Deep Isolation – Innovation for the Storage and Disposal of High-level Waste and Spent Nuclear Fuel-19367

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ABSTRACT

Deep Isolation, Inc. is a private, Berkeley based company that has brought innovation to nuclear waste disposal. Deep Isolation has developed a disposal technique that adapts mature drilling technology and customizes it for the purpose of providing a safe and secure solution. Though the stalled nuclear waste program in the US has created unwanted burdens and costs, it has also provided object lessons which Deep Isolation has learned from and designed a novel approach. The solution proposed by Deep Isolation combines the best of the geosciences and social sciences to present the US and other countries with an optimized and tailored approach to disposing of a variety of nuclear waste. This system can complement existing potential storage and disposal sites, or in the case of countries with smaller amounts of waste--the national solution. Deep Isolation innovates where others have stalled and offers a means of deep geological disposal that costs less, takes less time to implement, and cuts down and in some cases eliminates the need for transportation of the waste.

The technical solution optimized by Deep Isolation uses established directional drilling technology from the oil and gas industry to drill a vertical drill hole thousands of meters deep and then transition to a horizontal drill hole that is thousands of meters in length. The target media is in or below shale formations, which are present at various depths throughout much of the United States and throughout the world. The availability of suitable geology allows for permanent disposal at multiple locations – including existing nuclear sites, without a need to transport the waste to a central repository.

This innovative solution not only offers options for commercial used nuclear fuel and defense spent nuclear fuel and high-level waste, but also other nuclear wastes such as those considered by DOE's past deep bore-hole program, i.e. cesium and strontium capsules. Greater-Than-Class-C (GTCC) waste is also an opportunity for Deep Isolation. DOE's preferred alternative for GTCC includes "land disposal at generic commercial facilities." Deep Isolation could provide safe, secure, and permanent disposal at a commercial facility.

Deep Isolation complements the technical innovation with best practices from the social sciences. In acknowledgement that the past challenges to implement nuclear waste disposal facilities have been primarily due to socio-political failings, we have designed a means to deeply engage with public and stakeholders. Our approach is committed to partnering with communities, local jurisdictions, states, and Tribes to determine a path forward that benefits all involved, that is fully transparent, collaborative and accountable.

INTRODUCTION

Deep Isolation's patented waste disposal concept leverages mature drilling technology to emplace nuclear waste—including spent nuclear fuel, cesium/strontium capsules, suitable forms of defense high-level, and GTCC waste —thousands of meters underground in a long horizontal drillhole within deep, highly stable geologic formations.

Well understood and existing mature directional drilling technology would be used to drill an access hole vertically thousands of meters deep. The diameter of the access hole is dependent on the nuclear waste being disposed. At depth, the drillhole would begin a gradual curve and become horizontal. The drilled hole would then continue horizontally with a slight upward tilt (1°–3°) for one to three kilometers.

Once the hole is drilled, a continuous pipe called a casing is inserted into the length of the hole using well understood and existing methods. This casing consists of long segments (typically made of steel, although other metals or alloys can be used) that are joined together and then lowered into place. The curved part of the hole typically has a radius of 200 meters. Once the casing is in place, it is common to fill the space between the casing and the surface of the drillhole with cement.

Specially designed and sized (based on the type of nuclear waste) corrosion-resistant waste canisters containing the nuclear waste would then be lowered into the casing and pushed (using wireline tractor equipment) so that they are placed end-to-end within the horizontal section of the drillhole. The tilt in this section provides additional isolation from the vertical access drillhole, because any mechanism that transports radioisotopes in a vertical direction will either move them to the dead end of the horizontal section, where the curvature of the drillhole creates a natural "plumbers trap," or upward in the opposite direction toward the dead end of the drillhole. Once waste canisters are in place, the drillholes would be backfilled and sealed with cement, bentonite and other materials.

The Deep Isolation approach builds on two key features. The first is the very compact nature of used nuclear fuel and other high-level waste. A typical 1-gigawatt (1000-megawatt) nuclear power plant produces 20 metric tons of used nuclear fuel every year, but this waste, which consists primarily of ceramic pellets, occupies only 2 cubic meters (6 cubic meters when held in an unmodified form in its original PWR fuel assemblies). A single drillhole of appropriate length could provide enough space for 20 reactor-years of waste.

The second key feature is the evolution of inexpensive but precise technology for directional drilling that enables far deeper placement of nuclear waste than prior conventional mined repository designs. At depths of a thousand meters or more in stable sedimentary formations, the billions of tons of rock between the surface and the waste provide a robust natural geologic barrier that, combined with the engineered barrier of the corrosion resistant canister, minimizes risks to human health and the environment. Drilling and canister placement and retrieval techniques are proven, reliable, and low risk as demonstrated by their extensive use in the oil and gas industry.

As an initial demonstration in November 2018Deep Isolation tested equipment, tools, and methods to emplace a mock disposal canister into a horizontal drillhole and retrieve it back to the surface. The test was performed at a commercial testing facility for oil and gas drilling using standard, off-the-shelf, tools and equipment that are common in the oil and gas drilling industry. The test used an existing horizontal drillhole approximately 2200 feet deep. The mock disposal canister was placed over 100 feet into the horizontal section of the drillhole. The test crew used wireline cable as the placement and retrieval technology. To fully demonstrate retrieval, operators released the mock disposal canister and returned the wireline to the surface. The crew then replaced the delivery tool at the end of the wireline with a recovery tool. Operators lowered the wireline and recovery tool into the drillhole, latched onto the canister and returned it to the surface. There was no damage to the canister or well during this test.

ADVANTAGES of the DEEP ISOLATION DISPOSAL CONCEPT

Compared to a conventional mined geological repository, which has been the default disposal concept in the United States and several other nations with civilian nuclear energy programs, the Deep Isolation concept offers a number of potentially important advantages. Without the need to mine a large repository, the disturbance of the host rock is minimal compared to a mine that fundamentally perturbs the system by the mining activity.

Specifically, a reducing environment at depth becomes oxidizing once there is a mine. Sealing a mine is a complex problem with many variables. The Deep Isolation approach essentially avoids the issues of a mined repository including complex performance assessments.

In addition, Deep Isolation's approach has significant advantages compared to traditional borehole concepts, which envision vertical emplacement of waste canisters within the host rock. The vertical emplacement results in great long-term stress in the "stacked" canisters due to their weight and requires a robust canister design to handle the stress. Horizontal emplacement of canisters eliminates the stress that results from vertical emplacement.

The most important consideration for any disposal concept is, of course, safety. This is because isolating radioactive waste away from possible contact with humans and the environment over very long timescales is an inherently challenging task. In this regard, the use of small-diameter horizontal drillholes to dispose of spent nuclear fuel and high-level radioactive waste has important advantages because it provides for much deeper isolation compared to other disposal strategies. With minimal perturbation to the host rock, it is possible to leverage the exceptional isolation properties of deep geologic formations whose stability has endured for hundreds of millions of years or more and maximizes the effectiveness of both engineered and natural barriers in terms of preventing the release and transport of radioisotopes from the repository to the biosphere.

Any effort to license a horizontal drillhole disposal repository would, of course, involve preparing a rigorous safety case that would carefully consider the whole range of risks and uncertainties involved, including the risk of "fast path" leakage channels that could allow for more rapid migration of leaked radioisotopes to the surface or to groundwater supplies. With proper selection of drillhole sites and host rock formations, however, the general safety advantages of the deep horizontal drillhole approach can be summarized as follows:

- Greater depth allows for placement well below aquifers, in deep geological formations where the mobility of water is very low.
- Greater depth provides a very slow transport time to surface.
- Ability to place waste below a layer of "tight", low-permeability cap rock with demonstrable barrier characteristics (e.g. shale formations that hold natural gas).
- End-to-end horizontal emplacement of waste canisters, which reduces heat load relative to denser configurations in a mined repository.
- Horizontal emplacement of canisters essentially eliminates the stress resulting from "staked" canisters emplacement vertically in vertical boreholes.
- No need for humans underground (in contrast to a mined repository), which reduces danger to workers and avoids potential leakage through ventilation paths. Note that this point also applies

to the ability to mechanically retrieve waste canisters from drillholes if the need arises.[1]

Beyond these characteristics, the Deep Isolation disposal concept offers additional advantages in terms of cost, modularity, and siting that are potentially quite important, particularly considering the difficulties encountered over several decades of attempting to site and license a geological repository in the United States.

Improved safety performance, coupled with the fact that drillhole sites can be restored to near-pristine surface conditions without any need for extensive permanent infrastructure at the site, could make such repositories far more acceptable to local communities. Greater siting flexibility and a wider geographic distribution of disposal facilities would in turn reduce the need to transport nuclear waste over long distances, thereby avoiding or reducing the need for related safety precautions and reducing transport costs.

Though cost has been viewed as a potential concern in earlier proposals for borehole disposal, recent advances in directional drilling mean that the Deep Isolation concept holds promise for substantial reducing nuclear waste disposal costs. The oil and gas industry routinely drill very deep holes with great than three kilometers horizontal sections at a cost of a few million dollars. Individual drillholes can store a significant quantity of used nuclear fuel and high-level waste.

STAKEHOLDER ENGAGEMENT

The potential benefits and advantages offered by the technical viability and costs of the deep horizontal drillhole concept, can only be realized by conducting a sound and robust public and stakeholder engagement process. For this reason, Deep Isolation has developed a detailed plan for outreach and engagement that is equal in measure to the importance of the technical components.

A Public and Stakeholder Engagement (PSE) plan has been developed to create a framework for Deep Isolation engagement with stakeholders with the long-term goal of consensus for the emplacement of nuclear waste in a horizontal drill hole for permanent disposal. The purpose of the engagement strategy is to build stakeholder support for the effort by active integration into the planning process. By doing so the aim is to consider input as a “value added” feature and when practical adapt design and implementation plans to include these inputs. This will be accomplished by engagement with stakeholders at the local, regional, tribal and state level and include them as active and collaborative team members.

In 2015, DOE issued a Request for Proposals for conducting a deep (vertical) borehole field testing project. The project was ultimately canceled primarily due to the lack of emphasis put on engaging the local communities. The Deep Isolation team has studied DOE’s previous efforts and we have taken the lessons learned to inform the development of our approach to stakeholder engagement. While the PSE plan may not be required at our present stage of development, we believe that a critical element to success in nuclear waste-related project is the development and maintenance of public trust and confidence.

The PSE plan outlines Deep Isolation’s project and potential communities, states, Native American tribes and the PSE guides our efforts to effectively engage with these stakeholders.

The primary objectives for stakeholder engagement are:

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[1] In fact, techniques for retrieval, including for the recovery of uncooperative objects (such as detached instruments, broken drilling equipment, cement plugs, and even sections of casing) are well developed in the oil/shale in industry, which routinely hires specialized companies to rapidly retrieve unwanted objects from deep inside drillholes.

- To create relationships with interested public, stakeholders, tribes and elected officials of the project and engage with them to better understand their values, concerns, and inputs;
- to consider and address the inputs expressed such that the final resolution accurately reflects the community values and aspirations;
- to continually make ourselves available and accountable for our actions and steps taken in order to create the level of trust and confidence that will be needed to form a lasting partnership with the community.
- to have made the communities better off with a Deep Isolation solution than they were before

CONCLUSION

Horizontal drillholes are a promising concept for the permanent disposal of used nuclear fuel and high-level radioactive waste that offers substantial advantages relative to previously considered disposal strategies. The ability to use established directional drilling technology from the oil and gas industry to permanently isolate the nuclear waste from the biosphere at multiple locations near existing nuclear sites sets this solution apart from the more traditional solution of a mined repository. Not every community will be willing to support a deep horizontal borehole for disposal, so this is a complementary solution to a centralized mined repository.

Deep Isolation is committed to partnering with communities, local jurisdictions, states, and Tribes to determine a path forward for the best locations to deploy a Deep Isolation solution using an open and transparent process. Deep Isolation – using private funds – has already begun to engage with stakeholders and communities across the United States using their Public and Stakeholder Engagement plan.

A deep horizontal disposal solution offers safe, secure, and permanent deep geological disposal of nuclear waste while reducing the time and cost of licensing, constructing, and transporting nuclear waste.