition of reversibility is saying~~een~~ somewhat different than the other speakers. It seemed more like a technical issue, whereas theirs was more policy-oriented. So, my question is, in terms of the regulator, is it written with the notion that the regulator would make a corrective action and things would continue, or does the regulator have the authority to completely terminate the project?

VAN GEET: It’s not defined yet, but based on what I have read, I suppose that they might ask for corrective actions in some cases. So, for instance, if a supercontainer goes down, normally it’s not to hit the other supercontainer that is already in the disposal facility. Maybe if something happens and it hits anyhow the supercontainer behind it, they might ask to retrieve it and check it if the supercontainer is still functioning as it should, for instance. These might be actions they can ask~~’ve taken~~. So, it goes more in the direction of corrective actions than really to stop the exploi~~ort~~tation of the repository.

So, maybe just to mention, we also have of course the ideas of political changes or changes in thinking and decisions that were made. Again, we use the term “flexibility.” So, it is more reversibility in the French case; it’s in our case we invented the term “flexibility” to come up with these ideas or to integrate these ideas.

BAHR: Please.

PESCATORE: Claudio Pescatore. Just to give some, say, additional details regarding the questions that Dan Metlay asked about transposition and the law, you know, there are these stealth thing that happened. This was a stealth thing that people put in the law in Belgium without being in the EC. And the same thing happened in Finland when they had the decision ~~and~~ in principle to go ahead. The government, at the time, was in the hand of the Greens, and the Greens added the retrievability, which was not, in fact, in the -- so, and then later on, when they make another decision, the political atmosphere was different. So, in 2006 I believe it was, another decision for the additional waste, they did not have these retrievability requirements. So, for a long time, they had two kinds of waste. The first -- on~~e of~~ the first decision~~s~~ was you had to retrieve; on the second position, they do not have retrievability. And then, in the end, they're working these things out and they are now -- I don't think they're talking about it too much, but they have the same position as the Swedes.

Regarding the Belgian regulator, they have a complex slide, in fact, a complex ~~aware~~ where ~~of~~ all of these terms are defined. In fact, the top term is "flexibility," as Maarten was saying. And when we were in this NEA project, or post this was decided, this was discussed. And you can go very specific. For instance, you can use recoverability when it's compact with stuff, and retrievability only when you take whole containers. And so you can really make up a whole terminology about it. And we decided, you know, to stick just to terms in our project because it would become too difficult to be communicating. At that time also, we were communicating with so-called stakeholders. So, in several countries, those pictures you've see, this going back picture and the other one with the several steps or levels of retrievability, they went over, like, a hundred iterations, and many of them with actual people in communities and so on. So, we wanted to be fairly simple. But the Belgian regulator went really complicated with all the subtlety of several things you can do.

BAHR: Thank you. Any other questions or comments? I understand we don’t have anyone signed up at this point for public comments, but if there’s somebody who would like to make a public comment at this point, I’d invite them to do so. Okay, seeing none, we now have a lunch break. And we’re scheduled to start back again at one o’clock. So, we have a little bit longer than the originally-scheduled one hour for lunch. And I don’t know if the staff have any suggestions about lunch options. I think there’s [inaudible].

MALE SPEAKER: Yeah, there’s a list of restaurants right out on the table with the handouts.

BAHR: Okay, thank you all for an interesting morning session.

BAHR: Okay, well, welcome back to the Afternoon Session. We have some additional very interesting speakers this afternoon. And just as a reminder, we'll be having a panel discussion at the end that we'll be setting up after our break that will happen at about 3:30.

The first speaker this afternoon is Horst Geckeis who is from the Karlsruhe Institute of Technology in Germany. Germany is the one country that's actually in the process of testing these concepts of retrievability and reversibility, albeit not for a high-level waste repository, and so we're going to hear a little bit about their experience and some of the challenges. Thank you.

GECKEIS: Thank you very much for the kind introduction. And also thank you very much for the kind invitation to come here. So, it was a pleasure to come here and I'm quite honored to be here. So, topic of my talk was just introduced. So, I just would like to tell you a little bit about the situation, about nuclear waste disposal in Germany with a focus on what is happening at the Asse Salt Mine.

So, I will just follow a little bit the question list that the Nuclear Waste Technical Review Board asked to me, and we'll start with the radioactive waste disposal situation in Germany. So, I'd like as well to start a little bit also in the history, then to say something about how it came to the Asse case, some legal aspects related to the Asse, some consequences of the decisions for retrieving the waste from this repository, and some conclusions at the end.

So, actually, it's that in Germany there was quite early, in 1961, a decision made by the German Nuclear Commission to dispose radioactive waste in deep geological formations, and it was a strong recommendation to go for salt deposits. And quite early there were research programs initiated.

In 1977, there was the initiation of a licensing process for the Gorleben site. It's a salt rock ~~[inaudible]~~diapir, which was the reference repository site for high-level waste. Actually, in the beginning, it was for all kinds of waste. So, I should mention that during this time there was the development, from the beginning of the seventies, of a strong antinuclear movement in Germany. And basically the

Gorleben site was one of the foci of where this antinuclear movement was really focusing at.

1986 was certainly one of the key events, the Chernobyl accident, which further ignited this antinuclear movement in Germany. And in the year 2000 there was a government coalition, Green Party, Socialist Party who decided to have “Gorleben-Moratorium” to stop exploration work at the Gorleben site for ten years. And in 2002 there was the first German decision to phase out of nuclear. In this case, it was not clearly defined when this phase out will be terminated.

So, in 2010, we had a different government, now it was a Christian Democratic Conservative government. So, the “Gorleben Moratorium” was terminated and there was a decision for nuclear power station lifetime extension. And then Fukushima came, and with this event there was a very strong and very strict and rapid decision to shut down eight of the oldest nuclear power plants in Germany, and there was the decision for an accelerated nuclear phase-out until 2022. So, while we had here a strong let’s say stop in all kind of decisions and all kind of developments in the field of nuclear waste disposal, it was just some kind of a struggle around Gorleben. So, this situation changed a lot in Germany. So, now we had, with broad political consensus, Site Selection Act passed by the government in 2013. One of the contents was that Gorleben is not anymore the reference site for high-level waste repository in Germany but it has also not been excluded from the process.

2014 to 2016, there was a commission initiated who defined the criteria for site selection. And 2014-2016, two new entities were founded as a regulator and a new implementer organization. So, that’s at the moment the situation. If you are just looking a little bit to this Site Selection Act, 2013, with some kind of amendments in 2017, so it’s like new development taking place, everything in a very broad political consensus. Site selection should take place in a science-based, participative, transparent, self-examining, and learning process. So, this includes already the concept of reversibility, as you can see. As always, there should be some kind of milestones and as well some kind of possibilities to steer the process in a different direction.

It was also fixed that radioactive waste disposal should be in a mined repository in a deep geological formation. So, different options have been checked and have been examined. And it was also said clearly that we would start from a wide map of Germany, that means it’s a consideration of rock salt, clay rock, and crystalline rock as possible host rocks for a site. So, this is certainly a challenge, I also have to say, because it’s not only comparison of the host rocks but it’s also comparison of different repository concepts which has to be done within the process.

Finally, it also said that there should be a retrievability option during the operation of the repository, and the possibility -- this is strong -- should mean as well not to recover but to retrieve the waste for up to 500 years after closure of the mine. And this is a specific requirement to the container. So, actually it points to some kind of the necessity of a thick-walled container which cannot corrode within this time period. So, that’s the main things of this Site Selection Act.

So, the timeframe is really challenging. It’s very optimistic. So, it will be a three-phase site selection process where the selection of regions and sites should be narrowed down until phase three where at least two sit~~d~~es will be compared and then finally proposal for a site will be done. Narrowing down each decision will be done by law, by the Parliament, and there will be a strong implementation of public groups, consultation and participation processes. It’s also partly at least outlined in the law, and this is also something which has already happened, the foundation initiation of a national accompanying council where representatives of our society will just have looked to the process and have as well some kind of contact to the public on the entire process. So, the site should be found then in 2031, which is very optimistic. And actually there is also some numbers that in different papers that the repository should be in operation in 2050, but that’s really challenging.

So, we have some repository sites in Germany for the negligible heat-generating waste. So, one is the Morsleben site, it’s an abandoned rock salt mine. It’s a repository --

previous repository of East Germany, so this is, at the moment, under decommissioning, backfilling, some problems with the licensing process, but it’s on the way. Asse I will just focus later on. The Konrad site is the licensed site for low- and intermediate-level waste, however, with a restricted capacity of 303,000 cubic meter. So, the planned operation will be -- just recently they have postponed that. Now it will be 2027 should be in operation.

Coming to the Asse site now. So, the Asse salt mine originally was heavily exploited from 1909 to 1964 as a potash and sodium chloride salt mine. And after shutdown, there was a very large void volume left of 3.5 million cubic meters. In 1965, it was decided to have the Asse salt mine established as some kind of research mine for testing demonstration of the disposal techniques for nuclear waste. So, it was not too expensive, also not in a very good shape, I have to say. So, this is clearly seen from some kind of reports on this time. So, in 1967 to 1978, this was, however, the Asse salt mine was also used for the disposal of low-level/intermediate-level waste, these 126,000 drums. So, it was now not only research laboratory but also a repository. So, this is something which, in the current view of many people, is not understood how this decision could be taken at that time. So, if we just, however, look to the time, then one has to look probably also to the contemporary view how to deal with this type of waste. A number of our neighboring countries at that time preferred to have sea disposal or open sea disposal of this type of waste. So, from this point of view, it was probably not so bad decision to use the deep geological disposal for this type of waste.

However, in 1991, there was an increasing inflow of brine from the southern flank in the mine. So, this is something which was certainly not a good evolution of the site. So, I will just show you a little bit later how this looks like. In 1994, there was reports on contaminated brines, mainly tritium, cesium, and strontium found in these contaminated brines. These were internal reports; was not so much communicated to the public. So, it’s also scientists from our institute who work for the Asse salt mine at that time, for geochemistry issues, were not informed about this type of contamination. So, this was not so much openly communicated.

So, the antinuclear discussion in Germany increased and became more and more violent as well, and there were a number of protests against, again, the events in the Asse salt mine. So, finally, in 2007, there was decided to have a monitoring group initiated with members of the civil society. They had a closer look at what has happened, and then in 2008 there was an article in the local newspaper on the side that water in the Asse repository was radioactively contaminated, and this was a scandal at that time.

It was really initiating a very rapid process. So, I just wanted to show you a little bit what has happened. So, this is the Asse salt mine. You can see these are all these caverns where rock salt has been mined during the beginning of the last century. Here is one cavern where intermediate-level waste has been disposed, and most of the low-level waste, mostly cemented waste, has been disposed at the level of 725-, 750-meter depth.

So, the incoming water from -- can you see that the mining has been made until very close to the border of the rock salt diapir, and there is water now inflowing into the mine. So, most of the water which is coming in is not contaminated, so it’s a constant inflow of about 13 cubic meters per day. So, this is captured here and then brought to the surface. And here’s a small amount of water which is coming in, and it’s probably also coming from outside and apparently has some contact with the radioactive waste that’s contaminated. So, that’s the situation as it also looks like today.

So, in 2008, then it went very rapidly. So, the responsible organizations initiated another working group on the comparison of options, how to deal with the Asse salt mine. A new operator was nominated, now the Federal Office for Radiation Protection, BfS. Now it is the BGE, the new implementer for nuclear waste disposal in Germany. There was a committee of inquiry set up. And the BfS made a comparison of remediation options, everything within a few months. And then some years later it was, so to say, written in the law what was the outcome of these investigations.

So, the working group on the comparison of options made suggestions for three options what could be done in the Asse salt mine. There were feasibility studies completed within a few months, as you can see here, whether this work can be done or how they can be done. And then one year or a few months later, the BfS made an evaluation and presented the results to the public.

So, what were the three options? So, the first option was complete retrieval of the waste out of the mine, where everything out. Second was complete backfilling of chambers and drifts, leaving the waste where it is. And the third option was an internal replacement of all or parts of the waste to lower depths, to about 900-meter level below surface.

The evaluation of the BfS was made like this, that they set five criteria where they ma~~k~~de an assessment of the individual options. So, the first one was safety during operation; environmental impact due to uncontrolled water access; assessment of long-term safety, of course; technical feasibility; and duration of the measure.

So, for all criteria except one, the backfilling option was considered the best. It was, however, doubted that it would be possible for the backfilled mine, that there c~~w~~ould be some kind of a reliable assessment of long-term safety, and that was the reason to decide for the second option, and that means for the retrieval of the waste.

This was then written by -- or decided and also fixed by law. This is an amendment of the atomic law in Germany, the Lex Asse. This is the Act to Accelerate the Retrieval of Radioactive Waste and the Decommissioning of the Asse II Salt Mine. So, the main content of this law was that it was said that it’s not necessary to have a licensing procedure which is usually taking quite a long time for these activities, and Asse salt mine would be required until closure. So, this should accelerate the entire process. It is, however, also said that waste retrieval must be interrupted if the implementation is not acceptable, if it poses too much risk to the population and the employees to radiological and other safety-related issues. Other safety-related issues is you have a large void volume in the mine and for a long time not very much done to stabilize the mine, so there is a certain risk that there's some kind of mechanical instability and some kind of breakdown of individual chambers. So at the moment it looks pretty stable but this risk is certainly not to be excluded. What is a little bit amazing is that there is also a passage in this Lex Asse that the licensing authority can in an emergency case stipulate the design basis accident planning value at a value above the usually taken 50 millisievert to the population. This shows a little bit that the authors of the law recognize very clearly that retrieval of the waste poses as well some risk. So the other things I want to make clear is that some things have changed from the original idea to retrieve the waste and it has been – another option, the best option for closure has to be selected but this has to be communicated and discussed with the parliament and the public.

So coming now to the consequences of all these events and the decision for retrieving the waste from the Asse salt mine. So first of all it is not really clear after all these events and after the discovery of contaminated brines in the mine how the wastes and the emplacement chambers really look like. So there's some kind of exploration has been started was taking over several years so in the meantime there have been two chambers have been explored. They look pretty well, so the waste barrels look pretty [inaudible], and also the backfill material which is saltcrete has compacted during all these years, so they look pretty well. However, they did not look at the moment for these exploration processes to those chambers where really the contamination was detected. These were chambers where nothing was detected before. So it's at the moment not clear. So there has been some kind of a decision to start with these chambers because they look very good and it should be possible to do the retrievable starting with these two or three chambers.

Second point is it is not clear how to retrieve the waste. So in any case there will be a stabilization of the mine requires all kind of retrieval operations, need stability of the entire mine, and part of the radioactive waste might not be retrievable. So, the contaminated brines in the repository have been pumped down to 900-meter depths, so it’s a total of about two gigabecquerel of radioactivity, so mainly tritium, cesium, and strontium. So, it’s not clear whether these contaminations can be retrieved, and it’s also not clear whether the contaminated rock salt in these chambers can be retrieved totally.

So, for these technical measures for waste retrieval, there has been some kind of studies made as well as KIT, at Karlsruhe. So, there is a group of engineers who made some kind of a check for different technologies that are available on the market which could be used for retrieving the waste. So, they identified main steps for retrieval, uncovering and loosening of the ~~barriers~~barrels, bite and lifting, loading, and transportation. So, basically they found a number of different technologies, for instance, a lot of challenges as well. So, they made some kind of test with some kind of salt concrete where they had some ~~barriers~~ barrels inside. And if you are taking then a milling machine, so the milling machine must then be able to remove the backfill material but not to destroy the ~~barriers~~barrels. So, this is already a challenge.

So, one of the things that came out of this study is that there are some technologies available but there is definitely a need for development of these existing technologies. So, one of the probably planned technologies is some kind of a sheered tunneling machine, so this is a scheme ~~tier~~here, so this is a machine, a tunneling machine which is equipped with some kind of manipulators. They can loosen them in the theory, the ~~barriers~~barrels, and take them away into these containers and move them away so it’s a real factory which is then intended to move through the repository. So, it’s certainly also not something which is available from the shelf.

So, these are, more or less, the technical problems. The other things that at the moment -- I happily discussed that something has to be done with the waste if it is taken away from the mine. Conditioning interim storage facilities are needed at the surface, and there are also nuclear transports necessary to the disposal facility which is final~~e~~ly selected, and also from the mine to the interim storage facilities. So, with these accompanying and monitoring groups, there’s heavy discussion where this interim storage facility should be located to. So, it’s more and more clear for the population on site that they realize that even if the waste can be retrieved from the mine, it will stay on site for the entire lifetime. So, it’s also decided that or said that the retrieval cannot start earlier than 2033, something like this. So, it’s clear that until the end of this century, at least part of the waste will remain there.

Another topic that’s also coming up that even if the waste has been retrieved, it’s not clear where to put it. We do not have a repository for this type of waste at the moment. For the Konrad site, this waste is not possible to take it there because this has just a limited capacity, and this estimated waste volume of 200,000 cubic meters approximately of this waste from the Asse salt mine would not fit here. So, there’s another suggestion to put this type of waste from the Asse salt mine to the same site as the high-level waste repository which is, at the moment, selected or found by this new process initiated. But also there are some kind of problems to be considered which are, at the moment, not answered, for instance, how would be the interaction of these different types of waste on each other.

And the other thing is that there is a heavy criticism by the Radiation Protection Commission in Germany about this point with the stipulation of the dose rate in the case of emergency cases. So, the Radiation Protection Commission says that the principle of justification and optimization of radiation protection measures is not really applied in the Lex Asse. And all these things that are happening here is clearly mistrusted by the local population because everything what is now said it’s not really believed and it’s very difficult now to find the process and to proceed with the different measures to be taken.

Some conclusions from all that. So, one of the main conclusions I would say right now is that the Asse case is certainly not representative for retrievability discussions for high-level radioactive waste that we have just discussed in the previous talks for two different reasons. The repository design is certainly not state-of-the-art, from today’s point of view. One could also say probably that the repositories that are developed right now will be also not state-of-the-art 100 years in the future. And there were no retrievability measures initially planned, so this is very much clear. It was never the intention to retrieve the waste from the Asse salt mine.

Probably there’s some things, some issues in the sense of lessons to be learned from the Asse case, which also could be transferred in future planning for retrievability options in a repository. At least in the Asse site it was very much clear that there’s a totally different perception of waste retrieval by the public and what it means in practice. So, it was very clear that the communication to the public, the explanation, how it was done was not adequate, and that’s certainly a requirement that has to be done. I mean, in many of these nuclear waste disposal projects, retrievability, reversibility are things that are clearly considered by the public as necessary. And in this case, they are also implemented in the existing nuclear waste disposal projects, but it must be clearly communicated to the people what it means. In any case, it means long timescales have to be considered. Even if the decision is taken that the waste will be retrieved from the repository, it will take decades or centuries until this has been accomplished. And this has to be considered and has also to be communicated to the public that it -- so, I mean, one of these technical feasibility studies said for the Asse salt time, removal of one barrel would take four minutes. So, it was clearly not the reality, but it opened up -- yeah, it wasn't -- it made some kind of expectations for the public which finally cannot be fulfilled.

Retrievability measures, so, in many cases or in some cases, it is also combined with the concept where there is some kind of a simplified access to the waste. In this sense, there is probably some kind of shafts and access tunnels are probably filled and sealed at a later stage of the process. Some parts of the mine left open for a while. So, I did not see that for the presentations that have been just shown here in the morning, so and I think it's also a good plan to have -- to close the mine, to seal the mine as soon as possible, and then to have some kind of measures where the retrieval of the waste can be simplified in a certain way. But if there is some kind of open parts of the mine, then one has to think about the timescales that we are considering with these opening times of parts of the waste. There are some risks coming up.

Regarding economy development, is there some kind of money available for close the mine? Then afterwards I think Piet has said that there’s also the risk that the interest in the public is decreasing and nothing will happen, and there is no impetus to close the mine at the end, so this should be considered. It can also, regarding risks about a society evolution. I mean, if you’re just looking for several decades or even a century, I mean, we do not know how societies will evolve. And during that time, if there’s not some kind of appropriate measures to be taken, then one has to expect some decline of technical robustness of the barrier system. So, all these things have to be considered, so we are just, in this case, if we are just implementing such kind of retrievability options where the mine is not really sealed and closed at the end, then we would have a problem, and the problem has been postponed into the future. And that is just what I wanted to say. And I would like to thank you for your attention.

BAHR: So, thank you very much. Sort of in the theme of this meeting, which is retrievability as well as monitoring, it sounds like there was not much in the way of monitoring at the Asse site in the beginning. Has there been an implementation of a monitoring program there now as part of the exploration that's going on, or is that still to be developed?

GECKEIS: So, at the moment, there is, of course, some kind of intense monitoring of the mechanical stability of the mine because they are just making all these seismic exploration monitoring in order to see how the mine will behave in the future. And, of course, there is continuous monitoring of the ~~primes~~ brines that are found in the mine on radioactive contamination. I mean, there is quite a number of monitoring systems that have been established, even before these cases, but it was never assumed that this would pose a problem.

BAHR: Paul.

TURINSKY: Somewhat off the direct theme of this meeting, but the fact that brine did penetrate the mine, was that due to a lack of scientific understanding of the time or was it due to just lack of applying science in a systematic fashion?

GECKEIS: There is a strong debate about this. So, ~~there's not much there~~ I would not dare to make some kind of an assessment from my side at the moment. So, if you are just looking to the past, I mean, the Asse II mine is one of three actually. So, there was the Asse I and the Asse III. All three of them have been heavily exploited. And Asse I and Asse III finally have some kind of water access to the mine, and finally we are flooded. So, there were some kind of assessments of the status of this mine, of the Asse II mine that the probability for water intrusion is relatively low. So, that was basically said in the beginning. So, whether this was really justifiable, this is an open question at the moment.

BAHR: Steve Becker.

BECKER: Becker, Board. What kinds of communities and populations reside in the vicinity of the Asse mine?

GECKEIS: So, there are a number of environmental and civil NGOs, if you would like, so different organizations who have really the focus to be against the Asse salt mine. And they are coordinated in some kind of an Asse II coordination group, so to bring all these arguments and also the representatives into this monitoring group. So, there are quite a number of these civil science institutions there.

BECKER: And do many people live near the Asse mine? What kinds of villages or towns are located there?

GECKEIS: There are two or three smaller villages in the surrounding of this mine. They are really addressing this issue very strongly.

BAHR: Tissa. And then Efi.

ILLANGASEKARE: Illangasekare, Board. Is this working? So, in the criteria, I didn’t see any cost. Did you consider cost in here, the cost of the operation, like going 900 meters below, that would be a major, much more expensive?

GECKEIS: I think that costs have also to be considered, but I think it was not the major issue in this. So, it’s basically, as you can see, the long-term safety was considered as the most important criteria.

BAHR: Efi.

FOUFOULA: Foufoula, Board. Are you hopeful that you will have operation of your repository by 2050?

GECKEIS: I’m just citing what has been said by some organization, so this was just an estimation of the Federal Ministry for Environment. So, but even the commission that has been set in by the Parliament was very critical about this date, so they did not believe that it’s possible until then.

FOUFOULA: Yeah, no, I appreciated the history that you presented. We know all these facts, but, you know, every 30 years, if we have a Chernobyl or Fukushima, then it changes the direction.

GECKEIS: But, I mean, in this case, we saw that the decision to phase out of nuclear by 2022, and this is certainly an irreversible decision. So, this paved the way to have some kind of process initiated, and it brought -- so, even the Green Party was part of this Site Selection Act, and this is certainly some kind of optimistic view unto the things. So, that gives some kind of hope that this time it could happen. It’s not clear. I mean, there are always some risks that something would fail, but at least there is some kind of a political consensus. This was not so in the past.

BAHR: Sue.

BRANTLEY: Sue Brantley, Board. I didn’t really understand what happened. I understood that water came in and then you used the word “flooding” and contaminated brines. Can you tell us what you think happened, and then also how did the people in the area find out about it? Because it all seemed kind of murky, like it wasn’t being reported or it was reported internally but not externally. So, what -- can you tell us what happened?

GECKEIS: So, initially, there were different organizations responsible for the mine. So, in the earlier days, it was the mining authority of the local state was responsible, and they got these reports as well about contamination of the brines. So, for a long time, the contamination was below exemption levels. So, then they decided they'd pump it down. And then after a certain --.

BRANTLEY: But how did they know the brines were contaminated? Were they sampling periodically or something?

GECKEIS: Yeah, they made it periodically.

BRANTLEY: They went down there and sampled?

GECKEIS: Yeah, yeah.

BRANTLEY: Yeah.

GECKEIS: No, it was -- the contaminated brines came in at the 750-meter level, in this range, but these contaminated brines, they were captured there and then they were brought into a level of 900-meter depths, because they could not bring it above ground, so they put it in these lower levels of the mine.

BRANTLEY: So, there was internal reports and you were --.

GECKEIS: But not very much openly communicated, which was then, when it came out, I mean, it was a disaster.

BRANTLEY: How did it come out?

GECKEIS: Hmm?

BRANTLEY: How did it come out?

GECKEIS: They had looked to the reports. So, they were just installed as a kind of monitoring group, that means they had access to the papers and the reports. So, they could have looked what has happened and then they found it out.

BRANTLEY: So, there were public reports but nobody was looking at them carefully enough to notice it or something, and then somebody started looking at them, and when they looked at them, some reporter put them all together with the group's understanding and published it.

GECKEIS: Yeah.

BRANTLEY: And that's when it became --.

GECKEIS: Yeah, mm-hm. So, I do not know what you mean with public report. I mean, there were internal reports, so from the Asse salt mine, from the implementer at that time to the mining authority, but this was never published. So that means the reports were available, but it was not communicated.

BAHR: Other questions from the Board? I have one. So, given the fact that salt is quite plastic, what kinds of things, if you were designing a repository in salt that would allow retrievability, what would you do differently from what --

you know, Asse was not designed really as a repository to begin with, but what kinds of features in a repository design in salt would facilitate retrievability?

GECKEIS: First of all, you should not take a mine, an abandoned mine, so with a large void volume. I mean, this is something that cannot be done in this case. So, if you want to -- this was the concept for the Gorleben site, and this was also something where the Gorleben site was heavily criticized because it was said what happened in the Asse salt mine is something which will also happen at the Gorleben site. But for the Gorleben site, it was always planned for this, that there was just drilling of these emplacement chambers so the waste could come in, and then it would be backfilled. So, it would never be the case that there is some kind of large, open void volumes available. So, this was clearly the plan.

For the retrievability, I mean, this is also an issue. We saw that for the retrievability, there would be some kind of different emplacement concepts to be developed. So, they have made some kind of, for instance, borehole systems, similar to the French concept with the liner, where they put the containers in, and the pressure coming from the rock then is then kept by the liner. So, that means the containers could be retrieved afterwards. I mean, such kind of concepts were planned and developed could have been implemented in this case for retrievability in the salt mine. So, this principle, it should be possible to have something like this.

BAHR: Sue.

BRANTLEY: Sue Brantley, Board. You said that the public perception of waste retrieval was different. Can you just be explicit about that? What do you mean exactly, the public thinks it’s really easy and it really isn’t? What do you mean?

GECKEIS: So, I mean the local population from these three villages close to the Asse salt mine had the impression it is now decided to retrieve the waste, and within, let’s say, ten years the waste is away, it’s gone. And this was certainly the wrong perception and wrong expectation.

BAHR: You also had a bullet that said some of the waste may be irretrievable. Is that just the brine that they pumped down lower, or are some of the barrels themselves that are so compromised that it would be very dangerous to bring them back up to the surface?

GECKEIS: Well, it was not always so that the waste barrels have been explaced in a very regular way. So, they had in earlier times also the idea to reduce the dose exposure to the employees there so that they are just made some kind of a wide deposition of the barrels. So, it was not clear whether the barrels survived for this operation. The other thing is that it’s clear that there has some kind of corrosion taken place because there is some kind of contaminated brines. And it’s not clear whether all these contaminated soils and these contaminated regions can be retrieved from the mine. So, that is basically what I mean. And also these contaminated brines that have been brought in the deeper layers, deeper levels of the mine, they are just migrating somewhere. So, it’s also not clear whether everything can be removed. It can be probably, but there is some kind of a risk that a part of the radioactivity remains in the mine. And the Asse salt mine remains a repository.

BAHR: So, is that the result then, that it just remains a place where you try to institute some institutional controls once you've removed what you can, you backfill what's there and walk away?

GECKEIS: This is also something which is, to my opinion, a little bit strange. I mean, the emplacement of the waste has been terminated in 1978, 1979, but there was no real concept of a complete backfilling of the entire mine. If this would have been done, I mean, probably this problem would not have been appeared, if the mine would have been stabilized. It has been partially stabilized but not completely, so there is still some kinds of large void volumes available. So, under these conditions, I mean, it should be possible also to completely backfill the mine but also stabilize and prevent further brines from outside penetrating into the mine, but it has not been done.

BAHR: Are there other questions from the Board? Paul.

TURINSKY: Turinsky, Board. What if you do nothing, what are the consequences if you do nothing?

GECKEIS: There have been studies in this case. I mean, one of the consequences to be expected would be really all of a sudden intrusion of large volumes of water into the mine. And if water coming from outside that can be as well cause some kind of redistribution of the rock salt and that means also some further mechanical destabilization of the mine. And that could also bring -- with this development, it’s also possible that large contaminated volumes of contaminated brines are pressed out into the overlay of the rock salt formation. I mean, this is something which is a so-called emergency case. They are also looking at the moment to this. In this case, if they see that there is some kind of an unmanageable water access to the mine, and also some kind of mechanical destabilization of the mine, they are preparing to have some kind of magnesium chloride brine tanks prepared so that then the mine is flooded with magnesium chloride brine. So, the advantage of this kind of a measure is that the rock salt would not dissolve anymore and some kind of mechanical stabilization of the mine as well. So, this would be, so to say, the emergency measure if something is going in this direction.

BAHR: Any questions from the staff? Bobby.

PABALAN: Roberto Pabalan, Board staff. So, if they flood it with magnesium chloride brine, what volumes are you talking about?

GECKEIS: You saw that. I mean, this is hundreds of thousands of cubic meter. Must be quite a lot.

PABALAN: Second question. In your slide number 19, there’s an illustration of one of the possible technologies for waste retrieval. It looks like it’s a facility -- it’s a building actually, it looks like it’s a building. You said it’s a shielded facility I think with some arms that will be used to lift and retrieve the waste. Has there been a study to look at the remotely-operated vehicles to actually retrieve instead of just these arms?

GECKEIS: So, this facility would be remotely controlled, of course. So, I mean, there are some experiences with these geo tunneling machines in the case of tunneling through cities, for instance. That's certainly not entirely new, but for this purpose of retrieving the waste, it's entirely new. I mean, there are a number of developments would have to be taken in order to make it applicable.

PABALAN: Okay. I'm just wondering about the length -- the reach of the --.

GECKEIS: It's a small factory which is then moving through the mine.

PABALAN: Okay. Okay.

BAHR: Dan Metlay, did you have a question?

METLAY: Just have a follow-up. Dan Metlay, Board staff. So, when you presented the BfS analysis of the different options, I'm wondering if you could go back to that. There we go. So, clearly, these options have a different set of tradeoffs; okay? There’s no single option that is superior across all three rankings. So, at some point, tradeoffs have to be made. Obviously in this case, the tradeoff was made by BfS and ultimately by the German Parliament. Can you tell us something about the process in which those kinds of tradeoffs were discussed?

GECKEIS: I mean, there is a report. This is available how the Federal Office for Radiation Protection makes this kind of assessment, and basically this is now in a very short mode, the conclusion that has been taken. Tradeoff, I mean, in this case is that actually I saw that they had to make some kind of ranking of the criteria as well. And the main criteria which was really put as the most important is the long-term safety assessment of the option, which is also -- I mean, it’s not clearly understandable because also for the retrieved waste it’s not so a priori that you can say that the safety assessment is now for sure can be done. This is also not the case. So, it’s certainly also some kind, as we discussed, some kind of political decision also behind. But, at that time, I mean, you have to also have to look to the situation which was taking~~en~~ place at that time. There was a big scandal about the discovery of these contaminated brines, and it was clearly communicated and perceived that the Asse salt mine is completely unsafe. And that is probably also the reason that the main aspect was really the assessment of long-term safety, to say we have to go this way, retrieve the~~d~~ waste.

METLAY: Right, but the way I look at the chart at least, the long-term safety was so dominant that it overwhelmed all of the other considerations.

GECKEIS: Yeah.

BAHR: Okay, I think we’re -- yeah, we’re about out of time, so maybe we can leave it to the panel. Will that work? Okay, yeah, just to keep us on time.

METLAY: Okay.

BAHR: Thank you. We’re going to change gears a little bit now and switch to a couple of talks about monitoring. Our first speaker is Dani Or from ETH Zurich, and he’s going to be talking about sensors and monitoring technologies for subsurface seepage in a geologic repository. And you're mic'd up?

OR: Thank you. Good afternoon. It's a great pleasure and honor to be here and share some thoughts about the challenges of the long-term monitoring in the deep vadose zone. For the non-experts in the audience, I need to define what a vadose zone is. It's very simply the region -- oh, of course -- it's simply the region between the land surface, as you can see here, and the water table. In the case of Yucca Mountain, it would be a few hundred meters below the surface, but in temperate regions in Europe, East Coast, it would be a few meters below the surface. So, the focus will be on how do we monitor processes in that extensive zone that is relatively dry, not saturated, let's put it this way, it's not so dry.

Okay, so, in a way of an outline, I'll talk about some common features of deep geological high-level waste repositories, what d~~e~~rives the need for monitoring in performance assessment. So, I'll touch upon stuff that has been already discussed this morning but from the angle of the monitoring itself. We'll talk about measurements in the vadose zone, what variables we are interested in, how do we measure them, what technologies we have. I'll try and be minimally technical, just for the -- not to bore you too much with details. We'll talk about long-term vadose zone monitoring, some of the limitations of present technologies and capabilities. We'll also create a differentiation between the shell of vadose zone, which tends to be highly dynamic, and the deep vadose zone that tends to be relatively stable, and that will ~~fixture~~ feature into the way we plan monitoring activities there. What's missing will be an important aspect of how do we move forward to meet that monitoring challenge, and I'll make some suggestions, I guess, for the Board of what I think needs to be done, what kind of technology advancement we need to be making to meet this challenge.

So, just to recap about the objectives, I put this as a deductive safety net in case nobody mentions the objectives. So, we like safe placement of spent nuclear waste, with minimal human interactions as related from environmental fluxes, and contained against leakage, inaccessible to, or maybe at least warning for future generations, and resilient to climatic and geological perturbations, that's kind of my summary of the needs.

The landscaping or the places where these repositories are built are different. They are hosted in different geologic formations, from clays to granite to tuff. They are sitting at different climates and biomes, from deserts to alpines to tundra; different containment plans; different engineering designs, as we heard; maybe retrieval considerations; monitoring protocols; and, in general, different regulatory landscapes that feature into the way they operate.

So, all of them, though, share some feature, in one form or another, of monitoring. ~~Other~~ Either as an integral part of site performance assessment, to provide safety measures, alert for design deviations, for variations in environmental conditions because of the long-term planning horizons involved. Leakage and other failures, that's the purpose or the primary purpose of this monitoring.

I like very much this summary from Hanks, et al, from the USGS circular in 1999 that kind of summarized this, they said that “We regard continuous monitoring to be both a safety issue and a site-credibility issue.” These are really two separate things. One has to do with the operation, the other is building the public trust that everything is okay, and that, I think, is quite important, and we’ve heard that before. They also added that we believe that careful description of proposed monitoring strategy and a detailed list of what is to be monitored and why, where, how, and for how long should be developed expeditiously, which means this is not something you do afterwards, this is something that you plan well ahead of the repository construction.

So, what are the challenges that we face in the deep vadose zone monitoring? We need to -- so, this is kind of a picture from Yucca Mountain with the fluxes on the surface and the geologic formation below. We need to sense quantities very deep, a few hundred meters below the surface. The duration of this observation is unimaginably long, a few hundreds to thousands of years. The environment is quite heterogeneous, and system is relatively slow-responding in the case of deep vadose zone. And in general, none of this collection of activities has ever been attempted before. So, that, by itself, is already quite a challenge. And I'll come back to highlight some of the specifics when we talk about the technology itself.

So, here's a sketch of the cross-section of Yucca Mountain, in this case. Here is the vadose zone, the water table. And you see all this bunch of blue arrows, they represent hydrologic fluxes, and we worry about them because they can carry with them accidental release of canisters or they can accelerate corrosion, for example, of canisters by fluxes over the canisters in the drift. So, basically, we'd like to monitor the hydrologic state variables in this system, in particular the water content and the matric potential. Again, for the non-expert, the water content would be the amount of water held in the pores of the rock and the matric potential is how tightly they are held there by these capillary and absorptive forces. So, these are the two primary ~~qualities~~ quantities that we need to monitor from which we derive later on fluxes, a magnitude of fluxes, maybe pathways also.

We also would like to track pore water composition. This is primarily for detection of release of radionuclides for example, but not only. We can monitor the composition of pore water also for corrosion considerations, especially over long period of time. And we also heard that we need to monitor the mechanical state of the repository. So, all of this happens in this system.

We have -- maybe I'll show this. So, we have the challenges of how do we place sensors in such a depth. We don't have that much experience with that. How do we power them? And the whole list that Piet showed in his presentation. If these are sensors that measure over extended periods of time, to trust the information, we have to know that the data coming from the sensors are reliable, so we need some diagnostic or some self-calibration for these sensors. Near the drift, we'll need special provisions to ensure that sensors are radiation- and temperature-hardened, at least for the initial phase of the operation. And very important and we are not paying enough attention to it I think is the measurement protocols that we need to develop specifically for this deep vadose zone monitoring. And a threshold for action that we heard earlier, what do we do with the information, how do we convert it, if necessary, to action.

So, the sensing technology that we have at our disposal is not very broad. It's quite narrow. For measurement of water content, of volumetric water content, we have neutron scattering techniques in which we lower a probe below the surface in some access tube. That probe would then ~~make~~ emit fast neutrons that collide with hydrogen atoms in the water. And from the slowing down of these neutrons, the thermalization they call it, we can deduce the amount of water that is held in that volume that is probed by this neutron probe. This technique has been quite popular in the sixties, seventies.

And I think by the eighties and nineties, being superseded by less radiation hazard techniques, such as this electromagnetic base technique called time domain reflectometry. The principle is simple, you have a fork-like sensor placed in the rock or in the soil. You send an electromagnetic wave down this probe, and from the speed of propagation or reflection, you can deduce what the average dielectric constant, it’s a property, around that probe. And from that, we deduce the water content. So, this is not even now not off-the-shelf technology, but it is quite well-established.

In more recent years, rather than sending waves and having all these timing issues, people have developed a sensor that also measure the dielectric constant of the soil or the rock, but they use a capacitance. So, these probes are, again, inserted into the soil or the rock, and you measure changes in the capacitance and deduce from that the water content. So, these are very popular. They have less accuracy than these, and we’ll talk about that.

Finally, there is a class of methods that are geophysical methods, such as ground-penetrating radar. In the context of a repository, it would be some form of a cross-borehole radar. So, we have two boreholes in which you~~r~~ lower an ~~meter~~ emitter and a receiver, and you measure a quantity in between that is sensitive to water content. They don’t provide water content measurements that we can plug into models, for example, but rather some inversion sensitive quantities that are related to water content. So, they are not there yet, but they are elements that we should consider for monitoring. So, all of these were for the water content, the measurement.

For the matric potential measurement, we also have a very narrow suite of sensors. Some of the sensors that are based on relative humidity above a sample. So, you basically measure the vapor pressure or the relative humidity above a wet sample. From the equilibrium between the energy state of the liquid phase and the vapor phase you can deduce what the water potential in the sample is, and we call this psychometric measurement. There are basically little sensors of the order of a few centimeters you can place in the rock, and you can measure from that, monitor the water potential. It is extremely sensitive to temperature, but, much worse for us, it is extremely sensitive to very high relative humidity, exactly where we need them to function. So, that’s what we have.

A bunch of other sensors, a group of sensors are based on measuring the water content in a calibrated porous block from which we deduce ~~to~~ the potential in the rock that is in contact with it. So, basically, take a sensor, you place it in the rock in ~~[inaudible]~~ hydraulic contact, let it equilibrate, and we have plenty of time to do that in the monitoring scheme that we are talking about, and from the measurements of the water content inside these porous blocks we can deduce what should be the water potential in the rock in contact with it. So, these are the way you measure the water content can be either by heat dissipation in these types of sensors or by direct measurement, very much marrying these two sensors to get the matric potential. Okay. So, that's the second group of sensors.

The last group of sensors is tensiometers. They are, again, measuring matric potential. It's nothing more than a tube filled with water, with a ceramic cup that is in contact with the rock. If the rock is dry, then the sensor basically pulls water out until equilibrium is reached, and we read that equilibrium either with a pressure transducer, and we basically deduce what the matric potential is. The point here is that it’s been very successful for agricultural applications. I don’t think it is very useful for a deep and long-term vadose zone monitoring simply because these sensors require heavy maintenance. You have to refill the sensors every so often. And also they operate in a very narrow range of potentials between zero and -.8 bar, for example, and in some formations this is not enough to ensure functionality.

So, this is kind of a very brief overview of the techniques we have to measure these variables. I’m showing here a table from a recent report from Argonne National Lab, from Sheen, et al., basically listing the techniques, listing the property measured, the derived information, and the resolution. The point of showing this for you is primarily just that there is consensus among -- very broad consensus about what techniques we have at our disposal and what they use and also what the resolutions associated with them. Okay.

One additional point with respect to these water content sensors, just to give you a visual picture of these sensors that are available in the market. With the exception of these two here on the top, all of these are capacity- or impedance-based sensors. The point I wanted to show you is because there is electronics embedded in all of these heads that would be required to be radiation-hardened and temperature-hardened for them to operate in the near-drift measurements. And also to point out that all of these sensors are point measurements, and it's a very important point when we talk about the monitoring network.

Some of the measurement errors associated with these sensors, most of the dielectric electromagnetic-based sensors would have an average measurement error of two, maybe four percent volumetrically water content. This translates maybe to five to ten percent of the total range of water contents in terms of errors. It's not clear yet whether it is critical or not, depending on how this error propagates into your ~~entrances~~inferences. For the matric potential sensors, the situation is a bit less favorable. We're talking about average errors of about 25 percent of the measurement, especially in the wet end. So, the wet end is actually not so favorable for measurement of the matric potential.

In terms of other sensors that I mentioned, for example, for pore water composition, we have something called suction cups. Basically these are, again, tubes with a ceramic or porous stainless steel in contact with the rock, we apply suction onto this device, we pull ~~pour~~ pore water from the rock, and we sample with another tube that periodically we sample that collected water and we analyze it outside. So, that's the basic idea. So, it's not a bad kind of legacy-forming measurement, but it is laborious, it can be done only at a few points, and that's it.

There is a new -- there is a drive for in situ chemical sensors for detection of compounds in the pore water, like this chemiresistor array from Sandia that measures volatiles. And more recently there is a whole slew of sensors that -- I'm sure you cannot read this, but, again, it's from that report by Sheen -- of sensors for measuring radionuclides in situ, for example, this fiber optical sensor for tritium detection. And there are evidence -- I'm not an expert in this, but there are evidence of emerging technologies to accomplish this for a broad range of types of radiation.

Finally, in terms of sensing technology in the last decade, a whole suite of sensors based on fiber optics have entered the field of hydrogeology or environmental measurements. Theses sensors are based on sending a pulse of light down a fiber core of glass, and the interaction of the light with the lattice of the glass and their different ambient conditions will have a signature on the scattered light that comes back. And we can analyze from the spectrum of this scattered light, for example, what was the temperature at different segments along this cable. The attractive feature about this technique or technology is the fact that it is both spatially resolved and also a continuous measurement. So, it can measure along, say, ten kilometers, and get information at the resolution of one meter almost continuously. It has been, this method ~~[inaudible]~~ in the normal term, it's called DTS, distributed temperature sensing. It has been used successfully for looking at groundwater, the people have launched it down a borehole and you can see from seepage of cool and warm water where fractures are, for example; along streams to see seepage of groundwater into the streambed and things of that nature. So, temperature-wise, it’s been very well-established. Also, more recently, for mechanical application, it has been used extensively. We used it for landslide -- for precursors to landslide detection. So, mechanically, interactions of stressors on the fiber optic will modify the light and you can measure that.

And there are some derived applications that are up and coming, for example, this use of this DTS to measure water content in situ. So, you can imagine -- so, the idea basically is that the fiber optic is coupled with some heating element that raises the temperature, and from the temperature dissipation we can deduce what the water content around the fiber optic is. It's still a method in its infancy. It's not yet widely used, but it shows a potential to measure water content along kilometers at resolution of a meter, and I think that's very, very promising if we are able to convert it to a usable technique.

So, to summarize the situation, from my point of view, the technical challenges of the deep vadose zone monitoring are hampered by the fact that we have limited experience in long-term measurements of water content matric potential. I don't think that we have records that are extending beyond a decade of continuous measurements. Most of the sensors are not designed to operate this long, and I think we heard Martin before mentioning that sensors would fail after a few years, and that's basically the experience. We're talking about three, four, five years we have to replace the sensors.

The designs of these sensors, the cables, and everything associated with them, is designed for near~~w~~ surface. They were never designed to operate for very large depths. Most of them are point measurements, and so in a~~n introduced~~ heterogeneous environment we'll have to think of something else. They don't have stellar accuracy of these measurements. It is good enough for hydrological applications. It may or may not be good enough for legally binding monitoring requirements, for example.

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So, in general, we are lagging behind with the technology of monitoring the deep vadose zone in terms of sensing technology and measurement protocol. This is not new. This has been recognized early on and, in fact, in 2001, DOE and Bechtel proposed this advanced monitoring systems initiative for the purpose of acceleration, development, and application of advanced monitoring systems.

So, when you read the conclusions about the state of the systems or of the technology, and what is to be done in terms of sensor requirements, they are basically -- I completely agree with what they have said, they said it, of course, I don’t know, 15 years ago or more, and that need is still there. I think that we have not made the necessary progress to develop sensors that are suitable for this type of task.

So, okay, where am I? So what do we do with that? So, the question is how do we meet this deep vadose zone long-term monitoring challenge given the status that we are in? So, in my view there is no question that there is a need for a strategic investment in the next generation of vadose zone sensors that are rugged, redundant, self-diagnostic, self-calibrating, and some of them, not all of them, need to be radiation- and temperature-hardened. And that, I think, is not something that can be done just relying on the market forces, and I'll explain in a minute why, but it's something that needs to be maybe coming from a board like this, as a recommendation or forming incentives for partnerships that will develop this.

Second, we need to develop a detailed monitoring plan well in advance, one that considers spatial representation, redundancy, replacement, regular replacement of sensor power supplies, sampling schedules, and intervals and so on. So, this is something -- I really like the French. This is the intermediate level design of disposal cells, where every sensor has a place, and it's really well in advance articulated in the planning. I don't think I've seen something similar in other plans. So, this is actually, in my view, very important.

We heard today about monitoring information, and I still think it's an incredibly important subject, to not only address the technicalities of how do we retrieve information from the subsurface, and I gave an example here of some wireless effort people trying to develop for that purpose. But more for processing, archiving, and, of course, formulation of monitoring-based threshold. We heard that also before.

Adaptive monitoring, also, I don't think can be done as an afterthought. I mean, of course we cannot anticipate technology, but we certainly can set in advance the decision points, say, every decade or every 20 years, we have to have a look at the system and decide whether it requires the technological advances, warrants an~~d~~ upgrade~~s~~ of the system. And that, of course, carries with it some issues with information legacy, you know, how do you maintain continuity of information if you change completely technologies and things of that nature.

Finally, in terms of meeting this challenge, I think that subsurface monitoring begins at the surface, and there are things we can do at the surface to constrain or to have better information about what will happen in the subsurface, say, a decade from now for example.

So, just to expand a bit on this point in the remaining time is the idea that in the deep vadose zone, it's really tough and challenging but we do have a break from time to time, and the idea is that the deep vadose zone tends to be relatively stable, unlike the shallow vadose zone, which is, say, the top few meters that tends to be very dynamic. So, especially in an arid region like this, we would expect very, very slow-changing deep vadose zone, and that might need to be factored in the way we monitor. We don't need information every half an hour or an hour, but, rather, we can be fine with monthly, or annually, averages of certain quantities. Also, we don't necessarily need gradients, which are really incredibly difficult to measure in very wet systems, but rather average quantities would suffice for estimating fluxes. Of course, this still does not absolve us from having to worry about uniformity of the flows; for example, focused flow pathways that we still have to worry about.

The second point, already recognized by Dinwiddie and Walter from last year's report -- and, again, I apologize for this, this is just a table copied from their report, showing the different monitoring elements and the urgency of having radiation- and temperature-hardened sensors, especially for the near-drift monitoring. The point is that there are companies already building these radiation-hardened CPUs or temperature sensors, either for the nuclear plants or for space and defense industry. So, we need to perhaps promote technological partnership for this to partner up with these companies to develop these necessary next-generation sensors, maybe by identifying other deep vadose zone potential partners or the gas industry, EPA, maybe the critical zone observatories that are facing practically similar problems of longevity and below-surface monitoring.

Just kind of a cute observation by someone in NASA that the hardened, in this case, CPUs, follow Moore's Law, but they are in a ten-year lag behind the market, but, nevertheless, you can see that even a company like Texas Instruments will have this temperature- and radiation-hardened sensor already today. So it's not a far-fetched concept to say let's invest in developing these sensors. But these are point sensors still.

I would like to advocate, if I may, just the consideration of moving, in addition to point-based sensors, to linear sensors based on fiber optics. For example, the Bragg Grating sensors have been shown in this paper and others I have seen to be already radiation- and temperature-hardened sensors that are easily -- I don't know about easily but readily implemented for this type of monitoring. This fiber optic technology is expanding rapidly. We now have temperature, maybe water content, maybe acoustic emissions and deformation, and I can see applications and can also monitor with fiber optics matric potential.

So that's the kind of ~~hardening~~ heartening story. Just two more slides. One is about the optical fiber sensors as potential backbones for the monitoring that I kind of revised my thinking in response to this invitation, to actually look at it a bit closer. The field is expanding rapidly. In fact, the French, in their design, have prominently featured the fiber optics in most of their planning of the Cigéo monitoring. We should probably consider a similar approach here.

In addition to being extendable from the surface to do the repository footprint monitoring, I can imagine -- I don't know how technically it's feasible to have along-the-drift type of fiber optics, primarily for capturing these focused flows that there is no other way for us to capture them reliably. And I think that the technology itself is advancing so rapidly that it needs to be on the table for us to consider for the monitoring challenge.

The near surface that I mentioned earlier, the thinking is that if I can estimate the flux that leaves the surface today, I can basically predict what will be that flux at the repository level, say, ten years from now. So, if we have a record of the fluxes near the surface, we can basically either check fidelity of what we do below the surface or also anticipate maybe ~~the~~ extreme event, if they occur. So that's one reason to consider monitoring near the surface. The second is that we can create a clock on the fluxes by, say, intermittent release. Every ten years you release environmentally-friendly tracer to mark the water, like t~~h~~ree rings in a study of historical climate, basically to either confirm if the flux is really what we predict or check the fidelity of the in-situ sensors that we have to monitor the po~~o~~re water. So, I think it would be a good idea to think about some kind of -- it's basically active marking of the fluxes as they travel down to the repository.

And finally, the upgradable of the monitoring infrastructure, I think, is incredibly important. Freifeld and Tsang already, in 2006, talked about how spatially we expand the footprint of the monitoring as information is being gathered. And I would add to that also the fact that, in addition to space, we also need to have time imprint, as I said, anticipating technological advances and say, okay, every 20 years we have to have a review of the monitoring and whether or not we need to replace it. Maintaining compatibility and record continuity is, of course, also important, very much like we do with climate, and so that's basically my thoughts about fluxes, tracers, and upgrades.

So, to summarize, and I thought instead of conclusion, I'll add recommendations. Long-time monitoring is part of performance assessment. It ensures the repository functioning and alerts for failure. Continuous monitoring of high-level waste in the deep vadose zone presents challenges, primarily because of our lack of experience, but also the limited technology. However, we cannot just extend concepts from the shallow vadose zone to the deep vadose zone because it is hydrologically quite different. It is more stable, wetter, and so on, and we need to factor that into the thinking.

We need an effort to generate or to develop new generation of environmentally-hardened vadose zone sensors. What's good enough for hydrological applications may not be good enough for monitoring. And for that, you probably need to form partnerships with industries that are experienced in this type of sensing in harsh environments, and also maybe broaden it to other potential partners who might find the use of sensors like this useful.

I think the most important advance in the sensing technology of the last decade for this type of application has been the fiber optics, and I think we could capitalize on that to improve our monitoring capabilities. And, finally, information management and monitoring infrastructure updates should not be just afterthought, but, rather, should be an integral part of the planning of this activity.

So with that, I'd like to thank Stu Stothoff and Cindy Dinwiddie and Randy Fedors from the CNWRA, and John Selker from OSU for many inspiring discussions. I'd like to thank the members and the staff of the NWTRB for this invitation, and the audience for their patience. Thank you.

BAHR: Thank you. So, Dani, one thing that you didn't emphasize, but I think it's important to recognize, is that a lot of the monitoring, a lot of the sensors that are developed for agricultural purposes in the vadose zone are developed for unconsolidated materials. They're probes that you can stick into soils. And if you’re looking at something like the vadose zone in a fractured tuff, it's a rock, and so there are some other limitations on some of those kinds of sensors. Even if you put them into back-filled boreholes, you have to sort of worry about what's that opening and what's that backfill going to do to the water content in the fluxes that you're trying to measure.

OR: Yeah, it’s absolutely true. The introduction of the sensor to the rock is not a big deal. I think the French and Cigéo have basically they drilled TDRs right into the rock, and we have done it also. So, the placement of the sensor I don't think is a critical issue, depending on which quantity. Okay, so for water content, if I need to place a sensor at 500 meters into the rock, I don't how to do it. I completely agree with that.

However, if I'm to measure, if I'm using, say, fiber optic in contact with the rock and I can infer, say, the water potential from the water content of that backfill material, then that opens a possibility. So, there are things that would not easily be translated, and you're absolutely right of placement, or there are certain quantities that we could get by with boreholes. I know it’s not remote installation, but it's borehole installation.

BAHR: Thank you.

OR: It's not.

BAHR: Questions from other board members? Dr. Peddicord.

PEDDICORD: Lee Peddicord from the Board. So, given the timeframe that we're interested in, in monitoring in, shall we say, the mismatch of that timeframe compared to the expected lifetime of sensors, so is it even feasible to have strategies, as you kind of implied in the French installation, or thinking ahead how they're going to instrument and so on? They have a strategy to replace these over decades, or maybe even centuries, or, alternatively, this last point you were just discussing with Dr. Bahr of, instead of putting the sensors down there, have a strategy to bring up the material -- I'm thinking water -- and measure it after you withdraw it, and then back-calculate and determine what the conditions are in situ? It seems to be something more innovative than where we are now if we're really wanting to keep an eye on the stuff on the conditions.

OR: If I understand the question correctly, we have two issues here. One is the longevity of the sensors. It is too short for the task that we are after.

PEDDICORD: I think I got that message from you.

OR: Yeah. So that's one aspect of it. I did not propose to actually bring the material up, I mean, to measure it there. But if, for example, we create a backbone of monitoring that is based on boreholes, for example, then there is a potential for inferring some quantities through cleverly backfilling these boreholes with certain materials, and fiber optic and so on and so forth. But, still, the fundamental question that Jean mentioned that sticking a sensor into the rock with the configuration we have, we don't yet have a solution.

PEDDICORD: And I guess the downside is we're not very keen on putting boreholes into something that you never want to have compromised.

OR: Yeah, of course. I mentioned the fact that we need to have safety measures for puncturing a mountain that contains this. But, okay. So, I didn't emphasize that in my slide on the strategies, but I was thinking of having a far-field and a near-field strategy, one that is more forgiving than the other. But, okay, the details of that, and the safety consequences needs to be factored into the strategy of it, obviously.

BAHR: Other Board members? Tissa.

ILLANGASEKARE: I won’t take a lot of time. Thanks for coming. It was good. So, I think you made an important point, the difference between the deep and the shallow. And then I think the technological advances in the shallow is coming fast in a way.

OR: Not fast enough, but, yeah.

ILLANGASEKARE: Yeah, but the deep. But I think you also mentioned another important point, was the fact that the deep zone is sort of stable. That's true, but, at the same time, in a scenario -- you sort of touched on this -- in a scenario, the deep soil flow to measure as a front in sensors, you happen to have a big flood or something on the surface. But, otherwise, I think the way and most possible pathways is on the fractures and some sort of thing like that. If that is the case, in my view, that this point sensing methods will never work, because you will never know where it is going to be. So, I think I like the idea of the fiber optics for that purpose. So, I think we need to sort of identify the differences and then expect the scenarios, the site-specific scenarios, which will require this type of thinking.

OR: Tissa, just to follow up on this, in what I presented, I thought that there would be a strategy for the near-drift that will have some more -- where point measurements will be more prominent than in the vast out volume of the mountain, I don't see them playing a very important role ~~in~~ --- the point measurements. So that's, I guess, the only distinction I could make, otherwise it depends a bit on heterogeneity and how much money you're willing to invest in putting this.

ILLANGASEKARE: My point is more that if we have to have, really, more innovative thinking when it comes to deep, and we cannot really transfer the technology from the shallow to the deep.

OR: I agree.

BAHR: Sue.

BRANTLEY: Sue Brantley, Board. First of all, I love this thing from Nimmo et al., 1994, I guess that's John Nimmo. Was that measured with things stuck into the wall? Because that goes down, like, at least it's down to 600 meters or something.

OR: Yeah. The data are from Wu, I think they did a borehole actually, borehole measurements.

BRANTLEY: But then they couldn't have put TDRs in the wall.

OR: No. No. So, they used a ~~neutral~~ neutron probe, for example. They lower a ~~neutral~~ neutron probe and measure the profiles of moisture.

BRANTLEY: Okay.

OR: And you can close sections and measure the vapor pressure over time.

BRANTLEY: And then I guess can you just talk a little bit more about geophysical techniques like GPR, because you just mentioned it in the beginning, but that would be brilliant if it worked, right?

OR: Yeah. The problem with GPR and the geophysical method in general would be that it is sensitive to assumptions about the inversion, and, therefore, it requires quite a bit of knowledge. It's not that it's -- I think it has a role, but, at the moment, I think it's qualitative. It's diagnostic. It tells you regions that get wet and get dry, but not necessarily quantitative if you want to feed into a model.

BRANTLEY: But, I mean, like a borehole with all these sensors, or whatever, is so time intensive. It seems like what we really need is a couple boreholes and then a lot of geophysics in between, and then all of a sudden you can interpret your geophysics.

OR: Yeah, I -- that's why I didn't discount it, saying that even if it's qualitative, it is exhaustive in space, enough to give us a picture that point measurements will not be able to. But we still are obliged to provide some --.

BRANTLEY: Grandeur.

OR: Yeah.

BAHR: Other questions from the Board? Just a comment on the cross-hole GPR. It's probably most useful to show you changes over time in moisture content, but that means that you have to go back and do the cross-hole GPR frequently.

OR: Yeah, but it's in the deep subsurface. Things don't change that much. Maybe on a decade long.

BAHR: Unless you're looking for a rapid flow path event, you could easily miss it.

ILLANGASEKARE: [Inaudible] GPR is used for shallow, and that is from the lab to go to the field, I think one idea is actually using more integrated sensor systems. You combine the geophysics with point sensors. So, basically the geophysics to get the qualitative picture, and then you -- so that there are -- there are another field in sensor technology, the computer sciences are working on getting these sensors to integrate, you know. So, basically, what you can do is you have the shallow -- the geophysics to get the qualitative data, then you activate another network for different point sensors to capture those.

FOUFOULA: Foufoula from the Board. So, on that same point, is the future technologies, measurement technologies, or more emphasis on the data analytics; that is, it's an inverse problem. I mean, if we can measure soil moisture down to a few centimeters from space, which is all an inverse problem, and precipitations and so forth. So, how much emphasis should be, now, given in this interpretation?

OR: I tried to emphasize that interpretation information management in the sense of already anticipating not only the volume of data that we heard earlier today, but also what we do with it and how do we leverage it to improve what we'll do next is critically important for the success of this monitoring program. But I think that we first need to get over the obstacle of what we measure and how we measure first, and then, of course, then based on that, we will know what the qualitative information at our disposal. But I think that it needs to be factored into the planning early on rather than wait for data to come and then we'll do something with it.

BAHR: We have time for about one question from the staff, if there is one. Bret.

LESLIE: Bret Leslie, Board staff. You had a figure that was performance assessment and site credibility, and I was wondering at the bottom of the timeline for monitoring, was that just your personal opinion or were you trying to describe --.

OR: Which one is this?

LESLIE: It's the monitoring performance assessment and site credibility. It's, like, the fourth slide in.

OR: Oh, fourth slide, that would be -- it's probably not my opinion, but --.

LESLIE: Well, it's important to clarify.

OR: This one?

LESLIE: One more back. So, observations and stewardship for greater than 10,000 years.

OR: Oh, yeah. That's my opinion, yeah.

LESLIE: Thank you.

OR: So, yeah, you're right. I didn't go to 100,000 years. I don't even know how to think about it.

LESLIE: Well, no, I think the point is, is that monitoring isn't considered for 10,000 years.

OR: Okay. Okay. Fair enough.

BAHR: Okay. Well, thank you very much. And our final presentation, formal presentation before the panel discussion, is from Raul Rebak from GE Global Research who is going to talk about another kind of monitoring related to corrosion of the waste packages.

REBAK: Okay. Thank you very much and good afternoon. So, as the chair said, my name is Raul Rebak. I work at GE Global Research in beautiful Schenectady, New York. It's not Switzerland, but it's no Yucca Mountain either, so.

So, this is the guidelines that the Board sent us to work on, so I'm going to work on those points that you all have in your agenda.

So, this is a triptych that I made regarding the US Nuclear Waste Repository stakeholders. The word "stakeholder" was brought by Maarten from Belgium. And we have this triangle that I made here, the three most important parts. The Department of Energy is responsible for creating this repository, and then the regulatory part is the Nuclear Regulatory Commission that's going to give the okay, or not, to operate the repository. And then we have our wonderful Nuclear Waste Technical Review Board that gives a word of sanity to everybody about how we are going, and then all three will create that. But it doesn't end there. We have a Congress here, and I think the repository now is stalled in Congress somehow. We have the reactor owners, the Nuclear Energy Institute and, of course, the courts. We have more courts on the other side. We have the public opinion, Environmental Protection Agency, and, of course, the State of Nevada. Of course, we have these wonderful Blue Ribbon Commission recommendations, which were all very logical and very sensitive and sensible, and I think they should be implemented.

The good part of all this is that everything rests on this ~~nuclear~~ Nuclear ~~waste~~ Waste ~~plan~~ Fund that should be about $40 billion there, and it would be important to start spending some of this money on the science of the repository. So, this is a triptych that I made. I had nothing to do with any of the Hieronymus Bosch triptych, so no correlation.

So here is Yucca Mountain. That doesn't look like Switzerland. And then the plan, the regional plan, of course, was, as the Chair mentioned, 1982, the Nuclear Waste Act, and then it came 1997, the modification, which designated Yucca Mountain as the sole repository for the U.S. nuclear waste. At that time, it was decided that, 31st January, of 1998, the first waste will arrive to Yucca Mountain.

That didn't go as fast, but we have the different steps through Yucca Mountain, so we're almost in the last step.

Viability assessment was done in '98. President Bush, 43, had the site recommendation 2002. And then President Bush again, 43, was able to apply through the Department of Energy for license application. And at that time, it was decided that in 2020, the first nuclear waste shipment will arrive onsite. Of course, we know that in 2010, more or less, Secretary Chu said that we can do better, and ~~we~~ withdrew the license application from NRC.

So, the definition of performance confirmation is a period of time in which the repository will be monitored. As Bret said, it will not be a thousand years. Maybe it will be a hundred years, and possibly the time starts at the licensing time. So, whenever the NRC says it okay, go ahead, that's the time it will go forth on hundred years or so. The last time that a document was updated was just before the license application in 2008.

So, the waste package is generally a container, plus other things, which are called the engineered barriers. So, everything that we put inside of the mountain, that will slow the diffusion of the nuclides outside of the mountain.

In the very early times where we had three concepts, which later on was just Yucca Mountain, it was considered just a very thick layer of carbon steel -- that would be the concept.

Evolving to 1982, more or less, there would be just a thinner wall of carbon steel. You don't need much because, at that time, people were talking about the paper bag concept, you could put the waste in the paper bag because the mountain itself will be responsible for containing the waste and not spreading to the atmosphere or the environment.

At that time, the design times, of course, for Yucca Mountain was maybe 300-1000 years. And since the container will be hot for many, many years, that would keep the water away. I always tell people -- I'm a corrosion engineer. I'm not a sensor person. I'm a corrosion engineer, so I tell people, you don't have water, there is no corrosion problem.

So, the Yucca Mountain environment, later on, people measured that Yucca Mountain was not as tight regarding the diffusion of radionuclides, so we may start putting a more robust container. So, it would be less emphasis on the mountain and put more demands on the package. So, the package had to be designed just like it would be in the open space, without the Yucca Mountain containing the waste.

So that is when the criteria of the double-wall container, putting carbon steel on the outside and a corrosion-resistant alloy on the inside. First, they said, at the Southwest Research Institute, incoloy 825 would be good enough, very corrosion-resistant for Yucca Mountain environment, and then they started upgrade 625, and they finally went to the top of the top, which is C-22. And then in ’99, they reversed. They put the corrosion-resistant alloys outside, and inside put not carbon steel, but 316 stainless steel, which is very resistant on itself. So, this is about 20 millimeters outside and about 5 inches inside. And, of course, the time went from 10,000 to a million years through the EPA and other litigations, and so just in case this is not good enough, which it was super, super good, they decided to add the drip shield.

So, this is a modernized map for environmental degradation at Yucca Mountain. You can see it is very dry, even though Dani just said that it's not dry, it's not saturated, which is not the same. But it's incredibly dry. So, the material was selected is~~,~~ C-22 ~~[inaudible] –~~ – Hastelloy C-22 -- so we had to be sure what is the~~re~~ metallography, the microstructure of this alloy, how welding~~ and ~~, cold work~~ed~~, and the microstructure. All that will be affecting corrosion behavior. And, also, the corrosion behavior of the container will be affecting what's in the ~~bottom~~environment, ~~and ~~which will be the water with whatever anions -- ~~, ammonium,~~ chloride, sulfate, phosphate, anything; microbe activity; heat, of course; and radiation.

Again, we have to ask this question, is water in the repository? There is no water, there is no corrosion. So, we have anything that is dry, there is no condensation, we can ignore that time, ~~and ~~let's say for corrosion processes.

If there is water, condensed water -- it has to be condensed water -- at least I would say for carbon steel maybe higher than 60% humidity, that would condense one layer of water on the surface. Then you have to see what is the electrochemical potential of the alloy in that environment. If it is below a critical potential for localized corrosion, it will be passive. The material will be passive, and even though thermodynamically it says that the material should corrode, it will take a long time due to a kinetic issue, which is called passivity. If that corrosion potential is equal or above the critical potential, we may expect localized corrosion, which is the most dangerous part of corrosion because it can perforate a perfectly passive container in one spot only. But we ran, when we were at Livermore, many, many studies on that, and we found that localized corrosion doesn't progress forever. Generally, it stops.

And then if we have residual stresses, like in weld~~l~~s or other areas, if there is a collision with a rock or a hammer or something during the laying the containers inside of the mountain, you may expect environmental cracking. And then again, for the thick wall, it's very unlikely that a crack will propagate through the wall. So, all these factors are the one that control the life of the container.

So, talking about passivity, since I'm a corrosion engineer, I want to say this is what is called a Pourbaix diagram. This came from Belgium in the 1950s or so. It is a beautiful piece of work by Marcel Pourbaix. And what it shows here is the electrochemical potential of the metal in the environment, and this is the pH of the solution. This is for 20° C. And it says if you have chromium on the surface, for example, the one that controls the corrosion of stainless steels, if you have potential below -1000 millivolts, it’s an area of immunity. That means that even chromium will not corrode. If you want to see gold, gold goes very high because it is more noble than chromium. But then you have a very large area here, which is called passivity. It means you form a chromium ~~outside~~oxide~~,~~ on the surface, and it slows down the process, and materials that should be going from metal to ~~upside [ph]~~oxide, thermodynamically, it will slow down you to the passivity.

Again, we have to remember this, no water, no corrosion, so this is another thing. Sometimes the designer gets a lot of questions from oil and gas, “How it's going to corrode? It's going to corrode," and say, "It's just natural gas, if you don't have water, no corrosion." "Oh, seriously, no water? Okay." Okay. No water, no corrosion. Remember that. So, as I said, through engineering, we kind of slow down that process, which is called passivation.

When I was in Livermore, we had a very extensive long-term corrosion test facility. We tested more than 20,000 specimens over ten years, and a lot of data was gathered then. We had, like, 36 of these tanks. Each tank was 2,000 liters in volume. There were six racks of this material. In each rack we have specimens, like hundreds and hundreds, I think 256 for each rack. The water level was exactly here, so these were immersed in the solution; this one, the vapor phase. So there's a lot of data regarding these materials in the literature.

So, these are the materials we tested, 14 alloys we tested. But we only got funding from DOE from time to time to investigate C-22, which is the letter D. If you see anywhere in the literature the specimens that starts with a "D," it means this Hastelloy C-22, which is the container, and then letter “N” for Titanium Grade 7. But all these elements here were tested at the same time. These materials are ready for studies whenever the funds reappear for research.

So, sensors and sensing, I have disclaimer. I'm not a sensors person, but I work at GE, which they do a lot of research in sensors. A lot. More than a lot.

So, what is it about the monitoring and the performance confirmations? I said once the license is granted, we have the performance confirmation period starts. It may last 100 years, and then that's the time we're monitoring on the waste packages. Like people already said many times today, the key variables for corrosion, for example, the temperature; relative humidity; if there is condensation and electrolyte conductivity; which ionic species are present; radioactivity; what are the radionuclides; what are the changes of the chemistry of the atmosphere; is there a gas release, no gas release; the accumulation of solid species over the containers, are they nitrates, are they chlorides, sulfates; is there a microbial activity; and then how the stresses in the package evolve as a function of time.

So, sensors and sensing are both here. There was a huge surge in sensor development since 9/11, especially driven by Homeland Security in the United States, but huge. When I was still at Livermore, I remember we were constantly building all these buildings and working on sensors all the time. The word sensor is not a very old word. It's only from 1928 according to Oxford Dictionary, and it's a compounding~~ed~~ of sensory motor, so first "sen" and “motor”, you got sensor. And the word has not been used much until only recently, but recently it's a huge use of that word. People didn't know, but sensors were used before 1928. For example, a Canary on a coalmine was a sensor. So, poor canary, of course. You could use only once, but that's okay.

So, nowadays, sensors now control self-driven cars, so using sensors to monitor environmental degradation of a static, sitting there, the metallic package in Yucca Mountain should be easily, easily achievable. But they should be developed specific for this application. Like the previous talk by Dani, you can hardly use something~~ensing~~ off the sh~~af~~elf~~t~~. You have to develop for this specific application.

Other specific characteristic of Yucca Mountain is irradiation field, maybe changes temperature, and then the changes could be extremely small, while the periods are extraordinarily long. So that's another thing that should be developed.

So, the sensors could be different types, and I think that's the better part when you have ~~the ~~defense in ~~that~~depth, several ~~are ~~var~~v~~iables. One could statics mounted on the packages themselves, other could be mounted on surrogate specimen that would be near the packages. Others could be on rails that would travel for a hundred years inside of the container in tunnels, and even we could use drones before backfilling and things like that. So, all these things are very easily achievable. And we can use a robot to fix them and to retrieve them.

I was recently at the Fukushima site, and due to this horrible accident, it was an opportunity for them to develop very advanced robotics to go into the reactors and retrieve the waste from the reactors. Compared to the Fukushima problem, this problem is very minor, I would say.

So, what's a sensor? It generally has two components. It's used to measure quality or quantity; for example, temperature or motion and returning a very characteristic electric signal. It generally has two parts, a sensing part and a transducer, which is the one that converts the signal.

A good sensor should obey very specific rules. It should be sensitive to the measured property, it should be insensitive to any other property that is there, and it does not influence the measured property, of course. So again, repeating that we should develop sensors specific for Yucca Mountain. And the good thing is, as I said recently, the development in sensors is outstanding, so they are finding a new -- it's like polymers, metal oxides, and carbon allotropes that are very sensitive to changes and measure quantities and qualities.

GE recently, I think just last week, received an award for developing a sensor. I don't know if you remember that methane escape just north of Los Angeles. So, they developed a sensor to detect not only if there is methane but how much methane is there, so in a very short time. It was not me, I am not the sensor person.

So, GE~~Ge~~, for example, and many other industries, they use sensors everywhere. But long-term, like for Yucca Mountain, it has not been used, like many speakers said before. For civil engineering, nowadays we are using sensors that may last a hundred years for bridges and things like that. For oil and gas, which could be very harsh environment, up to 250-degrees C down hole, GE and other companies designed equipment, pumps and other things that go into the hole that will last for 20 years, because that's the life of the well. And for appliances, for example, you know that very well, it may need only to last ten years, or it will die just after your warranty expires; you know?

So, regarding radioactivity, that's not new because sensors are already used a lot in radioactive environments, like, for example, in healthcare and medical and agriculture, where there is a need for food sterilization. So, corrosion sensor can measure the direct changes, for example, metal strips on the package itself, but also can measure indirect things; for example, a change in pH, the presence of a gas, the presence, for example, of aluminum oxide in aircrafts and things like that. So, this is some of the few industries that are being used in a lot of sensors, and, of course, we have Homeland Security. Of course, they also rely on dogs as well as sensors, but, you know, that's a good thing, defense in ~~that~~depth.

So, for example, this is a very simple case for sensors that we worked on this when I was at Livermore. If you have a dry salt on a package, for example, and you have two maybe electrodes of platinum, and you measure the ~~system~~ resistance between these two electrodes, it should be infinite, if it is dry.

Whenever you have enough water or humidity in the environment, and the ~~[inaudible]~~ salts deliquesce and then you can say this is conductive, and then corrosion may be possible. Corrosion here is no corrosion, it may be possible. So, it's only in occasions where you will detect a condensation or~~of the~~ deliquescence is where corrosion will be of importance. In Yucca Mountain you may have a lot of mixture of, for example, nitrates and chlorides. Some of these salts could absorb humidity even at low ranges of relative humidity, maybe 30%, 40%.

So, what are the challenges for sensors and sensing? The good thing is that the growing number of disciplines involved in building these innovative new sensors is truly impressive. It's mostly in material science and nanotechnology, and these additive manufacture and biological chemistry.

The main limitation of sensors, like was mentioned before, is the lack of sensitivity and the drift changes as a function of time. So, they may need to be calibrated, new sensor be used, or be several in parallel so the defense in ~~that~~depth, it's like suspenders and a belt at the same time.

So, despite these rapid development sensors and sensing, their long-term reliability are still unknown, which doesn’t contradict what Dani just said. The good thing, some of the transducers that are being developed now can increase the signal that the sensor reads of smells by six to nine orders of magnitude these days. And the issue also for long-term is that most of these current sensors are built with very discrete or very small amount of material; for example, a few grams of, or even less than grams of gold nanoparticles type of things. So, their long-term stability still needs to be tested and confirmed, but for Yucca Mountain, I envision that you can install the sensors and then you can send a robot and replace them and continue with the measurements, so it shouldn't be an issue.

This is just a cute thing that I took. Radislav Potyrailo is an expert in sensors in our group, and he just published his review. This was done with the gold particles that were added on top of this organic compound, and they were all put in seven different jars that had 40% relative humidity, and measured the signal. And each jar contained these teas that are here. So, these sensors can determine what tea it is. So, if you go to your cupboard and say what tea is this, you can use their sensor and it will tell you it is Dilmah Earl Grey tea. It can do all these things.

So, recommendations regarding sensors and sensing, there is a very bright future for sensors. I will say again, we have to use the Nuclear Waste Fund, like the Blue Ribbon Commission recommended, and work on that. It's important not to rely just in sensors, I'm going~~ and not~~ to recommend, but, also, we need to use the old method of the coupons, which is a very doable thing. And people -- it's like we were talking about, the general people give you the information, they would like the direct measurement of a coupon and then we corroborate it by the sensor. Some people say monitoring performance confirmation a hundred years, is a very long time, and it represents only 0.01 percent of the expected life of the containers.

So, these coupons for example, they extend the wall of the containers. Hastelloy C-22 was the most corrosion resistant~~of a system~~ alloy that exists, and for these nickel, chromium, molybdenum ~~aluminum~~ alloys, and for the drip Titanium Grade 7, it has palladium in it. So, the issue has to be, when we install these coupons in Yucca Mountain and retrieve at different times, we have to start with carbon steel, a low alloy steel, 13 chromium steel, 316, Inconel, and this.

So, if we, after 40 years, we don't see corrosion even in carbon steel on these, you can say that Hastelloy C-22 will be well behaving, extremely well, and ~~subsequently have~~absolutely no problem. But if in 20 years we see that ~~something that~~ 13-chromium steel is starting to corrode, then it's coming to these other guys with the time. So, this is important to have a very large range of corrosion-resistant alloys for this testing.

And then I will say remove coupons every 10, 20, 40 80, and 160 years because corrosion is generally a function of the ~~[inaudible]~~ logarithm of time, so we have to spread the time as we go forward. And then correlate those changes in the coupons directly with changes with the sensors in the drift and things like that.

So, nowadays the reason for monitoring in dry cask storage systems, this report by Xihua He and I think Bobby and Yi-Ming are coauthors of this, and then the NRC license these dry cask storage to complement the pools for storage. And the first was intended to be used only for 20 years or so because Yucca Mountain was coming. Now they have to use it for 40 years, and they will be licensed for 60 years waiting for Yucca Mountain to be a reality. So, the monitoring methods used in these dry cask storage systems include temperature, relative humidity, and microbial activity, so EPRI is very heavily involved in the stuff as well.

I'm not going to talk about this because we had a lot of wonderful talks already. And then my conclusion is that the performance confirmation is a period starting from licensing and maybe last 100 years. During this period, the engineered barriers, including the containers, will be monitored for performance. Monitor may include direct coupons or sensors evaluation. Typical variables are the temperature; all the offenders for corrosion ~~of the system~~ resistance, of course, we need too humidity and the condensation.

The development of sensor is currently booming, mainly due to advances in nanomaterials and functional compounds. And they should be specifically developed for Yucca Mountain application for a small change and variable extended periods of time. Thank you.

BAHR: Thank you very much. In talking about the water quantity and potential measurements, Dani referred to these distributed temperature sensors that can monitor over sort of a large area, so you can see variability in water inflow. I would expect that in a repository drift there might also be variations in relative humidity from drift to drift, or even within a draft. So, are there analogous kinds of sensors that would be relevant for monitoring corrosion that would give you the kind of spatial coverage that you might need.

REBAK: Yeah, definitely. I think based on models of things like that about air flow and where condensation or the relative humidity can be higher or lower, we have to put sensors in very typical or different representative drifts or packages. And, again, we have to measure condensation. And relative humidity, that will give you an idea of the condensation. But based on the salts, then is ~~that~~ it possible ~~to~~ the salt will deliquesce ~~solve that request~~ or not? And then ~~the liquids~~ deliquescence itself can be measured. Yeah, we have to use representative data. I don't how much ventilation will be used in performance confirmation, but the ventilation period that I saw in Yucca Mountain was supposed to make more or less uniform the environment. I'm not sure how much is that going on.

BAHR: Thank you. Questions from other board members? Tissa.

ILLANGASEKARE: So, you mentioned quite strongly that there is no moisture, there is no corrosion.

REBAK: Yes.

ILLANGASEKARE: So, if that is the case, the canister measurement is still a point measurement.

REBAK: Say it again.

ILLANGASEKARE: A single canister.

REBAK: Yes.

ILLANGASEKARE: In corroded point measurement. So, if you can measure humidity and other variables you put in there, is that sufficient to guarantee that you don't need sensors on the canister?

REBAK: That could be, yes. It depends what position it comes, because we all know that carbon steel only corrodes -- starts corroding, which is the lowest possible, above 60% humidity. Below that, you can have something in my backyard in California, whatever, it will never corrode; in New York it corrodes in two years. So that's direct observation. But you are right, if we can control the relative humidity below a certain value, and there is no dripping or anything over the packages because of the drip shield you may not even need sensors. But why not, to have reassurance and have them.

BAHR: Other questions from the board? From the staff? Nigel? Bret?

LESLIE: Bret Leslie, board staff. I think your observation about not just testing the alloy that you're going to use, but using a range of less corrosion resistance is probably a way of upping your sensitivity to the potential problems that could come.

REBAK: Yes, definitely.

LESLIE: And that's something I had not thought about, and I'm not sure that others have thought about. Even though it's not the same thing as having sensors everywhere, it does give you more information.

REBAK: More information, more confidence that your design is more robust, that it is, yes, definitely.

LESLIE: I have another question. Would remote monitoring visible -- I mean, one of the things for dry storage casks are they're sending in little robots to actually crawl along the surfaces. From a corrosion science perspective, is that something that you can envision adding value?

REBAK: Yes, definitely. Yes. You may use the robot to go and install something, or maybe retrieve or have something that would do, like the Chair said, going from drift to drift and measure relative humidity just to compare that the static sensors respond well by using this one the most.

BAHR: Are there any questions from the audience? Dani.

OR: Dani Or, ETH Zurich. You mentioned biology in passing, and I'm wondering, are there any provisions about the role of biology down the road, you know. None of this is going to be sterile.

REBAK: Regarding MIC you’re saying, or regarding?

OR: Just generally, accelerating corrosion.

REBAK: MIC stands for Microbiologically-Influenced Corrosion, and I always say that in the paper that I read in the literature, whenever people cannot find other explanation, they always blame the microbes, because there is nothing else. But I always tell people that don't believe

me, microbes don't eat anything on the corrosion. They don't go and attack your package. What they do, for example, if there is organic compounds or there is sulfates or other things like that that has oxygen, and they feed on the oxygen, they may excrete substances. Those substance they excrete are the corrosive substances. For example, they excrete oxalic acid or acetic acid, and things like that. Those are the corrosives. And especially if they are under some type of slime or under part of dust, you can form a localized environment that doesn't mix with the rest, that part will be more corrosive than the rest. You can form micro-galvanic couples in which you have more oxygen outside than underneath, and then you can favor corrosion.
But microbes by themselves don't attack package, but it's definitely an issue that we have to say that we would monitor. And the way to monitor is just to monitor the poop of the bacteria, which is see if there is any organic acid that they excreted.

BAHR: Any other questions? Okay. Well, then we're ready to take a break until 3:30, and we will reconvene at that point and ask all of the presenters to join the panel up in the front of the room.

BAHR: Okay, well, welcome back for the final session in a very interesting day. We have all of our speakers in the front of the room on a panel. And Bret Leslie, one of our senior professional staff members from the Board and one of the staff members who’s helped organize this meeting is going to facilitate the panel. So, I’m just going to turn it over to Bret.

LESLIE: Thanks, Jean. And what I thought we’d do is we’d go down the row, starting with Claudio, two to three minutes, kind of what are the key messages that either you want to reemphasize from your own talk or from what you’ve heard from others. And we’ll just go down the row. And remind you, if you hear something as people are saying their two or three minutes that you want to respond to, just turn up your name card vertically and that will help me facilitate the discussion. So, Claudio. And make sure you speak into the mic.

PESCATORE: Yeah. Thank you. Yeah, I have a few reflections just perhaps to start a discussion. The first one is I liked very much the sentence that I'll rephrase from Patrick when he said that during repository development, retrievability is at the service of reversibility. I think this is important because it allows this flexibility that we all want. And it connects, in fact, also to something that Piet said, where he said that deviations in an emplacement process or in the waste form quality, et cetera, will always be possible. So, we must be prepared for that.

And in this sense, I would like to remind perhaps the Board that here in the States we had two retrievability events already. There was before 2011 it was the WIPP, they had to stop the WIPP twice to get out packages which had escaped quality assurance checks. So, and that also can be an interesting experience to analyze, to go back, to remove certain containers, to pick up the right one, and then to reshuffle again the containers.

I heard also that monitoring may offer very little on the vital signs of a repository once it's closed. And because any signal -- real signal manifests itself a day late. And, of course, we must be very clear on this, but I still think that monitoring has a connection to memory. So, if you monitor or you keep the memory going, and also the knowledge going, and you make lots of people happy.

And the issue of memory has not been really addressed very much here. It seems to me that everybody’s -- and this is really one of the ~~light~~leit motifs from my presentation is everybody talks about we want to remember, but still we have to ask the question why, what, how, and these are open questions at this stage. And, in my opinion, I put request in, especially in the context of retrievability. And there is~~is~~ work that has been done in this, for instance, this memory group that I started at the NEA, which is now ending, and that has interesting results. So, we have to think not only in terms of a rolling present, memory is not only a rolling present but also breaks in continuity of this rolling present. And there are things you could do. And all of this has to be still, they say, systematized. Still, there are good hopes. It’s a good field to be working on. Thank you.

LESLIE: Okay. Patrick.

LANDAIS: The first thing concerns the tools, and especially almost all my colleagues and Piet also, and Maarten, to just emphasize that we got quite a lot of tools in order to provide complementary possibilities for getting experience for reversibility and retrievability, also for long-term evaluation of the systems with dedicated sensors. We have the URL. We have the test facility. We have a pilot system, the pilot facility, which will be probably the first phase of the repository. And we have the main facility is the repository by itself. And each of those facilities, each of those tools should be used on the more reliable and the more easy way in order to get the experience and to have the adequate data for deciding what we should do for the future.

The second thing is that the behavior of the different component of the system of the repository, which is a whole system, should be very well evaluated in time and space, especially during the first thousand years because it is during those first thousand of years that the main processes and the main coupling between processes are occurring. You have the hydrological modification of the system, you have the thermal evolution, you have the main geomechanical evolution which occur during those hundreds and thousands of years. So, it's very important to have this type of evaluation quite precise. And this at least partly allows to tell, and I will use the same terms as Claudio, what, where, how, and when parameters should be monitored. For example, there is no need to measure the composition of the pore water during the first centuries because we are ~~exaggerating~~ resaturating the repository, so the flow of water converging into the repository, they're not going outside, they will go outside much later, at least for the repository in clay environments.

The other thing, and all the colleagues say that both reversibility and monitoring should be fully integrated into the reference concept, which is issue from the design detail studies. And it's absolutely needed to have -- if you want it, to have the reversibility, or retrievability also, and monitoring system data just designed together with your reference design for your future disposal.

And the last thing is that the post-closure monitoring is a real problem by itself for different reasons. First, it's a technical reason because it is not easy to monitor from the surface something which is 500 meters below at this stage. The second thing, it's a safety issue, is that, at least in our case, and I'm sure that in other case also, we are not allowed to have boreholes which are penetrating within the Callovo-Oxfordian formation after the closure of the repository for safety reasons which are obvious. So, we can just monitor what is going on above the Callovo-Oxfordian formation, not within the Callovo-Oxfordian formation, through boreholes. So, that means that the post-closure monitoring is something difficult for both technical ~~measure~~ reason, at least at this stage, and also for safety reasons.

And the last thing, because we have all discussed about the public concern on reversibility and also from the data which are obtained via monitoring. I think that we have to keep in mind -- it's what I feel from the French case -- is that much more than reversibility or much more than the simple monitoring, operational safety is a general issue which is probably at this stage the real concern of the public. So, it’s not only reversibility or retrievability, it’s not only measurements monitoring; it’s the overall operational safety for the workers, for the public during the operation, during~~oing~~ so 100, 120 years or so. Thank you.

LESLIE: Thank you, Patrick. Piet.

ZUIDEMA: I have seven points. The first one is we have no big disagreements. So, we hadn’t coordinated beforehand, but I must say it fitted pretty well together. The second point is that monitoring and retrievability, that’s what we heard today, are a part or a small part of the overall institutional process of implementing the repository. So, it’s part of the governance.

The third point, if we do that, then I think there is a few distinct characteristics of a disposal project. First of all, it’s felt important and it’s of being broad of interest to many interest groups. So, you know, we cannot just implement it; everybody looks at it. It has noble aspects, the very long timescales, and then implementation takes a very long period. You know, it’s a project from, you know, beginning to the end, it’s more than 100 hundred years, 150 years ~~that~~ so we will have changes. And in that sense, implementing in a step-wise manner is really something you have to see because things will change.

Okay, so the next thing is then how do we do that? And because we have that step-wise approach, at each step we have to take a decision, and a decision means that you have to choose between options, and that means we have to have two things. First of all, we have to have the information, and second, we have to choose. And if we have to have the information, that monitoring comes in, but there are also many other things. And if you look at the options we have, then we have retrieval as one of the options; there are also many others. So, I think it’s very important that we are clear about that.

And then I think very important is when we take these decisions, that this evaluation and decision-making process is done in a very balanced manner, and that means all have to be involved, but we have to find a way how we express ourselves. So, that’s the fourth issue.

The fifth issue is, I think, when we implement, we have to find the balance. I think Patrick just said, you know, first of all, you should not damage the system just to monitor. Then the next thing is how far do we want to implement repository and have it easily retrievable but less safety, or the other way around, do we really want to go for full safety and less easy retrieval; and then again, you know, if we keep it open, we have to be aware, that needs not only money and resources, it also needs knowledge to finally get it done. So, I think it’s very important that we find the balance.

The sixth point is that I think we see cultural differences, cultural differences between countries, but also cultural differences with respect to time. I think it’s very interesting the presentation on Asse where you saw in the early days, you know, when it was on the mining authorities, you know, you just go ahead and mining is conventional, and if a mine gets flooded, okay, it gets flooded, don’t -- so, you know, it was a completely different environment than it was let’s say ten years later. And so I think that is important to recognize. And then we obviously also have differences between countries.

And the last one is obviously also the whole question of technology. That will evolve, and that is true for monitoring but it probably is also true for the whole of our repository. So, this, again, goes back to the step-wise implementation process. We should be open if technology evolves, that we are ready to take the necessary steps and improve or change. Okay. That’s it.

LESLIE: Thanks, Patrick.

VAN GEET: Okay. Some of my colleagues mentioned that probably everything is retrievable. And then as I saw this presentation of the Asse mine, I think that, well, they are trying to demonstrate this. Even if no measures were taken at all, they will try to retrieve it. However, of course, these days, this retrievability is becoming more explicit and we are taking the measures to facilitate it. So, but I think it’s also important to mention some limits.

We all mentioned that we will try to take measures to facilitate retrievability. And we did not explicitly mention that this probably is limited in time after some time, and then I’ll probably speak about centuries. Your comment to world again where there are a lot of uncertainties, and the measures we take are not beyond that time. So, at a certain point, it will be limited again, or at least it will be retrievable as maybe Asse is today.

So, that’s what’s clearly mentioned in the NEA scale of retrievability, I think, where, with time, the retrievability becomes more and more costly and/or more difficult. The same counts actually for the monitoring. We cannot monitor everything, and certainly not forever and everywhere. Social demands are probably an important driver of these changes of concept with the fact that we more explicitly mention retrievability, reversibility, monitoring. And it’s important that we listen to society and as we try to integrate these aspects in our research and development programs, but it’s also important to start the dialogue with the society in order to better understand what they really want, and that they also are aware of limits, and to make sure that the expectations of people are in line with what we are capable of doing because otherwise if the expectations -- based on what we say the expectations should be too high, then we also make a mistake, I think. So, we have to be clear on that as well.

LESLIE: Thank you, Maarten. Horst.

GECKEIS: So, it’s not a situation that many things have already been said.

LESLIE: Well, it gives you the opportunity to reinforce some of the things that you want to say.

GECKEIS: Okay, good. Thank you very much. So, it’s actually -- I mean, just talking from -- as coming from Germany, I mean, there are some things really related to the experiences that we have made, and this is the experience that we have made from failing disposal projects. So, that was, Piet has said, something which is very important. All these repository projects are very long-lasting, so it’s decades, and within this time a number of things are changing. It’s not only technology, it’s also society which is changing. And this is something that we have to acknowledge. So, we have now in this new process, it’s clearly defined in the law that it should be examining and a~~the~~ learning process. So, this is certainly something which is very necessary. It’s, however, also something that has to be, to some extent, defined.

So, what do we mean with that and where can we set some kind of boundary conditions so that we cannot leave everything open? And in this context, I think that the monitoring is very important to see -- with monitoring, I do not mean that we have some kind of sensors putting somewhere and measuring something, but it’s also the entire process that is developed and has to be investigated and always I’ll say checked whether it’s still working, and everything only then has a chance to be successful if we are really looking for the robustness of this repository project, disposal project. So, robustness, I do not mean only the technical robustness.

So, this is something where we had a closer look and a very detailed look in the past. So, that’s the experience that we have also made in Germany, but it’s also the societal robustness. So, it’s basically these issues that we have to think about. We can’t have a very robust system if it is not accepted by the society, then it’s failing, and that means that all these interactions -- also in terms of reversibility, I mean, they have to be negotiated also with society as well. It has been very much and very strongly involved into the entire process.

And the other thing is very much related to that, I mentioned that during my talk. So, we have to clearly communicate to the public what the individual measures mean so it’s then something that everyone should have the same idea and the same understanding of what’s ongoing. There are certainly cultural differences. We see that in Europe, if we are going to Scandinavia and if we go to Germany, for instance, I mean, there is totally different culture, of course. Nevertheless, I would say that I’m quite optimistic that within this new site selection process, I mean, we have a chance to go this way together with the society and find a solution. And still, I mean, that for all these kind of project, there is one thing which is certainly not an option, and that’s the failure at the end. So, I mean, if the waste is there in any kind of countries, it’s not only in the European countries, it’s also in the U.S., and something has to be done at the end. And that means that we have to guide the process and to tailor the process in this kind of robustness that at the end there is some kind of a success.

LESLIE: Very good, Horst. Dani.

OR: So, regarding monitoring, which is a subject I was trusted in reviewing today in the vadose zone, there is the issue of safety and everything is okay. That is the superficial layer of activities. There is the issue of credibility, in other words, you build trust with the public, and those are very interesting, but there is also a hardcore technical aspect of what exactly do we measure and what we do with that information. And there I think that we are deficient in that aspect. And what I tried to convey is that it’s not something we can brush off with what we have today on the shelf, but rather we need to embrace the need to develop -- to invest the efforts to develop the sensing capabilities that we need for monitoring in that environment. I don’t mean to have a borehole drilled right into the canisters to measure from the surface, that was not my intention obviously, but there are many ways in which you can monitor from the surface, yet maintain some safety margins, backfilled boreholes, things of that nature.

But, in general, if there was a message for me, it’s that the need for dedicated efforts to develop a technological solution and the need to plan ahead about the use of information for either improving our future activities or maybe communicating it to the public, or deriving some inverse information from it already at the outset.

LESLIE: Okay, Dani. Raul.

REBAK: Yes. I would say that I liked what Claudio said at the very beginning. Paraphrasing him, I would say there is the means, there will be the will. If there is money available, for example, from the DOE point of view for research, people will come do research and find what is needed. And I think this program should involve more the younger generation. All the research or most of the research should be done through universities. And Department of Energy has an NEUP program now that are very successful. And recently, because of the Fukushima accident, they opened the research on accident tolerant fuel, and I see it's very vibrant in the young community, and I think the students should be more. They are very special and they will be the ones that will be carrying these projects to the next generations because, you know, we are not going to be here forever. So, we need more of the newer generation.

And I think we should move away from the secrecy a little bit, and from the sense of guilt about this project. This is a wonderful project. We should emulate a little bit more the Swedish people, how they are doing their program. And then I think that's the other -- the last point is that we should re-read the recommendation from the Blue Ribbon Commission. I think they have wonderful recommendations. They are very practical and we should follow them. It will be very open, a lot of science, and involve a lot of younger generation in research. Thank you.

LESLIE: So, unfortunately, I don’t see any -- okay, Claudio.

PESCATORE: Yeah, I had -- because I have this ~~light~~leit motif of memory, and one of the -- a question I would like to ask Horst, in fact, a comment, I understand basically one of the issues at Asse is, in fact, the lack of records. They do not know what they placed where. And so that will affect a lot. If they had these records, things would be faster and better. Is it correct, Horst?

GECKEIS: I think it’s -- so, I think actually they know where the waste is. So, it’s very clear that -- I mean, it’s probably that the inventory has some kind of uncertainties, so this is certainly true because this was waste and it was not such and did not have these certification as it used to have right now. But, I mean, ~~in Norway,~~ they know where the waste is~~[inaudible]~~ and they have an idea about ~~end-too-end~~ the inventories, for each chamber they have information on the inventory.

PESCATORE: Okay.

LESLIE: So, I’m going to ask a question, which I think several of you have talked about, which is how do you engage kind of it’s a multigenerational problem, the monitoring and involving the stakeholders? Have the countries that are moving along thought of ways of bringing those stakeholders in early in terms of having that dialogue on how best -- if you’re going to -- you know, these villages, how long have they been there? They’re not going to necessarily move away. How do you involve the local community, the ones that are most impacted, with moving forward and deciding? Patrick or, you know, Piet, have any thoughts about that?

LANDAIS: Yes. I can give a first answer about that. At the stage where we are, that means two years of providing the safety authority with the licensing application, and probably two years in [inaudible] before beginning the first of these works because if we want to have the first real work starting in, let’s say, seven years, we should have already the connection to the electricity network, water network, and everything ready before we [inaudible].

So, as soon as the beginning and as soon as the choice we have to make for the final design of the railway, of the road system, and so on, to go to Cigéo, we have to co-construct with the local authorities and to co-construct with the public. So, this is open. This is one of the decisions of our ministry in charge of more specifically the energy problems.

And we asked ANDRA and also the local authorities and the public to find the adequate framework for working together for the co-construction of different things. And, for example, we have to co-construct the railway, the roads, and so on. We have the first design, and we will do it with them. So, this is the beginning. That means that the co-construction, you should do it since the very beginning for things that have a real interest for people living there. You know, the railway, the electricity, the water supply and everything, it’s very concrete. It’s not the safety in 10,000 years; it’s now. And if you want to employ people and you want them to be involved in your decision-making process, you have to involve them on very concrete and very specific affairs. So, it’s what we are doing right now just to be in the process later to have them involved over time within generation and generation.

ZUIDEMA: I think that there is a critical point here. And the thing what we see is it’s very important that we are clear how we position the repository project in society. You know, if we make it bigger and more danger than it is, you know, then people say, “This is the biggest problem mankind ever has had and it comes in my community. How can I live with that?”

And I think there is a certain danger there also from these very, very long-lasting processes without coming to a final conclusion. You know, it’s like going to the doctor, “I have here something.” And the doctor says, “Interesting. Come back again in three weeks.” Three weeks, he says, “Aw, interesting. Come back in three weeks,” and that goes on and on and on. And at a certain stage you really get angry and say, “Doctor, do something.” And I think we, at the moment, have sometimes the tendency to start to see things like that; you know? If this repository becomes very important, it suddenly becomes a condensation point. And I think we have also seen that in France, sometimes it becomes a condensation point for socializing people that are against. They are not really against but it’s a nice place to come and protest.

LANDAIS: Nice?

ZUIDEMA: Yes, it’s nice. And think that’s another thing. So, with this -- you know, I think it’s very important, this whole government things, but we have also to work out that finally this repository is not positioned in a manner that it does not deserve it because that could then be really “contraproductive” for the overall process.

LESLIE: Okay. Maarten.

VAN GEET: Yes, I would like to refer to this surface disposal facility that was developed in Belgium because there we had the experience to work with local partnerships; yes? So, that started in the early 2000’s, and during more than ten years there was an interaction with the partnerships to develop this kind of disposal facility, co-design. So, the original design of NIRAS/ONDRAF was adapted to take into account some specific demands from those local communities. Now it’s submitted to the -- the license is submitted to the authorities. But there is still this interaction with the local partnerships, and there are still different technical issues that are discussed with them. They still ask questions on some specific types of wa~~y~~stes that should go into the facility or not, and these kinds of things. So, this interaction continues not only on the technical aspects. There’s also the more societal aspects or aspects of the project that could be of benefit for the community, et cetera.

So, there is some continuity in interaction that is foreseen. And for the purpose of disposal, we are talking about 50 years of implementation. So, it’s about half of a geological disposal facility. So, I think there probably are means to have this continuity of interaction with locals. However, if I look back to the Belgium program and looking towards the geological disposal facility, our major problem there is that it’s more difficult to define the stakeholders. As long as we do not have a site, you are discussing -- you don’t know who to discuss with actually. Well, you know, some of them, the regulator and the politics, et cetera, but at a more general level, it’s more difficult. Belgium is not that big, but it’s still 11 million people. You can’t discuss with 11 million people, and that’s making it more difficult for us to have this process going on to define the real stakeholders. But once you have those, I think there are possibilities to collaborate and to have a continuous interaction on several items, like, for instance, monitoring.

LESLIE: Other questions that you have for your coconspirators? Yes, Dani.

OR: So, in this discussion, you implied that there is some benefits -- sorry -- that there are some benefits to the community. Is there any -- in the history of the discussions that you had, were there ever any explicit incentives to embrace a repository? Like Amazon, what are there, there are 16 cities in the U.S. that are competing to host the next

Amazon headquarters. Are there similar incentives for repositories, tax breaks or so on?

LESLIE: Claudio.

PESCATORE: Well, I can tell you about the competition in Sweden. In Sweden, they competed too big and, well, they ~~still got in the waste~~[inaudible], it's not direct money. So, it's more complex than that because they want to hold a sense of --.

MALE SPEAKER: Buying them.

PESCATORE: Buying them, yeah. But they are there in disposal since 30 years, both communities. So, one will get the repository, the other will get the --.

LANDAIS: The money.

PESCATORE: Yeah. So, well, it's not -- well, I cannot go into details, but there has been this competition. There can be competition. And in Canada there is a lot of great competition, like, all the communities, there’s, like, ten, even more, communities.

OR: So, does it change the anatomy of the discussions, objection --.

PESCATORE: Well, first, people have to trust you a lot, and then. But Piet will say something.

LESLIE: Well, we’ll do Maarten and then Piet.

VAN GEET: In Belgium, it’s similar. Again, for these low-level disposal facility, there were two communities, that were actually two neighboring communities that were interested and that wanted eventually the repository. One choice had to be made and then there was really a disappointment in the other community. So, because it was neighboring communities, we have decided that partnerships of both would continue and that we would continue the interaction with both of them, because the repository is still close to the other community as well. And that’s similar as in Sweden where they have only one community the repository, the other have the processing or the --.

ZUIDEMA: Encapsulation.

VAN GEET: Encapsulation plant. So, it’s indeed, at one moment, it might come into a kind of interest from the communities to really get this repository, but it’s not always like that, of course.

And in Belgium, there is a fund. It’s like that, it’s not just money that’s given to the community. It’s a fund and there are specific rules on how to use this, but there is a fund that goes with it.

ZUIDEMA: I just think that it’s important that one is fully aware of, again, cultural differences and also real differences. What Claudio was talking about, there were two communities that anyway are facing nuclear, you know, so they’re used to it. And then it’s clear we also know that, you know, if somebody is interim storage facility and he can choose either that it stays there continuously in this interim storage facility or it goes into a final disposal facility, and you even get some goodies for that, you know, why should you be against it? And that’s rather different than when you go to somewhere where people were not exposed to it at all.

And then the second thing, it just depends, again, on the cultural environment. I just can say for Switzerland, for example, we are a rich country, so, you know, I mean, if you lower the taxes by a few percent, so what; you know? It’s much worse if the repository is perceived as being something from the devil; you know? That has a much bigger impact, and that’s where I think we have also to find the balance; you know? We have to do the job very carefully, but we should watch out that we don’t position it more complex than it is.

LESLIE: Got another question for the panelists. People have talked today about making data available, also kind of continuous learning, but we also heard problems with reporting. So, as people are developing their monitoring programs, are they thinking about, well, do I just continuously make my data available or do I, every five years, not only think about my technology but kind of do a synopsis or a summary of the monitoring and say, “Well, if we see this in another five years, we probably don’t need to measure this anymore,” or five years from now we think this is the new monitoring that we’re going to need? And so I’m going to kind of pick on that end of the table that are developing programs, how much thought has gone into that? Because you’re saying that you want to engage that community but, you know, the decision-making, unless you have a discrete decision, it’s hard to kind of, every now and again, come back and look and make those changes, because a regulator wants spaces, it doesn’t want to have to go through all of these changes. So, is there some sort of balance and do the regulators in your countries have different views of that? Piet.

ZUIDEMA: Well, I think one sees its differences in the legal system and the cultural system. In Switzerland, for the nuclear facilities, they don’t have, for example, a limited -- their operation life is not fixed in a license, but they have something else, periodic evaluation of safety. So, by each evaluation, the regulator could shut you down. And it also means that you have to make continuous improvements. So, in comparison to the United States, it’s a rather different system; you know? Continuous retrofitting, you know, if it’s not anymore state-of-the-art, it’s going to cost you 100 million, 300 million, you know, you put some additional [inaudible] there. And I think that if at least we would start tomorrow with our repository, it would be the same. So, you know, every five years let’s say an in-depth review what you have learned, and if you see that something should be improved, optimization, then you do it. And it’s not, “I got the license because license 40 years ago let it go.” We can now continue forever.

LESLIE: Patrick.

LANDAIS: We have already this process going on when we are discussing with the waste producers that are financing everything for Andra. I can tell you that the description between this type of stakeholder, Andra, but also, on the other hand, the safety authority about the way of integrating the optimization within Cigéo are really tough because you are speaking of billions of Euros. So, making the good balance between the necessity of cost optimization while keeping as a first principle the operational safety and the long-term safety, this balance, we have to keep it alive not only for our project but also for being able to demonstrate that to the public, that we have to do that.

LESLIE: Okay. Maarten.

VAN GEET: Well, even in absence of a political decision, we already have this similar discussions with our producers, of course, on cost, et cetera. And I think that I have shown a little bit in my presentation as well, in 2000, 2001, we had a safety and feasibility interim report. We had the proposal of the facility that we tested and that we assessed, but based on that, improvements could be made, and that's what we have done. And now we will make a new assessment of this and, again, we will have some optimization, integrating aspects that will come out from the regulator, but that might also be from others.

There is new law in 2014 that immediately asked for retrievability/reversibility. We tried to check if this can be integrated in the way we interpret it today, but with time this will change. It will be more concrete, what is really demanded, asked, and we have to integrate it. So, I fully agree with the answers that were given here. There will be updates several five or ten years, and if updates -- upgrades can be done, we will have to do it, and we will do it.

LESLIE: Horst.

GECKEIS: I just can say the same from the -- I just mentioned that in this new law, site selection law in Germany, it’s clearly written that should be self-learning and examine self-examining system and process. And this is something which, at the moment, has to be defined, of course. You can write something like this in the law, but you have finally to have some kind of ideas how this should be realized. And just can say, I mean, we have these two organizations, the implementer and the regulator, and the regulator has already started to have some kind of reports and some kind of projects where these things should be defined. And the first ideas are also, though, that every five years or something like this that the entire process should be reviewed and then there should be some kind of improvements or some kind of steering into another direction should be defined. So, that’s the idea.

LESLIE: Okay. I’m going to turn to the Board and give them the opportunity to ask panelists questions from previous -- if you want.

FOUFOULA: Efi Foufoula, Board. So, I mean, the repository is the prototype of an end-to-end system. I mean, we have the technical challenges, the social challenges, political challenges and all of this. And if we had the end point safety in 10,000 years from now, that would be difficult already, that’s why we have not made progress. So, now we add a time-evolving degree of freedom which kind of anticipates all the new sensors, all the new information, how to interpret small fluctuations versus emergency reactions and all of this. And I think instead of enhancing the whole system and its safety, we put more delays into it. If that was a panel on climate change, that we agreed to taking action, because we have to take an action now, and there were people pointing out uncertainties, “I don’t know, you know, in ten years, in 50 years, I don’t know what will happen,” et cetera, we would be ashamed not to do anything now.

So, how do we communicate this more to the public and how do we turn ourselves to make an asset out of this time-evolving degree of freedom that can act as the sensor overall for the safety but will not pedal back even further the whole process? I mean, we’ve discussed all this, I just expressed the ideas that we make the problem even more difficult despite the fact that we acknowledge the technology is evolving to our side, giving us more information. We can talk about how good is the information, but we know that. Or let me summarize my question, are the technological challenges smaller, equal, or bigger than the institutional social challenges?

LESLIE: Go ahead, Piet.

ZUIDEMA: I’m now talking for the three countries that have clay as host rock. And I think we should be know; you know?

Geology doesn’t read our reports, so geology stays the same how much ever we do. So, it’s in that sense the quality of the clay barrier doesn’t get added to our research. And in that sense, I think we should just be confident enough that we say it will perform. And if we do more research and it even performs better, it’s fine.

I see the same -- if I understood you correctly, I see more risk that we finally make it so complex that we don’t move at all. And I think that’s what we see, for example, in the big country here. You know, you have so many highly capable people, you have so many geological choices, and you -- probably you don’t have the money anymore, but, anyway, you have so many opportunities, and still it doesn’t move. And I think that’s what I tried to convey. You know, the danger is that we make it so complex that we don’t move and eventually people will lose interest, and then we have suddenly a safety problem.

LANDAIS: Just two things.

LESLIE: Sure.

LANDAIS: We know in France that if we lose the momentum, we will lose the project. That's clear. And then there are political issues. We are new members of the new "~~diplomaties~~deputies" and so on, and then we have to explain them everything because we need the political process to be together with the technical process. So, if we lose the momentum, I think that it will be very difficult for the project to restart one day or another. And if we see our colleagues from Germany, from Japan, and even from U.K., it took time before restarting the process from scratch, even on the governance aspect, even on the confidence with the public, and even also with the aim of the political power to say, "Okay, I'm here, I'm doing the job, and I'm behind you."

LESLIE: Claudio.

PESCATORE: All programs have had setbacks. And the ones who are really continuing, they're the ones who have a process. So, the issue of process is so important. You can have the technology. You have this knowledge. You can show along the process that you know, but you have to have this process of decision-making. This process has to be agreed upon. And somehow, in many of these countries, the process was not agreed upon to start with. I mean, in Switzerland, this new process came only ten years ago. In France, it came 2006, was it? So, once you really get into this process, and the process is now clear that you can move on. And so I would say the institutional process is so important. Of course, on the side, these guys have done their work and the technical work and they can respond to questions so they do not look stupid, but the process is very, very important in today's society, yeah.

LESLIE: Okay. Raul.

REBAK: Yeah, I think, answering your question, I think the sociological issue is much more an impediment than technology. Technology is there. There is, especially the last few years, a lot of distrust about scientists and what they are doing and things like that. For some reason, in my own family, I cannot even explain how nuclear is safe compared, for example, from fossil fuel burning. And the main reason is very simple, I think the project doesn’t advance because of the fear from the public. And the fear from the public is because it’s unknown to them. We have to explain very clearly and be very open how nuclear energy is produced, that it’s clean energy but we have the nuclear waste as the only throwback, and everything has to be explained and open, and educate the public somehow. If the public is opposed, nobody is going to do anything. That’s the basic thing.

LESLIE: Other questions for the Board? I’ve got some more questions I can ask, but Lee.

PEDDICORD: It’s not exactly -- oh, first of all, Peddicord from the Board. And it’s not exactly a question but I hope this is a cheery comment in order to make you all feel a little better, but it’s specifically on the idea of retrievability. And somebody mentioned, I don’t remember who it was, is one of the main things in the retrievability concept is to give confidence to the public that you’re not going to do this and walk away from it and forget about it, and if things go wrong, it’s tough -- maybe this was

Claudio's point with the rocket coming in. And Piet made the observation that here we have a broad set of countries here in Europe, and you didn't get together but you had rather common thoughts on the approaches and so on. So, on retrievability, I think this is particularly important to build this public confidence, to let them know that really capable people like yourselves and your organizations across the spectrum of countries are really thinking about this.

And so I'm going to give you a Texas metaphor about this, okay, that I view you all as the Ron Short and the Robert O'Donnell components of the nuclear waste endeavor; okay? And Ron Short and Robert O'Donnell, in October 14th, 1987, were involved in the rescue of Jessica McClure in Midland, Texas; okay? And at that day, October 14th, 1987, Jessica McClure, she was 18 months old and she was out in her aunt's backyard, and she fell down a pipe that was 20 centimeters in diameter, and she went down seven meters, and she was trapped there. And it turned out she was down there for 58 hours, this little girl.

So, what’s my metaphor here? Here you all are and you’re thinking about how to respond to something that maybe is not on our radar screen, but you’re going to come in like Ron Short and Robert O’Donnell, and if something goes wrong in these repositories, you’re there, you’re thinking about it, you’re going to be there for the public to come up with a solution to address an issue if these repositories don’t meet the criteria that we think they will. And I think that’s an extremely important component of what you’re doing.

So, I want to be encouraging in this because I think that’s really important. We have the capabilities collectively, as advanced societies. If a challenge like this, like Jessica McClure pops up on our radar screen, we can collectively respond. Remember the miners in Chile, another example of this as well, too. So, I think what you guys are doing are superb, by thinking about this. And while we may not have the answers now, if something happens in these repositories that we’re not anticipating, that is going to be, say, a risk to society, you’re going to be in there with the capabilities you’ve been thinking about to actually address these issues. And I think this is the kind of confidence that's important to bring to society, knowing that you're prepared to respond like this. So, I want to say you all are doing damn good.

LESLIE: Claudio.

PESCATORE: I think this reinforces a point, in fact, because you started and said retrievability is to reassure society. And, in fact, you ended up saying something that I would have said, that is, as an engineer, thinking in a reversible way really makes me feel better. And then I can really pass on my confidence to others because if I'm not confident, I cannot pass my confidence to others. And what I showed you in my presentation is all these engineers, they talk about they are not really able to say this. They sort of give the impression~~et detached in~~ that ~~they~~ we would like to be there but we do not know; okay? So, you are not giving this confidence. They are giving these subliminal messages which are not clear.

PEDDICORD: But the other part of it is you will be there, if needed.

PESCATORE: Yeah, but then I have to say -- I mean, you have to say, I mean, I’m thinking about it. I’m really thinking about it.

PEDDICORD: It’s good. It’s good.

PESCATORE: Yeah.

ILLANGASEKARE: I have a more short questions. I have listened to ~~hosts~~ Horst’s talk. ~~I~~ He talked about when the Green Party was in power versus things are better. So, you think there is some sort of a general acceptance that the politics at that level will not change the long-term planning for all these activities in Europe? It seems to be that there is not a -- this repository will be a reality someday, is that correct, in Europe? With respect to what’s happening at the high-level politics in Europe?

ZUIDEMA: So, you’re talking about Europe or in general?

ILLANGASEKARE: No, no, I mean, you talked about the Green Party was in power, they did some things, it stopped, and then it came back.

ZUIDEMA: Yeah.

ILLANGASEKARE: So, my question is that, in Europe, is it going to be a factor what's happening at very high-level politics is going to happen in the long-term planning for a thing like which you are going to do?

ZUIDEMA: I think so, yes. I think, again, that that is really country-specific, at least my understanding. I actually can talk for Switzerland, that is easy; you know? It's accepted. It is a national job we have to do. Full stop. And the only thing t~~w~~hat we have to watch out, all of us, that we do it in a manner that we achieve, and that means the policymakers to make sure that the process is run correctly, the regulator has to take its role in being very careful what we do, and I think we should do it right. And there, again, comes we have to be balanced in the challenges we have. It’s very important that we do a good job, but it’s not so complex that we cannot do it, you know, and I think that’s important. It’s manageable. I think humankind has more difficult problems, and I think that’s important. You know, we have to be very careful, very clear, very [inaudible] job, but we should not let it look more complex than it is.

FOUFOULA: [Inaudible] passed this message to the public, as engineers delivering the capacity that we have created to address this problem, I think we can see a lot of good coming out of that, change of mind and confidence.

LESLIE: So, I’m -- go ahead, Patrick.

LANDAIS: Just to come back on the comparison you made previously, the complexity of the modeling we have to perform has nothing to do with the complexity of people in charge of climate change have to do. I think it’s much more complex to evaluate the interaction between atmosphere and oceans than the interaction between steel and clay minerals, for example.

FOUFOULA: Yeah, and it is a more local problem, as opposed to the global problem.

REBAK: It’s more contained.

LESLIE: So, and we’re getting close to the end of the hour session. I want to check one more time with the Board members and then any final comments. You want to go down the line for any final questions for your other people? Piet.

ZUIDEMA: As always. Now, first, just a comment about this meeting. I think being invited for -- that it’s obviously nice, but I think it’s really good these types of meetings where you bring together, you know, a range of people, we sit together, and with your critical questions. I think it’s -- I found it really good. So, just feedback from my side.

LESLIE: Claudio.

PESCATORE: I will note that what you’re doing here is the first international meeting on reversibility/retrievability since 2010 meeting we did. So, possibly try to spread the word that you did this than just keep it to yourself, so that the whole community can have a look at the presentations.

LESLIE: And I would remind folks that when you go back, you can send them to our website because the webcast is archived.

PESCATORE: Yeah. Yeah.

LESLIE: And the presentations will be up on the website shortly after our meeting. So -- yes? Oh, okay. Dan, staff, question?

OGG: I wasn’t sure you were going to call on us over here, but I do have one question building on a comment made by Patrick, related to pilot facilities. And I think my question would be directed to the other four who did presentations on retrievability and monitoring, and that is do you view a pilot facility or an underground research lab as an essential part of the program? Is it necessary to have such a facility or do you think you can get by with just laboratory testing? What are your opinions on that?

LANDAIS: First, go to the URL. It’s my personal opinion. Testing things in laboratory is easy. Making experiment, constructing the experiments, it’s quite easy. It provides you with good data which are able to give the right orientation to make the in situ demonstration, but the demonstration should be in situ.

I think that all those colleagues who are involved in the international networks on URL can say, all of them can say the same thing, if we don’t have a URL, it’s very difficult, one, to demonstrate things at a good level, at the good scale; second, to show the public what is an underground installation, to show the public the type of installation we will excavate one day or another for the final repository; and to show the public the way we are testing the rock by the way we’re testing the materials, the concrete or the steel, or whatever. So, at least for this reason, it’s absolutely necessary in my mind, and taking into account the feedback in France, it’s absolutely necessary to have a URL.

It could be specific. It could be generic. It depends on the choice of the different countries, but being in situ, it’s important.

LESLIE: Anyone else want to respond? Claudio.

PESCATORE: I totally agree. And there is a report, in fact, on the NEA website, you can find on URLs, it basically explains all this. Like I tell you, I’ve done 15 peer reviews of safety cases and, you know, when you do not have this type of information, then it is very difficult to make the safety case.

LESLIE: Any other questions from the staff?

PABALAN: Roberto Pabalan. Just to follow up on Dan’s questions. You asked two things, one is the URL and the other pilot facility. I would like your comments specifically on the pilot facility which will be monitored, like in the Switzerland case. Is that an important component of demonstrating safety?

LESLIE: So, we'll go Piet, Maarten, and then Patrick.

ZUIDEMA: Because we are the ones who invented that. I mean, the pilot facility, the name, "we," I mean, Switzerland. I think it's important. I forgot something to say this morning in my presentation. So, one of the motivations was to do it for the unexpected, you know, because the perception was right, you know, we won't see anything. You know, we expected we see nothing. But then if you really want to be sure, you should -- I mean, the unexpected is the nasty thing, and that's why one said, okay, let's look for the unexpected; if it doesn't turn up, we are all happy; if it turns up, then at least we know about it. So, I think it's important to say, you know, if you really want to monitor things, phenomena that you know that they're important, there are much more efficient ways to do it. So, the dedicated experiments are much better for that, but I think to guard against the unexpected, it's, in that sense, completely open-minded, we just will see. That's just an explanation.

LESLIE: Maarten and then Patrick.

VAN GEET: So, one of the comments is that the URL might be generic or might be for more host rock. So, for instance, in our case, we have a URL in the Boom Clay, but we also consider Ypresian clays also a kind of poorly indurated clay. So, many of our information’s transferrable to that clay, but we are not -- if we would eventually go to the Ypresian clays, we were not thinking of making a new URL in the Ypresian clays, then we would immediately go to a repository with a specific monitoring zone and pilot facility, et cetera. So, then you would combine these things to avoid an extra cost of a URL in the specific host rock. So, that’s also in an item that has to be taken into account.

LESLIE: Patrick.

LANDAIS: For us ~~[inaudible]~~ in France, the different reasons why we will have a pilot phase, there are two which are important. The first one is that within the pilot phase, which will last at least ten years, during five years we will test in real conditions with real waste package. We are not authorized to have a real waste package within the URL; right? There is no way URL where you are authorized. And the second thing is that the pilot phase was asked by the public after the second public debate in 2013/2014. So, amongst other reasons, these two are very important.

LESLIE: Any final questions from staff? Jean.

BAHR: I have a follow-up on if the pilot is to look for the unexpected, and yet when you design a monitoring program you are usually looking for things that you expect. So, how do you design an effective monitoring program that is really going to find the unexpected for you? Anyone.

ZUIDEMA: Well, I think, again, I mean, in a way, you’re limited, then sensors comes in again. You know, you can monitor what you have to the tools for. But what we expect is that, let’s say you look, for example, at pressures or temperatures, et cetera, and if you suddenly get -- you know, in a way, you can say temperatures if they’re within certain bounds, it’s not something you’re worried about about safety. But if the curves really go differently than you expected it, then you know somehow you haven't captured the system right. And I think that is then the trigger that you say what on earth is going on here, and then probably you'll find the root of that and then probably you get worried or you say so what.

So, I think, you know, again, has to say you do as good as you can and you can't do more. You know, that's also for if it was ~~height~~ site investigations, you always say you should have some measurements that are two or three unexpected, and that's also difficult but that means you just measure broadly and then see if you see some behavior you didn't expect, and then you go after it and then probably you find the unexpected.

LESLIE: Dani.

OR: Yeah, I was going to say that it's a bit reflective of the luck or the culture of clay repositories versus Yucca Mountain type or fractured rock type of repositories. So, if you're smart in selecting the right site, then many of the unexpected events are diminished in their importance, whereas in a site like Yucca Mountain, the issue of focused flow will always be there and we wouldn't always be able to capture it. So, that would be the unexpected I guess in the sense of the -- that minute changes in climaetic background will basically translate to huge fluxes in ~~surface pores~~certain spots, for example.

LESLIE: Any final questions, Board, staff? So, I'd like to thanks the panelists. And if you'll stay up here while I turn the meeting back to Jean and do the public comments.

BAHR: Okay. Yes, so we have two last things. We have a little time for public comments, and then we also have a presentation that we are going to do. People in web land will have to miss that because we're going to do it after we turn the cameras off. But I just wanted to give people a heads up if you want to stay for that. But I do -- I don't have any notice on my table that anyone signed up for a public comment, but we certainly would encourage people in the audience to comment or to ask questions of the panelists as you desire. Anyone? No one?

Okay, then I think we will -- oh, somebody’s being pushed in? No? Okay. Well, thank you all for your attendance and your input. And spread the word, this will be on the web. You can look at it again and again, and encourage other people to view it. And I think we will turn the cameras off now and then we’ll have our final presentation.