Disposal of SNF/HLW in Deep Boreholes

Drilling Deeper for Safety

Andrew Orrell

Presented to the Swedish Land and Environmental Court

September 11, 2017

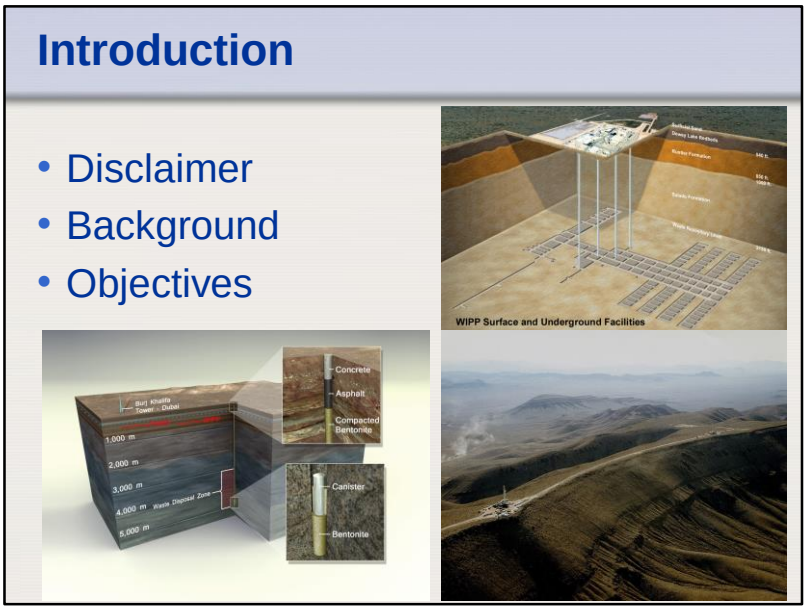
Good morning. It is my pleasure to address the Swedish Land and Environmental Court, and I hope you will find my commentary useful to your deliberations.

Let me begin by noting that all nations now possessing spent fuel and high-level waste face the challenge of achieving final disposal of their waste forms.

After 50+ years of waste generation, disposal in mined repositories remains the principal approach for most national programmes, but only a few have progressed to the point where an operating disposal facility is expected in the next decade.

The reasons for such challenged headway are many; some technical, some socio-political, and some simply pragmatic about the financial and logistical aspects of implementing high-level waste disposal in a mined repository.

Such experience raises the question as to whether there is a possible role for deep borehole disposal systems, as an alternative, or an adjunct to mined repositories.



I trust you understand that any comments or opinions expressed are my own and do not necessarily represent those of my current or previous employer.

Prior to joining the IAEA in 2014, I spent 24 years with Sandia National Laboratories in the United States, where my career was devoted to the issues of repository science and deep geologic repository development.

I served both the Waste Isolation Pilot Plant (WIPP) repository, and the proposed repository at Yucca Mountain. This included the responsibility to deliver in 2008 the world's first safety case and license application for a deep geologic repository for high-level waste and spend fuel, in what is arguably a very complex repository environment.

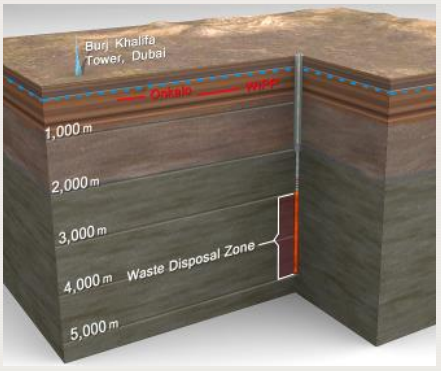
My experience in repository development and safety assessment also led me to initiate an effort to examine the potential of deep borehole disposal concepts, starting in 2003, and in earnest since 2008.

My objectives today are …

- To share my perspectives on deep borehole disposal systems, their origin and development, and
- To contribute to your own deliberations on the potential for DBH as a possible disposal capability.

Deep Borehole Disposal

- 5,000 m deep borehole(s) in crystalline basement rock, well below groundwater resources
  - Waste canisters in bottom 2,000 m
  - Seals in upper 3,000 m
- Bottom hole diameter
  - 17 in. for bulk waste forms or SNF/HLW
  - 8.5 in. for smaller DOE-managed waste forms



I believe Dr. Fergus Gibb has already briefed you on the technical details of the deep borehole disposal concept.

The key here is to recognize the safety objectives afforded by deep isolation of waste in the zone of 3 to 5 kilometers below the surface and in stark contrast to the typical mined repository of approximately 500 meters.

Such configuration is intended to address the inherent uncertainties associated with mined repositories, by providing high confidence in the isolation of the waste for very long time frames.

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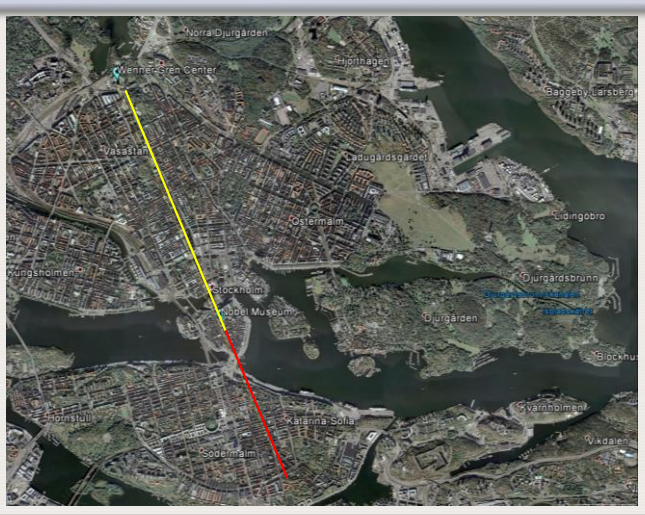
5 km Paths

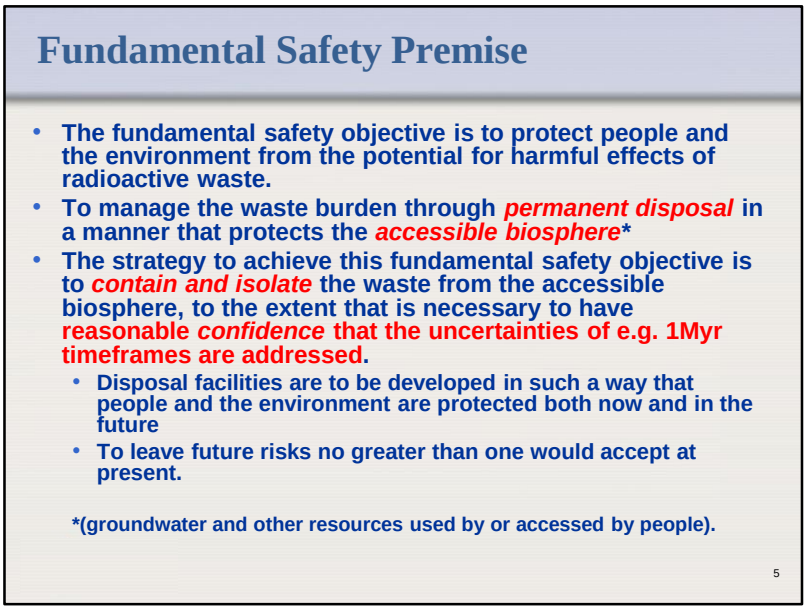


To help with the sense of scale it is useful to have a familiar surface analog when discussing the depths involved.

In the upper left, the Wenner-Gren Center is almost exactly 3 km to the Nobel Museum….and then it is another 2 km to the southern end of the Ringvagen on Sodermalm.

This corresponds to the 2km disposal zone shown in red, and the 3km sealing zone shown in yellow.

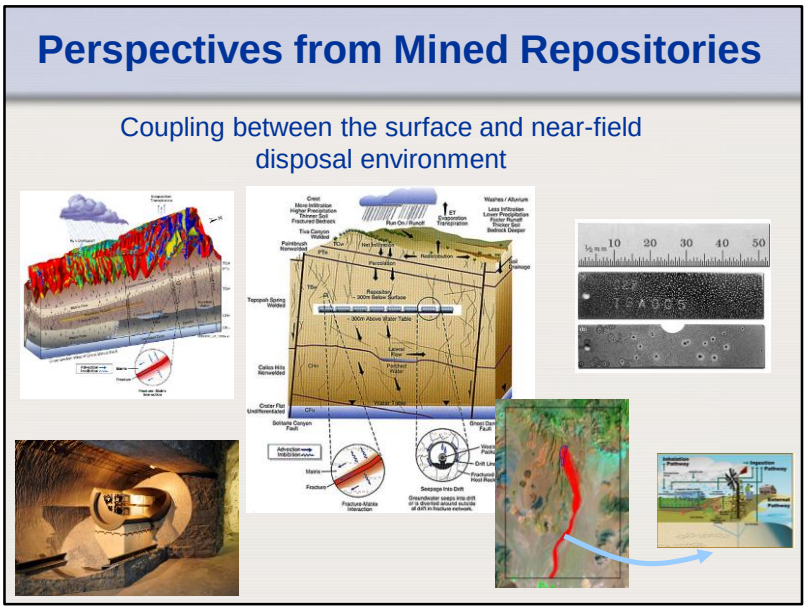
By contrast, most mined repositories, at about 500m depth, are within the length of Vanadislunden Park adjacent to the Wenner-Gren Center.



As a quick reminder, let me emphasize that, regardless of the disposal concept, (mined or deep borehole), there is a fundamental objective to achieve passive safety that calls for a high degree of confidence in the chosen system to contain and isolate the waste, from the accessible environment, for very long time frames.

ALL repository system designs, and their regulatory review framework, endeavor to secure this objective.

Thus in assessing various disposal design concepts (mined or deep borehole), we must contemplate our confidence in the isolation capability, and the tradeoff with such factors as cost, feasibility, and defensibility.



So what is the fundamental difference in 'isolation confidence' between **mined** and **deep borehole disposal** systems?

Mined repositories present some unique challenges that are a consequence of their location being only ~400 to 600 of meters below the surface.

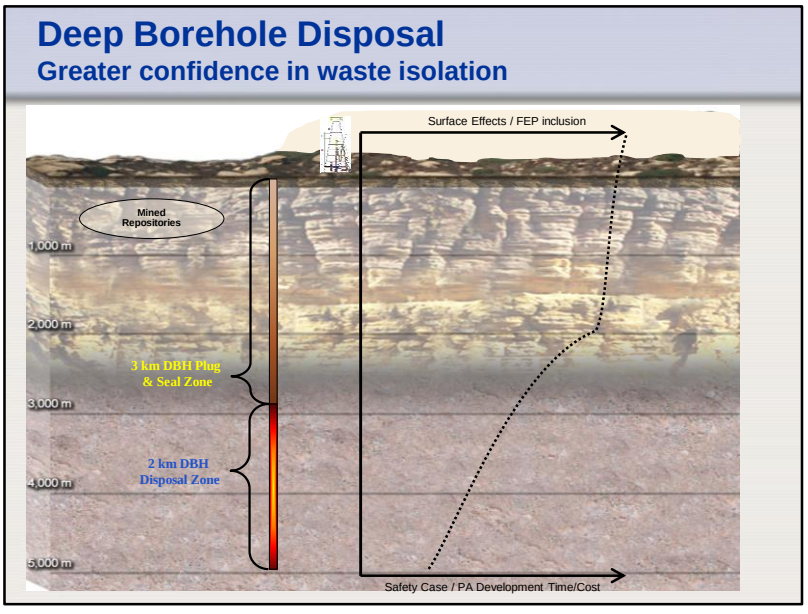
The primary challenge is in the greater potential for consequential interactions between surface phenomena (e.g infiltration and climate) and the underground (e.g. corrosion and engineered barrier integrity).

Traditional mined repositories are loosely to tightly coupled to the effects of the accessible environment, and this complicates the process of understanding the effects of the biosphere on the repository, and the effects of the repository on the biosphere.

This in turn complicates the site characterization, the safety case development and its regulatory defense.

It is a reality that we spend large amounts of time and money specifically trying to address the complexities introduced by near surface phenomena, their effects on the disposal zone, and the consequences to dose assessments.

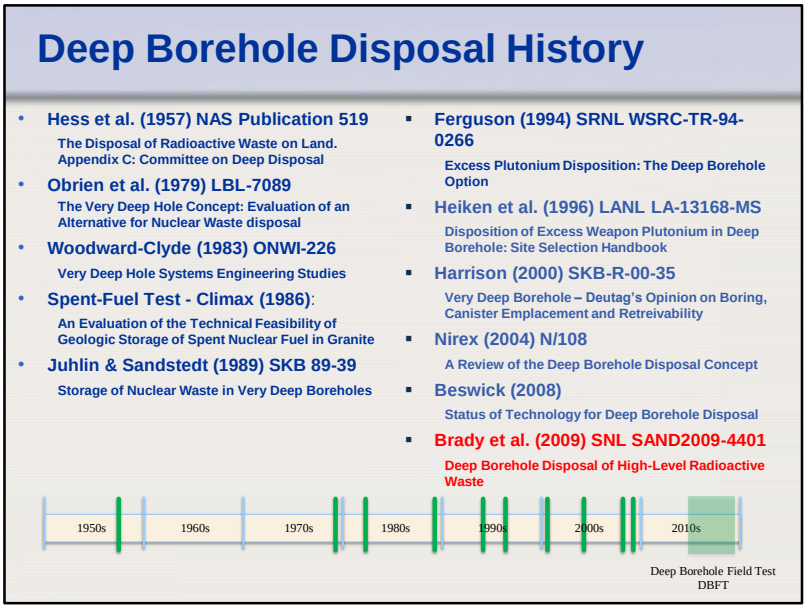
It is this reality of all mined repositories that led me to investigate disposal systems, such as deep borehole, that more **intrinsically** avoid such complexities and their uncertainties.



The intrinsic capability of a deep borehole disposal system to confidently isolate the waste is what makes it technically desirable.

The multi-kilometer depth of deep borehole disposal systems would appear to more effectively decouple and isolate the repository from the biosphere effects.

In contrast to most mined repositories, I believe the smaller number of features, events and processes that would require inclusion in a Deep Borehole performance assessment would reduce the time and cost of site characterization and for developing a high-confidence safety case and licensing basis.



The recognition that a deep borehole disposal system could provide greater isolation confidence is not new.

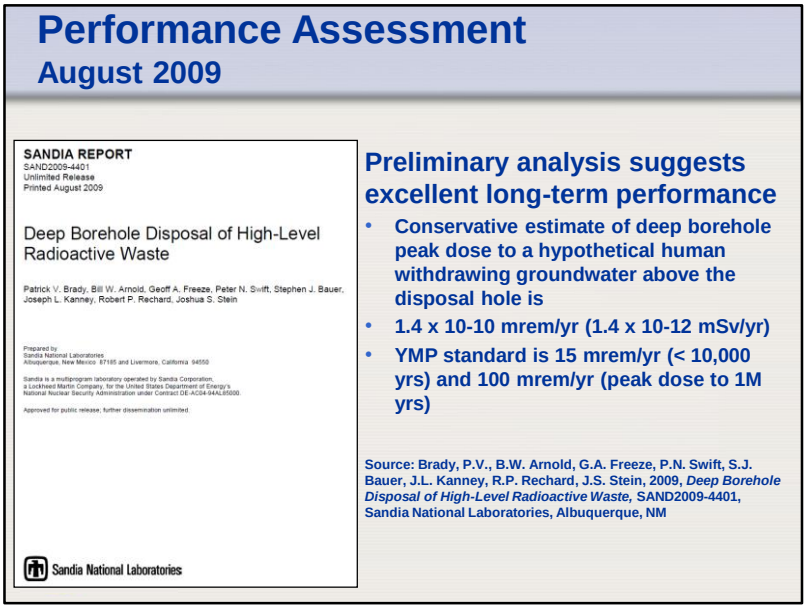
Deep borehole disposal of spent fuel, high-level waste, and excess plutonium, has been studied in increasing detail since the 1970s to the present, a few of which are noted here.

Most of these earlier projects focused on the engineering aspects of deep borehole systems.

Especially since the late 1980s, a few realizations have emerged which renewed interest in deep borehole disposal systems, such as;

- The appropriate drilling technology became more readily available,
- Experience with the development of mined repository site characterizations and licensing, and,
- New pressures for disposal systems for smaller nuclear programs.

Shortly after delivering the Yucca Mountain license application in 2008, I assembled a group at Sandia to develop the first **quantitative** safety assessment of deep borehole disposal systems, which produced the 2009 report noted in red.



When my colleagues at Sandia completed and published in 2009 a very conservative quantitative evaluation of a deep borehole disposal concept for spent fuel, the results were notable for the extremely low, diffusion-limited dose rates.

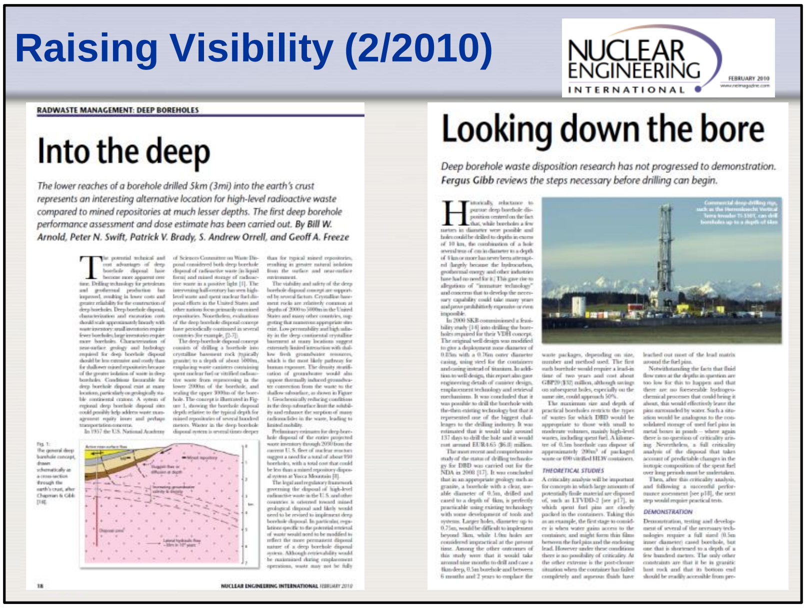
In addition, we noted the system was robust; that is having few factors that would perturb that performance.

And with regard to a hypothetical licensing, there was readily documented high confidence and conservatism in known or assumed parameters, and that makes for defensible safety cases and license applications.

Beyond safety performance, cost and schedule were also estimated based on available analogs from the geothermal industry and even when scaled by experience, the numbers were again compelling.

In short, a very experienced set of teams, primarily from Sandia, MIT, and Sheffield, were coalescing on building greater confidence in the now quantified merits of deep borehole disposal concepts.

The topic began to take on a life of its own, and gaining greater recognition among the science and engineering community, policy makers, and waste management organizations.



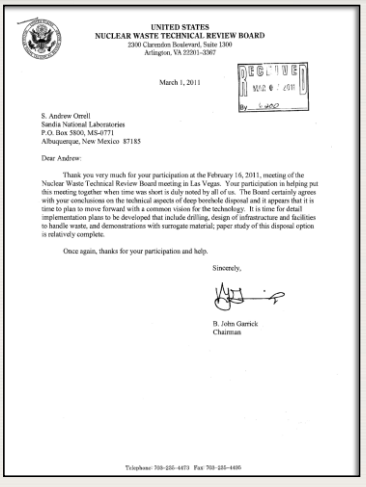
Within a year, the topic of deep boreholes was being widely covered in print, in symposia and other technical conferences.

More detailed work and formal collaborations with other institutions such as MIT and Sheffield also began.

Perhaps coincidentally with the political intrigue occurring on Yucca Mountain, the US Department of Energy, the Nuclear Waste Technical Review Board, and the Blue Ribbon Commission on America's Nuclear Future all took a vested interest.

Nuclear Waste Technical Review Board Meeting
Las Vegas, NV - February 16, 2011

- "The Board certainly agrees with your conclusions on the technical aspects of deep borehole disposal and it appears that it is time to plan to move forward with a common vision for the technology."
- "It is time for detail implementation plans to be developed that include drilling, design of infrastructure and facilities to handle waste, and demonstrations with surrogate material; paper study of this disposal option is relatively complete."



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

March 1, 2011

RECEIVED
MAR 0 7 2011
By

S. Andrew Orrell
Sandia National Laboratories
P.O. Box 5800, MS-0771
Albuquerque, New Mexico 87185

Dear Andrew:

Thank you very much for your participation at the February 16, 2011, meeting of the Nuclear Waste Technical Review Board meeting in Las Vegas. Your participation in helping put this meeting together when time was short is duly noted by all of us. The Board certainly agrees with your conclusions on the technical aspects of deep borehole disposal and it appears that it is time to plan to move forward with a common vision for the technology. It is time for detail implementation plans to be developed that include drilling, design of infrastructure and facilities to handle waste, and demonstrations with surrogate material; paper study of this disposal option is relatively complete.

Once again, thanks for your participation and help.

Sincerely,

B. John Garrick
Chairman

Telephone: 703-235-4473 Fax: 703-235-4495

The Nuclear Waste Technical Review Board (NWTRB) is an independent agency of the U.S. Federal Government, similar to the Swedish Council for Nuclear Waste, whose purpose is to provide independent peer review of the Department of Energy's program for disposing of high-level waste and spent fuel, and to provide findings & recommendations to Congress, the Secretary of Energy, & the interested public.

During a regular meeting of the NWTRB, we presented the results of the previous two years analyses, AND, more importantly, we also called for a full-scale demonstration, noting this would vet the true feasibility of deep borehole disposal and help address critical concerns.

We were pleased when the NWTRB endorsed a pilot demonstration, and noted that "paper study of this disposal option is relatively complete."

October 2011

Sandia Workshop: Pilot Testing Deep Borehole Disposal of Nuclear Waste

SANDIA REPORT
SAND2011-6749
Unlimited Release
Printed October 2011

Reference Design and Operations for Deep Borehole Disposal of High-Level Radioactive Waste

Bill W. Arnold, Patrick V. Brady, Stephen J. Bauer, Courtney Herrick, Stephen Pye, and John Finger

Prepared by
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Sandia National Laboratories

In October, 2011 Sandia brought together twenty representatives from the fields of radioactive waste disposal and drilling to:

- review the state of deep borehole science and engineering;
- identify the necessary features of a deep borehole pilot demonstration; and,
- consider organizational approaches to implementing a deep borehole pilot.

In response, we held one of the first cross-discipline meetings, with representatives from academia, the drilling industry and government. In short order, a reference design was decided and documented, and became the basis of the effort to mount a full-scale demonstration test.

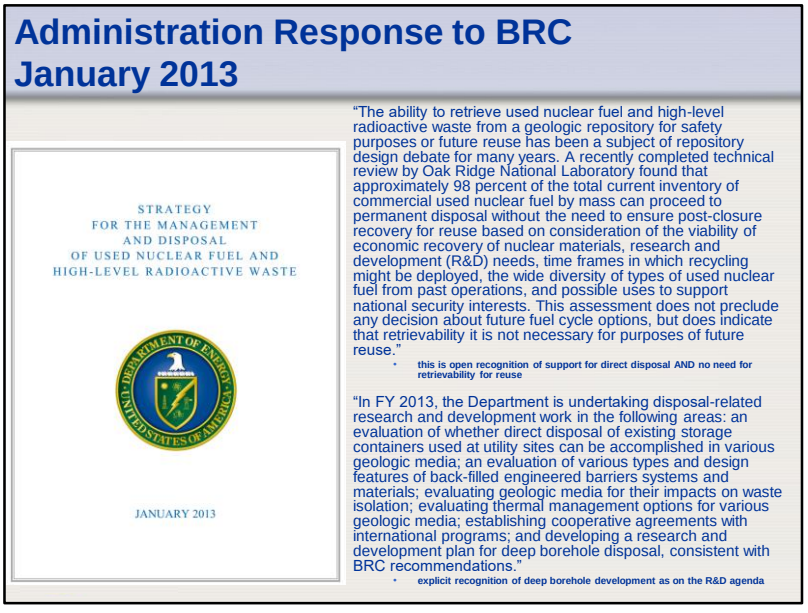
In parallel with the deep borehole design efforts from 2010 to 2012, the US Department of Energy had convened a “Blue Ribbon Commission on America’s Nuclear Future”.

The Obama Administration determined that developing a repository at Yucca Mountain was not a workable option, while noting the decision was not because Yucca Mountain was unsafe or that there were flaws in the license application, but that alternatives should be found.

The Blue Ribbon Commission was charged with deciding those options, specifically for disposal of HLW and SNF.

During their research the Commission visited several national programs including Finland, France, Japan, Russia, the UK, and Sweden.

While the final report of the Blue Ribbon Commission held many recommendations, I bring your attention to the ones echoing the NWTRB call regarding the direction to develop a research, development and demonstration program for deep borehole disposal, including appropriate regulations for the same.



A year later, the Department of Energy in response to the Blue Ribbon Commission's recommendations, issued a new strategy which, among other features, called for the direct disposal of most of the spent fuel inventory, "without the need for retrievability" for recycling, and supporting a research and development program for deep borehole disposal per the Blue Ribbon Commission recommendations.

In short, the US government had now expressed its full intent to develop a deep borehole disposal demonstration.

The commitment of the federal government does not come without considerable review and deliberation on the merits of such an investment.

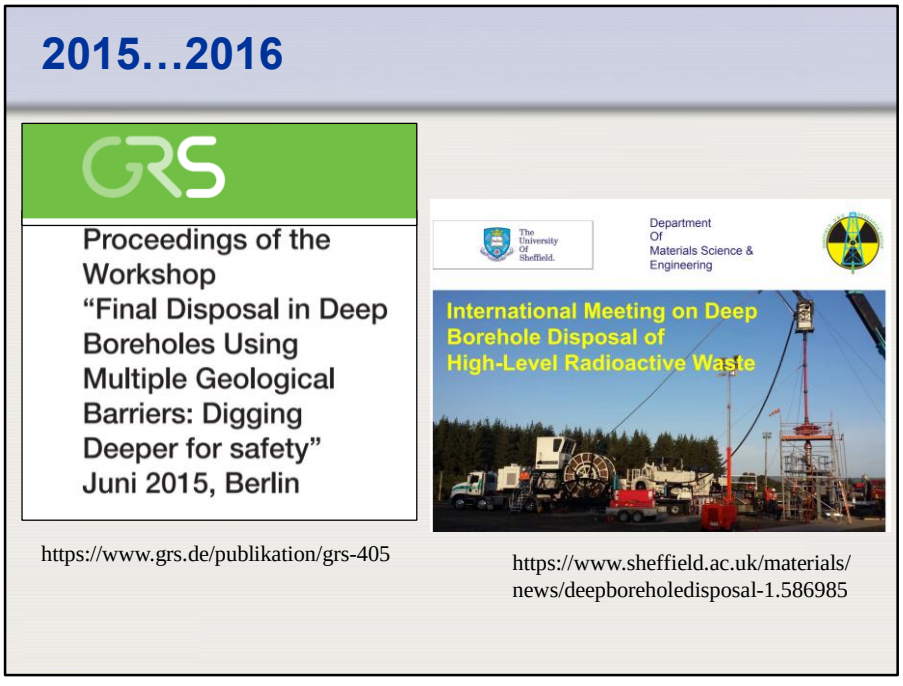
October 2014

Other countries have also expressed interest:
Germany, China, Korea, Ukraine…

Shortly thereafter, the Department of Energy set in motion the procurement efforts to identify and place under a competitively-bid contract, a suitable commercial team to implement the deep borehole field test, as elaborated in the design documents discussed earlier.

Multi-year funding for this effort was appropriated by Congress.

In parallel, my now former colleagues and I began to field more expressions of interest from other national programs.



After joining the IAEA in mid 2014, I continued to support the now rapid progress on the implementation of a deep borehole field test and the growing international interest.

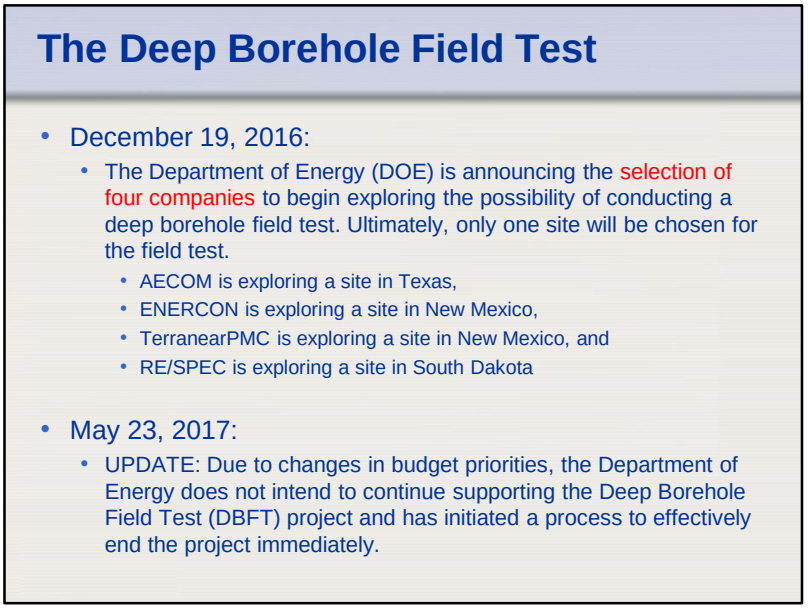
In 2015, an excellent workshop with a broad spectrum of disciplines was held by the GRS, a German non-profit that serves multiple German federal agencies with scientific research and expertise.

In concert with this workshop, I was also asked to provide input to the German Commission on the Storage of Highly Radioactive Materials and the working group on disposal, much the same as I am today.

This was followed in 2016 by another excellent meeting in Sheffield with a truly international cross-section of repository scientists and engineers.

A result of these two meetings was the compounding sense that it is possible to drill large diameter boreholes to 5 km, and that indeed much of the technology was commercially available to do so.

Both forums also confronted with equal affirmation that issues such as emplacement, retrievability, and down-hole characterization were well within or could be derived from available technology.



Which brings me to the end of last year, when, despite some early setbacks, the DOE had now identified and contracted with 4 commercial teams to propose a specific site and drilling plan for a deep borehole field test, of which one would be selected, primarily on the strength of the proposal to succeed and local public support.

Admittedly, all 4 had challenges with public acceptance…but what is notable here is the technical feasibility was not in question, and indeed, 4 teams had enough technical confidence to bid on and deliver the technology needed for a deep borehole field demonstration.

One might take note that all of these developments since 2008 took place under the Obama administration.

---CLICK---
However, the change to the Trump administration in January also brought other changes.

In addition to the sudden cancellation of the deep borehole field test, other projects aimed at a consent-based siting process, and a defense-waste only repository option, were also cancelled, ostensibly to focus on an intended resumption of the Yucca Mountain licensing process in fiscal year 2018.

Summary

- Each country has it's own unique 'value-engineering' in deciding upon and implementing a disposal strategy, whether by:
  - a mined deep-geologic repository,
  - a deep-borehole disposal system,
  - or both.
- The last decade of research and development by the international community suggests DBH disposal is quite possible.
- There is sufficient international interest that a full-scale demonstration is still possible.

Each country has it's own unique 'value-engineering' in deciding upon and implementing a disposal strategy, whether by:

- a mined deep-geologic repository,
- a deep-borehole disposal system,
- or both.

I suggest that deep borehole disposal should not be viewed as an either/or ALTERNATIVE to a mined repository, but rather as an ADDITION to the toolbox of capabilities and solutions for achieving the safe, confident, disposal of SNF and HLW.

As we have painfully experienced, to pursue and rely on a single repository model comes with the real risk of having a single point of failure.

---CLICK---

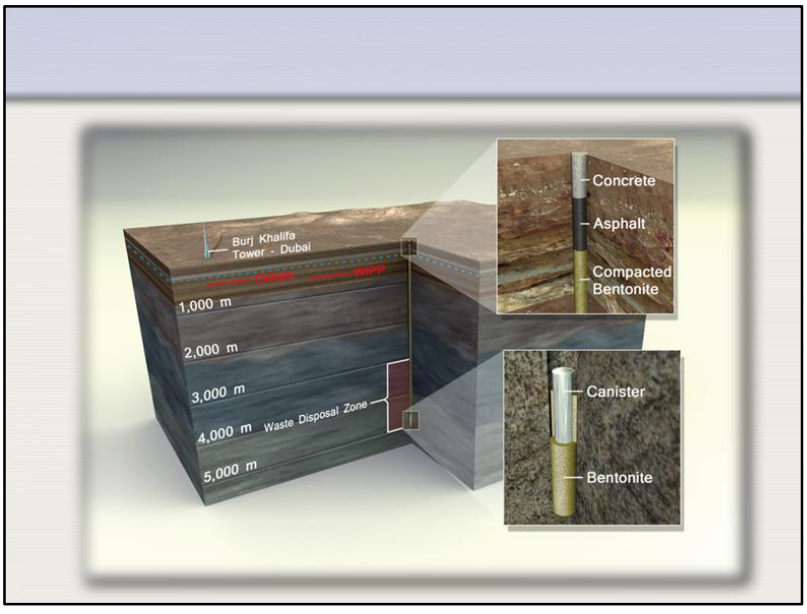
Regardless of an individual national strategy, it is clear the last decade of research and development across the international community supports the conclusion that deep borehole disposal is quite possible.

Any argument to the contrary must recognize that all current repository development programs based on mined repositories were begun with comparable questions of feasibility.

---CLICK---

Despite the recent US Department of Energy decision, there is a breadth of international interest in collaborating to resume the field test demonstration elsewhere. Several colleagues are in the process of exploring if a consortium can be formed that will pick up where the US has left an opportunity.

In this regard I welcome the interest and participation of any person, institution, or nation.



Thank you for your time and attention.