Position White Paper by Citizens' Oversight

A New Strategy: Storing Spent Nuclear Fuel Waste

Featuring HELMS Storage:

"Hardened Extended-life Local Monitored Surface" Storage

and

"Monitored Extended-Life Overcask" MELO containers

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ABSTRACT

Ray Lutz and Citizens Oversight are behind the recent settlement agreement with Southern California Edison which established action plan focused on moving the 3.6 million pounds of spent fuel nuclear waste from the site at San Onofre, only 100 ft from the ocean, to a safer place. Nationally, we need a better plan for dealing with spent nuclear fuel waste, and we should target safe storage for the next 1,000 years. The centerpiece is the "HELMS" Storage plan, allowing graceful upgrade of the investment in dry storage to date and prudently balancing risks. It is our hope that environmentalists and the nuclear industry will recognize that they share a common agenda for the storage of this waste while minimizing impact to the environment and safety risks, now that the nuclear industry is in decline.

HELMS Storage is Hardened, Extended-life, Local, Monitored Surface Storage, and implies that waste should be moved away from water resources and dense populations in the vicinity of the original location of the waste, but stored locally or regionally, probably within state or among state consortia, on the surface in terrorist-hardened monitored facilities with dual-layer MELO casks. The "MELO" Cask, short for Monitored, Extended-Life Overcask, is a sacrificial outer cask pressurized with inert gas enclosing the existing "thin" canisters in use in the U.S., so the internal cask will not suffer corrosion degradation. The outer MELO cask can be monitored for leaks by detecting the pressure of the cask itself, rather than relying on difficult and occasional robotic inspection technologies.

This paper provides the context and compares with other alternatives.

Finally, the paper defines a set of steps required to implement and phase-in the HELMS Storage proposal by the industry under the watchful eye of oversight groups on a conceptual level. This white paper does not attempt to quantify costs or exact implementation details. We appreciate your review and notice of any technical errors and omissions so those can be repaired.

This plan is focused on commercial nuclear spent fuel and does not attempt to create a plan for defense waste, but the same concepts can be employed in that segment as well perhaps with some modification.

INTRODUCTION

THE NUCLEAR EXPERIMENT

“Atoms for Peace” was our attempt to harness the destructive power of WWII atomic bombs for peaceful purposes. That experiment, which never would have occurred in the free market without extensive investment, promotion, and risk protection by the federal government, is now over. We know now that nuclear accidents do happen, with three major disasters so far, and it remains costly – commercial nuclear plants are financial disasters. They can’t compete with other sources, and it’s getting worse.

We now have an eternal “gift” from that experiment: the U.S. nuclear industry alone generates up to 2,300 tons of highly toxic spent fuel each year, and we have 76,430 tons to deal with so far.[1] By the time we get all nuclear plants to close, we’ll have much more, perhaps 120,000 tons of high-level nuclear waste at sites all around the country and a complete failure of the promise that this waste would be safely and effectively dealt with. Given the sort of casks we will be discussing below, we are talking about approximately 10,000 casks.

WASTE CONFIDENCE? Not at all.

The Nuclear Regulatory Commission (NRC) has the responsibility for the safety of nuclear materials used in a commercial context. It has conducted “Waste Confidence” proceedings over the years, based on the notion that as a matter of policy, it ‘‘would not continue to license reactors if it did not have reasonable confidence that the wastes can and will in due course be disposed of safely.”[2] The original plan was primarily focused on a deep geologic repository – Yucca Mountain (YM) – which was to be licensed and open for business by January 31, 1998. It is now nearly 20 years later and we can note that no geologic repository is open. YM is far from viable, and nothing is on the horizon.

In 2014, the NRC changed the name of the report to “Continued Storage Of Spent Nuclear Fuel,”[3] now stating that the waste could be left where it was generated: at the power plants all around the country, ***indefinitely***. At least the report does not continue the facade that the permanent solution of YM is right around the corner. We are told we must rely on the default solution: leave the spent fuel at the location where it was generated in canisters only designed for temporary use, that is until the promised repository opened. Those “thin” canisters have a 10 to 20 year warranty, and the manufacturer says they are designed for 60 years or perhaps 100 or 120 if you are lucky, wild guesses at best. The places where we find the short-term storage installations (each called an “Independent Spent Fuel Storage

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1 Nuclear Energy Institute, https://www.nei.org/Knowledge-Center/Nuclear-Statistics/On-Site-Storage-of-Nuclear-Waste Here, “ton” indicates metric ton, equal to 1000 kilograms, or approximately 2204 pounds, whereas the conventional ton is 2000 pounds, so the metric ton includes about 10% more mass.

2 BRC Report, Page 25.

3 NRC “Continued Storage Of Spent Nuclear Fuel” (2014) https://www.nrc.gov/docs/ML1417/ML14177A474.pdf

Installation” or “ISFSI”)[4] – at some 70 sites near 104 reactors all around the country, are hardly optimal for nuclear waste storage. **This default solution is simply not acceptable.**

This problem becomes even more pressing as nuclear plants are retired and we transition to a sustainable renewable energy infrastructure. The latest slogan by the Department of Energy (DOE), the agency responsible for the nuclear waste situation, is “consent-based siting,” but communities near retired plants never agreed to permanently host nuclear waste sites, so where is the consent there?

Local communities have no say over their safety concerns as long as the NRC claims the risk is “low.” This is due to the concept of federal preemption, where no community can set higher safety standards nor block anything due to safety concerns. If the NRC says it’s safe, then you can’t ever mention safety as a concern. Yet the NRC is primarily focused on licensing nuclear power plants, which are a many times more risky than an ISFSI, so anything you do in an ISFSI is safe on their yardstick, and there is no discrimination among options.

THIN TEMPORARY CANISTERS NEAR WATER RESOURCES?

The ISFSI designs we use in this country enclose the thin canisters in a thick concrete overpack. But the strength of these overpacks is largely an illusion, because the thin canisters must be exposed to airflow over the surface of the (very hot) canisters to cool them, flowing into and out of vents. This cooling must continue for many decades, and once they cool below about 52°C (126°F), corrosion and cracking will eventually occur, and the radiation boundary can be compromised, releasing radioactive particles out of the container, and also allowing oxygenated air to enter, with the threat that even more damage may occur, including the possibility of a zirconium cladding fire or criticality event.

Almost without exception, locations where this toxic waste is now being stored are far from optimal, due to their proximity to important water resources and dense populations. Nuclear plants need a means to cool and thereby condense the steam back into water, and so they tend to be built within yards of an important water resource, where nuclear waste definitely does not belong. And, since the power is destined for use by those major cities, the plants are nearby. By regulation, the ISFSI related to the plant has to be located within the exclusion zone of the plant

The waste problem is still not solved, and it still is getting more expensive. It is almost never included in the economic analysis of nuclear power.

THUS, we provide a plan to deal with the waste and define a new direction based on accepting the realities of the present rather than gambling that we will have better solutions in the distant future.

FACTUAL BACKGROUND

There is little dispute regarding most of the facts that define the problem. We refer readers to the “Report to the Secretary of Energy by the Blue Ribbon Commission on America’s Nuclear Future,”

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[4] NRC License requirements for ISFSIs is provided in 10 CFR Part 72.

published in January, 2012 (“BRC Report”), primarily Chapter 3, “Technical and Historical Background.”[5]

Although the BRC Report is now more than five years old, it is nevertheless a good place to start in terms of the technical and historical background for any reader who is not already well versed in those facts[6]. The BRC Report also includes definitions of many acronyms in use in the field.

HELMS Proposal

Because it is helpful to have this in your mind as you read the technical context, we jump ahead here to explain our recommendation, for which the acronym **HELMS** has been coined. It is primarily a set of criteria to which any proposal can be measured rather than a specific detailed plan, but we do have some specific recommendations for changing NRC regulations and operating philosophy, and this should also inform DOE strategy development in their quest to manage our nuclear waste.

HELMS simply means:

Hardened – to resist (terrorist) attacks such as by truck bomb, airplane strikes, etc.
Extended-life – meaning a design life of 1,000 years, and we suggest dual-canister design.
Local – meaning located in-state or within regional consortia of states.
Monitored – each canister is outfitted with a standard electronic monitoring package.
Surface – need to store on the surface for cooling for at least then next 200 to 300 years.

It will be easier to start with the second half in our explanation here to create the context and use-case for the canister design.

Local, Monitored Surface (LMS) Storage
Spent fuel from nuclear sites is thermally hot for many decades and will require extended cooling on the surface. Surface storage facilitates monitoring and it is obviously retrievable, so it fulfills the requirements defined in MRS – Monitored Retrievable Storage, as mentioned as one alternative in the Nuclear Waste Act along with YM.

Local – Probably In-State
Where we site these facilities will impact transportation requirements. “Local” implies that the waste will likely be moved from the on-site situation but not moved all the way across the country. There is a fairness to the idea that each state should be responsible for their own waste in a suitable location.

Keeping the waste in or near the state of origin mitigates “not in my state” (NIMS) legal action that may result otherwise. But we use the term “Local” because it may still be reasonable to site a facility in common with a number or adjacent states where the transportation is still limited to the local area. The limitation of the transportation of the waste is important to reduce the overall risk while still allowing

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[5] “Report to the Secretary of Energy by the Blue Ribbon Commission on America’s Nuclear Future” (BRC Report) https://energy.gov/sites/prod/files/2013/04/f0/brc_finalreport_jan2012.pdf

[6] Also recommended is the book, “Too Hot to Touch -- The Problem of High-Level Nuclear Waste” Cambridge University Press (2013) William Alley and Rosemarie Alley See: http://copswiki.org/Common/M1792

consolidation to a relatively remote area away from the most densely populated areas near where the nuclear plants are typically sited.

Some states with nuclear power plants surely have no room for waste storage. Some power plants straddle the borders between two states. Many supply power to more than one state. So siting is still not a trivial endeavor.

Characteristic	Surface Storage	Deep Geologic Repository
Siting Difficulty	Much Easier	Very difficult, requires extensive geologic characterization
Containment	Fully Contained	Problematic, relies on geology to contain
Ground water	Not Impacted	Will Permeate or flood
Cooling	Passive	>200 years of Active Ventilation
Transportation	Local	Remote, Risky
NIMBY	Local Responsibility	Severe
Monitorable	Yes	No plans disclosed
Maintainable	Yes	Only that the design must allow retrieval in the first 200 years.

Compared with a deep geologic repository, finding a technically suitable site for surface storage is immensely easier. The sort of dry storage facility we recommend is fully contained and does not rely heavily upon predicting the geology of the underlying rock or predicting changes over such a long period that there is no confidence of the results.

Consent-Based

We agree with the conclusions of the BRC Report regarding the need to find communities that consent to host the facility and the monetary benefit it can bring.[7] Such consent may be easier to come by if the facility is more robust in terms of its design so as to mitigate the risk which is otherwise a factor in that decision-making process. The trouble with this general statement is it flies in the face of all the rest of the nuclear energy legal structure, where the federal government – in the form of the NRC – is solely responsible for all safety concerns, making it impossible for states to object to the siting of a nuclear plant, for example, for safety reasons. So consent is almost an unknown concept in this industry. Thus, if communities consent to accept the waste, they must have a say if they want to institute higher safety standards.

Extended Life

This proposal targets an extended design life of 1,000 years. Yet, the storage is still "interim" because it is anticipated that eventually a deep geologic repository will be developed, or perhaps some other

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[7] BRC Report, Page 47

approach will be available in the future. But the proposal is not predicated upon a repository. We must consider that a HELMS facility is permanent in the human time scale, and that a number of HELMS facilities will exist for multiple human generations.

1,000 years is likely NOT feasible without replacing parts of the system on regular intervals. The design should provide graceful degradation such that if maintenance ceases due to an absence of administrative control, then it will remain safe for an extended period and only slowly release significant toxicity into the environment.

Although there maybe various approaches to achieve this, we suggest the following for purposes of explanation. Our suggestion includes only a single change to the existing modular canister design we see today, while still allowing the design to accommodate sealed canisters without the need to fiddle with their contents.

Monitored Extended-Life Overcask (MELO Cask)

For sake of description, we propose a specific mechanism for obtaining the Extended-Life criterion. Conceptually, each of the relatively thin canisters (1/2” to 5/8” thick) generally used today would be **encapsulated** by an additional “MELO Cask”, to form a dual-wall canister. We suggest that we consider the outside MELO cask be similar in design to the 3” thick canister proposed for YM, although we are open to discussion of the details. Key to the design is an “gas gap” between the internal canister and the encapsulating MELO Cask, to be likely filled with dry pressurized helium, thereby creating a dry inert environment for the internal canister, eliminating oxygen and the corrosive effects of moisture. The pressure of the helium should be about the same as what is inside the canister, about 50 psi (or more). Any leak to the outside environment could be easily detected just by sensing the gas pressure (described in more detail below).

The MELO Cask is the outer layer, exposed to the environment and thus to moisture, oxidation and ultimately, corrosion and cracking. As a result, it is sacrificial, and will deteriorate over time. When they finally crack, the unharmed interior canister can be removed and inserted into a new MELO Cask.

This two-layer approach is analogous to the double-hull design mandated in U.S. waters after the Exxon-Valdez disaster of 1989.[8] There, the inside and outside steel plating is about 15mm thick (0.59”) with a gap of about 2 meters between the two hulls. Thus, in an accident, if the outside hull is breached, it is hoped that the two meter gap will keep the inside hull from being breached as well. The difference in the two cases is that the risk to the outer hull in the oil tanker is due to accident, such as grounding, which was the case with the Exxon-Valdez. For spent fuel canisters, we are concerned about corrosion and deterioration over a very long period of time.

The detailed discussion of how to upgrade to the MELO Cask proposal is deferred to designers in the various firms offering their dry storage solutions to the industry. However, we offer the following.

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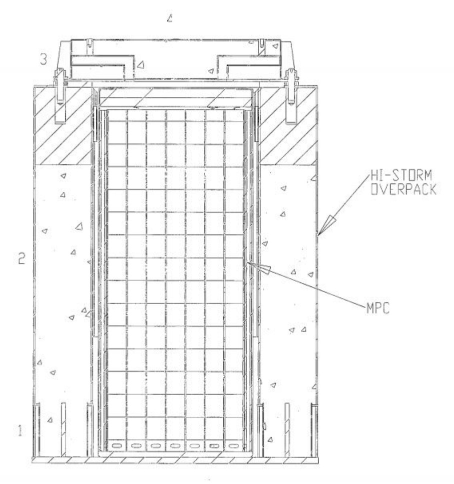
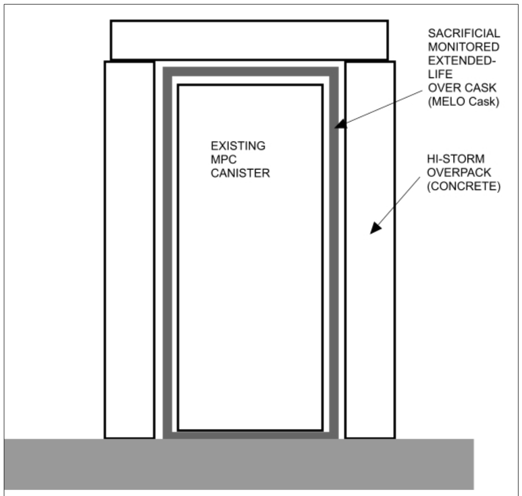
[8] “Limitations of Double Hulls”
https://friendsofwildsalmon.ca/images/uploads/resources/Limitations_of_Double_Hulls.pdf



CURRENT: Holtec HI-STORM above ground system w/o MELO Cask



PROPOSED: MELO Added to Holtec HI-STORM above ground casks

Above-ground systems can add the MELO Cask fairly easily by removing the outer concrete overpack and adding the MELO Cask, and then replacing the overpack (if there is sufficient volume inside) or by adding a new, larger concrete overpack.

There are perhaps several approaches to introduce the MELO Cask into an underground system such as the Holtec UMAX system. As mentioned, the cavities should be designed up front to be of sufficient size to accommodate the interior canister PLUS the MELO Cask.

However, we will suggest here for sake of simplicity that the MELO Cask is ADDED after the interior canister has cooled sufficiently but not below the temperature where cracks may initiate (52°C). Simply remove the interior canister from the cavity, and then insert the MELO Cask in the cavity, then replace the canister into the MELO Cask, and bolt on the top cover of the MELO Cask, similar to the manner in which a transportation or transfer cask is used today.

In either case, some thought will need be put to the design so the concrete vaults are compatible with the additional of the MELO Cask to the design.

Other desired attributes of the MELO Cask:

- **Sacrificial**
  The purpose of the MELO Cask is to provide longevity to the expected life of the overall container, and allow the outer MELO Cask to deteriorate without affecting the interior canister, and then replace it when it fails. It is not necessary, therefore, to constantly inspect the MELO Cask because it can fail without the entire system failing, as the interior canister is protected from the corrosive environment until the outer shell fails, and then the canister remains uncompromised due to the corrosive effects of the environment.

  The MELO cask provides a dry, inert environment surrounding the encapsulated canister. This isolates it from oxidation, and thus will prevent the onset of Stress Corrosion Cracking.

However, there are other aging effects that will come into play, such as vibration, irradiation[9], stress from pressure points of the enormous weight, as well as residual contamination. But without the MELO Cask encapsulation, deterioration will be much more rapid indeed.

- **Easy to Replace**
  Considering a dry canister system without the MELO Cask, the canister must be carefully inspected to anticipate failure and replaced maintain a radiation containment boundary. To replace the canister, the top must be first cut off, then all the individual fuel assemblies must be removed from the old canister and placed in a new canister, which requires a "hot cell" or fuel pool. This process is not clearly specified in NRC and industry documents and officials usually say it is "under study."

  In contrast, with the MELO Cask, there is no need to anticipate failure of the canister, as the outer cask is allowed to fail. Failure can be easily detected when there is a loss of pressure inside the MELO Cask. At that point, we still have plenty of time to react, as the interior canister can withstand corrosion for many years. Corrosion must be avoided to allow the thin canister to be transported. To "repair" the canister, we are likely talking about replacing it. To do so, the top is removed from the MELO Cask, and the interior canister removed. This does not open the interior canister at all and so there is no need for a hot-cell or fuel pool, and extensive inspections can be avoided because leaks are easily detected by a loss of pressure (explained below). The interior canister is inspected when it is move to the new MELO Cask.

- **Confinement Barrier**
  The MELO Cask as envisioned here is intended primarily as a corrosion barrier and as a secondary confinement barrier, not as a neutron or gamma radiation shield, although it would provide some shielding. Uranium and radioactive isotopes are physically held inside the fuel rod cladding (if they are not compromised) and the sealed canisters. Alpha and beta particles are stopped by the cladding and the interior canister. The surrounding concrete overpack (or below-ground concrete vault) would still exist to absorb the neutron and gamma radiation. When transported or handled, additional shielding would be necessary is it is today.

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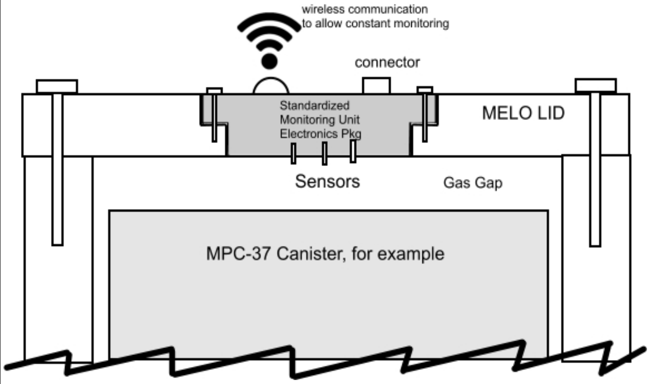
[9] Radiation embrittlement may be a factor. See the recent NRC MAPS aging management document on the subject:
Regarding Stainless Steel, 3.2.2.9 Radiation embrittlement:

> Embrittlement of metals may occur under exposure to neutron radiation. Depending on the neutron fluence, radiation can cause changes in stainless steel mechanical properties, such as loss of ductility, fracture toughness, and resistance to cracking (Was et al., 2006). Cracking has been observed in boiling-water reactor oxygenated water at fluences above 2 to 5 × 10**20 n/cm2 [1.3 to 3.2 × 10**21 n/in**2] (Was et al., 2006). Gamble (2006) found that neutron fluence levels greater than 1 × 10**20 n/cm**2 [6.5 × 10**20 n/in**2] are required to produce measureable degradation of the mechanical properties. Caskey et al. (1990) also indicates that neutron fluence levels of up to 2 × 10**21 n/cm**2 [1.3 × 10**22 n/in**2] were not found to enhance SCC susceptibility
>
> As discussed in Section 3.2.1.9 of this report, the maximum potential accumulated neutron fluence on DSS components after 100 years was calculated to be 2.63 × 10**16 n/cm**2 [1.70 × 10**17 n/in**2]. This fluence level is four orders of magnitude below the level that would degrade the mechanical properties of stainless steels. As such, radiation embrittlement of stainless steel exposed to any environment is not credible.

- **Logical Unit Option**
  If fully integrated into the design of a dry storage system, the MELO Cask could be handled in much the same way as the internal thin canister is today, with the MELO Cask and the internal canister forming a logical unit, to be placed inside the transfer or transportation overpacks. This would require substantial change to transportation procedures and other existing licenses and thus is infeasible at this juncture. (It appears this is the manner embraced by the canisters used in Chernobyl, see details below.)
- **Component Option**
  The more likely approach would use the MELO Cask only in the storage configuration, and continue to use the thin canister without the MELO Cask when moved, using the existing and unmodified transfer and transportation overpacks for shielding and structural support. This scenario DOES imply that the MELO Cask is sealed and pressurized with helium at the storage location, once the lid is bolted to the top.
- **Standard Monitoring Module**
  (See more in the next section.)
- **Seals**
  The lid of the MELO Cask would likely require the use of seals which would need to be replaced periodically. But we must note that this maintenance procedure does not open the interior canister, and does not require the use of a hot-cell or fuel pool. However, the MELO Cask would need to be purged of air and repressurized using helium in situ.



Electronic Monitoring Strategy

Monitored

Although the term “monitored” is mentioned as an assumed attribute of dry storage systems, the BRC Report admits that “Many current dry cask systems lack instrumentation to measure key parameters such as gas pressure, the release of volatile fission products, and moisture.” Yet decision makers, such as Robert List, Nevada Governor (1979-1983) said the canisters in YM will be monitored to the extent that “they’ll know exactly what is going on.”[10] In our review of the current dry storage systems, the only mandated monitoring is to perform a manual check of ventilation vents to verify they are not blocked. Very minimal indeed.

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[10] Robert List, Nevada Governor – “The thing is I think way too often overlooked is that this material is not just going to be stuffed in and covered up with dirt and forgotten, the idea is, it is going to be monitored, and it's going to be retrievable. And by being monitored, they'll know exactly what is going on with it, it's not going to be just a hope and a prayer that nothing happens.” 39:34 https://www.youtube.com/watch?v=c0emnrflYKE “Subversive Doubt: The Story of Yucca Mountain Nuclear Repository”

We are not aware of any DOE or NRC documentation of requirements for electronic monitoring, recommended standards for monitoring, nor any review of the electronic strategy.[11]

The only specific requirements for monitoring appear to be in Part 72.122 h (4)

> Storage confinement systems must have the capability for continuous monitoring in a manner such that the licensee will be able to determine when corrective action needs to be taken to maintain safe storage conditions. For dry spent fuel storage, periodic monitoring is sufficient provided that periodic monitoring is consistent with the dry spent fuel storage cask design requirements. The monitoring period must be based upon the spent fuel storage cask design requirements.

Standard Monitoring Module

The MELO Cask should be outfitted with replaceable standardized electronic monitoring module to allow constant real-time monitoring of conditions inside the MELO Cask, such as pressure, temperature, humidity, gamma radiation intensity, neutron flux, etc, as well as capture the ID of the canister and relay those data to a central monitoring facility. A monitoring module requires the penetration of the MELO Cask, certainly less problematic than it is to penetrate the hermetically sealed internal canister. Standardizing this module will allow various vendors to compete on price and functionality.

Real-time monitoring is a key shortcoming in the dry-storage system in use nationwide. Occasional inspections of one or two canisters once every twenty years with nifty robots is wholly insufficient.

The same monitoring module can be retrofitted into the design of the transfer and transportation casks so as to constantly track the location of each spent fuel canister by ID.

One caveat to the glamorous idea of such monitoring is that any gizmo added will likely also fail and may reduce the over-all life in an institutional failure scenario.

Detecting through-wall cracks

The MELO Cask is to be pressurized with an inert gas, such as helium. If a through-wall crack occurs or if any of the seals are compromised, then this can be detected by sensing the pressure drop in the MELO Cask. Such pressure sensors are to be part of the Monitor Module. This procedure is much less difficult than the status quo, which relies on inspections of the canister surface to anticipate any failure of the canister. Failure of the MELO Cask is an expected event, and does not compromise the ultimate containment boundary.

Detecting MPC Canister through-wall cracks

After testing the MELO Cask for leaks by pressurization, integrity of the contained canister can be tested with pressure tests. The test would include a purge of gas inside the MELO Cask, pulling a vacuum. If the vacuum does not hold, then the contained canister may be leaking. Even if the contained

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[11] Note to NRC or DOE: Please provide any additional information on the electronic monitoring strategy as it is not impossible that it exists and we are not aware of it.

canister has minute cracks, encapsulation in the MELO cask will eliminate the threat that canister failure may result in radiation release.

Hardened

The “Hardened” attribute relates to resisting malicious attack. Current ISFSI installations are far from acceptable in this attribute.

There are two elements which are envisioned for this attribute:

1. An enclosing building or bunker. This can provide several functions:
    1. Limiting release of radiation in the event of any accident on site, and thus providing another layer of defense in depth,
    2. Enclosing all storage system operations, such as loading, replacing enclosing MELO Casks, and maintaining the system, and
    3. Securing the facility and reducing vulnerability to simple malicious attacks.
2. Covering the facility with earth, rock or other material to further provide immunity to surface blasts.

One of the important obvious aspects of a deep geologic repository is resistance to many attack scenarios with even the most advanced “bunker buster” munitions. To provide similar resistance in a surface facility would require the addition of a bunker concept. Most “bunker buster” explosives do not penetrate more than about 60 meters deep (about 200 ft.), and much less if the material above the bunker is hard rock. For example, provision for spacing and additional footings for intermediate supporting walls may allow a structure to be added over the ISFSI to provide additional resistance to attacks and may be useful as a tertiary radiation boundary and to block access should institutional control be lost.

There's a problem with making it "too" secure, namely that the weight of the protection itself, when it eventually fails, it may then crush the casks and cause a release or a criticality event.

The point is that at this juncture, we need to concentrate on simplicity, getting the stuff to the right location, accessible, not sealed below the surface, and allow time and knowledge acquisition to work for us, for scientists to continue to evaluate risks and benefits, while the materials are still in view, accessible, monitored, and protected.

NRC regulation Part 72.122 (h) (3) states:

> Ventilation systems and off-gas systems must be provided where necessary to ensure the confinement of airborne radioactive particulate materials during normal or off-normal conditions.

It appears that virtually all ISFSIs in the country violate this provision.

Summary of HELMS

Thus in summary, the HELMS proposal requires three changes to the current status quo:

1. The use of a sacrificial MELO Cask over the current thin canisters to extend the design life to 1,000 years, including electronic monitoring to allow the detection of through-wall cracks.
2. Siting surface storage installations locally, near the nuclear plant (or cluster of plants) of origin but away from the water resource, high population densities, known fault lines, tsunami risk, sea level rise, etc. that is frequently present at the plant site, and
3. Improved hardening of the ISFSI site including a bunker or building surrounding the facility, or at least providing footings and locations where bunker walls can be added to the base structure.

Action Plan

We recommend the following actions:

- Each state, or local group of states, should determine its/their own spent fuel storage plan, probably with a consolidated site chosen in-state or among a few adjacent states, or to continue to store the spent fuel at shut-down sites indefinitely using a prudent, 1000-year design basis.
- NRC should review the design of spent fuel ISFSI canisters to resolve the discontinuity between the thin canisters and the current approval of ISFSIs to remain on site indefinitely. We recommend the adoption of the MELO Cask design, with the features we have mentioned. ISFSI owners should be required to upgrade to dual-layer and self-monitoring MELO Cask design after the canister has cooled to a temperature of deliquescence (about 52°C – 126°F).
- We recommend a moratorium on any movement of spent fuel to local ISFSIs until a top-to-bottom review is performed and a strategy at each site is determined.
- ISFSI vendors should determine an upgrade path so as to provide a dual-wall design, such as with the MELO-Cask upgrade for any existing or future ISFSI installations, and all CIS installations.
- A standard specification for an electronic monitoring module which can be used with a MELO Cask, in terms of mechanical dimensions, sensing capability, and wired and wireless communication should be defined. Such a monitoring module should be able to sense pressure, temperature, radiation flux, canister ID and any other standard metric that is feasible, and interface with the HELMS facility using wireless or wired communication. The module must be easily replaceable in the event of failure and include triple sensing redundancy to allow the module to detect internal failure. Such a standard specification will allow the module to be made by competing vendors and result in optimization of functionality and reduced cost.
- The Congress should act to provide

1. NWF money to allow the HELMS compliant CIS facilities to be built, and restart the collection from ratepayers who are still receiving power from nuclear plants. It is a matter of fairness to charge those customers who are using nuclear energy today rather than putting on the back of future generations.
2. Such CIS facilities must not be predicated on the approval of Yucca Mountain.
3. Consenting Local communities must be able to have a larger say in what level of safety they require, even if it exceeds the NRC safety levels.

Funding and Ownership

It is our position that HELMS compliant storage installations should be funded by the Nuclear Waste Fund with monies originally collected from ratepayers, and contributions from operating plants should be restarted. (Collections were improperly aborted in 2014[12].) The installations should be owned and operated by the federal government. With this said, HELMS storage is not a deep geologic repository and so it is not considered "disposal," but is an interim solution for the next 1,000 years, the first 1/150th of the minimum time we are concerned with.

TECHNICAL CONTEXT

With the BRC Report as a basis, we consider some key points to build the context for the HELMS proposal. The following passages are noteworthy, with our comments following:

- "The approach laid out under the 1987 Amendments to the Nuclear Waste Policy Act (NWPA) —which tied the entire U.S. high-level waste management program to the fate of the YM site— has not worked to produce a timely solution for dealing with the nation's most hazardous radioactive materials."[13]
  - **No Repository**
    Indeed, the original plan was to have a permanent "deep geologic repository" open and accepting waste by January 31, 1998, and points out a fundamental mismatch between legal decisions and political policy vs. scientific inquiry and engineering development. The concept that we can reliably predict what will happen 10,000 to one million years in the future, as was mandated by the YM project definition, is laughable.

    Plate tectonics, the overarching theory behind all earthquake predictions was only accepted after the 1964 9.2 magnitude Alaska earthquake, only just over 50 years ago. To now be able to say with any certainty what will happen even 1,000 years in the future is no more than a wild guess, let alone 10,000 or a million years. Thus, designing a geologic waste repository is very difficult indeed. Politics should not trump science, and thus, this is not just a political

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[12] E&E News, "U.S. ends fee collections with $31B on hand and no disposal option in sight" (May 16 ,2014) https://www.eenews.net/stories/1059999730

[13] BRC Report, Executive Summary, page vi

problem of “Not In My Back Yard” (NIMBY), but also there are honest concerns about the design of such a repository, and most particularly at YM.

  - **Plan B is now Plan A, must be better**
    Certainly, unless we figure an inexpensive way to detoxify the waste – and this is quite unlikely in the near term – then a deep geologic repository is one way to deal with the problem. But finding sites for such a repository and then developing it is a very difficult technical and political challenge, and given the recent sad history of YM, we plan now that it will not be available. Our “plan B” needs to be good enough to be considered effectively “permanent” rather than a temporary or interim fix.

- **The BRC Report says, After the Fukushima disaster**
  “...Americans became newly aware of the presence of tens of thousands of tons[14] of spent fuel at more than 70 nuclear power plant sites around this country—and of the fact that the United States currently has no physical capacity to do anything with this spent fuel other than to continue to leave it at the sites where it was first generated.”[15]

  - **Terrorism now perceived as a reality**
    The issue was further compounded by the post-9/11 perception that spent nuclear fuel at these sites represents more more than 70 terrorist targets, which could result in a nuclear dirty bomb without any need to obtain or handle nuclear materials by terrorists, and could potentially be activated with simple truck-bomb or hi-jacked plane scenarios. This is not science fiction, it is reality.

- **Wet (pool) storage**
  “Nuclear fuel will remain in a commercial power reactor for about four to six years, after which it can no longer efficiently produce energy and is considered used or spent. The spent fuel that has been removed from a reactor is thermally hot and emits a great deal of radiation; upon removal from the reactor, each spent fuel assembly emits enough to deliver a fatal radiation dose in minutes to someone in the immediate vicinity who is not adequately shielded. To keep the fuel cool and to protect workers from the radiation, the spent fuel is transferred to a deep, water-filled pool where it is placed in a metal rack. Typically, spent fuel is kept in the pool for at least five years, although spent fuel at many U.S. reactor sites has been in pool storage for several decades. Approximately 50,000 metric tons of commercial spent fuel are currently stored in pools in the United States.”[16]

  - **Spent Fuel Pool Risk Varies**
    There are two main configurations of spent fuel pools, those used in the Mark 1 design as used in Fukushima, with the fuel pools approximately three-stories up in the building, and

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[14] Actually 76,430 metric tons and increasing

[15] BRC Report, Executive Summary, Page vii

[16] BRC Report, page 10

the more recent designs with the pool at grade level. The grade-level design does not pose as great a risk, however, spent fuel pools require active cooling and thus if no other factors exist, passive dry storage is preferable. The NRC regards both as being "safe." But we must also state very clearly that placing spent fuel dry storage only yards from the ocean (such as at San Onofre) should never happen.

The primary radiological disaster at Fukushima was due to the full melt-down of three reactor cores. The fuel pools were damaged and were in a precarious situation to be sure. But the spent fuel in the pools represented a far greater risk in terms of the total amount of nuclear material. The most precarious fuel pool was in the Unit 4 reactor building, and it was all removed as of Dec, 2014[17]. Other fuel pools still have hundreds of fuel assemblies[18]. The dry storage canisters on site were not harmed, but they were of a thick-wall design with bolted lids, bolted to the floor of the dry storage building, far different from what we use in the U.S.[19]

- **Dry (cask) storage introduced when pools became full to overflowing**
  "After the fuel has cooled sufficiently in wet storage, it may be transferred to dry storage. Dry storage systems take many forms but generally consist of a fuel storage grid placed within a steel inner container and a concrete and steel outer container. The amount of commercial spent fuel stored in dry casks in the United States totals about 15,000 metric tons."[20]
  - **Pools Full, Risky**
    Operating plants initially increased the capacity of the spent fuel pools simply by re-racking them to much higher density, until now the density is the same as in the reactor core. Boron separators absorb neutrons to avoid a critical nuclear reaction in the pools. In desperation, plant owners started storing spent fuel in dry canisters in an inert gas, usually helium.
  - **An ISFSI At Every Plant**
    In response, the industry has built a fleet of ISFSIs, otherwise known as "dry storage" around the country at operating nuclear plants to allow the plants to continue to generate waste while not having any place to ultimately move it.

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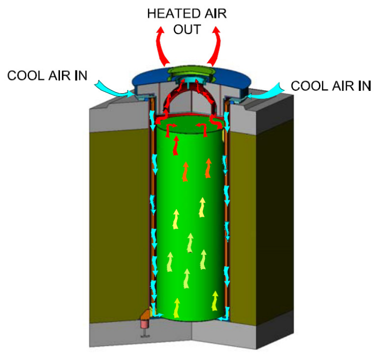
[17] https://www.japantimes.co.jp/news/2014/12/20/national/all-spent-fuel-removed-from-reactor-4-pool-at-fukushima-no-1-tepco-says

[18] https://www.japantimes.co.jp/news/2017/01/27/national/fukushima-reactor-3-fuel-removal-pool-postponed

[19] https://www.ncbi.nlm.nih.gov/books/NBK373721/ – The casks are steel, equipped with an inner and outer bolted closures that can be removed for inspection, and bolted to the foundation of the cask storage building, which is located at a low elevation close to the quay . Nine casks containing a total of 408 fuel assemblies were in storage on March 11, 2011. The building lost power and was inundated with sea water, sand, and debris by the tsunami, and the doors and louvers ventilating the building were damaged. However, the casks were not damaged or displaced, and air flows were not significantly obstructed (TEPCO, 2012a, p. 300). Inspection of the cask interiors in March through May 2013 revealed that there was no leakage of seawater into or helium out of the casks, and there was no damage to the fuel bundles or baskets within the casks (Tateiwa, 2015; Wataru, 2014).

[20] BRC Report, page 11 (as of 2012)



Atmospheric air flows right over the canisters, shown in the below-ground Holtec UMAX ISFSI design

- **Component System Uses Thin, Single Layer Canisters**

  The Multi-Purpose Canister (MPC), conceptualized by the U.S. Department of Energy (DOE) as a single versatile package equally suitable for on-site storage, transport, and permanent disposal in a future repository.[21] These MPC systems used predominantly in the U.S. are of this type, a component system with relatively thin (1/2” to 5/8”) welded stainless steel internal canisters, surrounded by an additional structural support and shielding element, such as concrete – when stored at a fixed site – or surrounded by transportation overpacks, which use lead and sometimes water, surrounded by a steel jacket – when transported. The original concept by the DOE did not include the concept that MPCs would be stored for more than about 20 to 40 years at any plant site.

  The MPCs are thinner than the width of a dime. If scaled down to the size of a soup can, they would be only about 22% the thickness of the walls of that can.

- **Water Resource at Risk**

  As the plants close and are decommissioned, the spent fuel remains at those sites and moving it away from the water resource is likely appropriate.

  Due to NRC licensing restrictions, the ISFSIs are within the exclusion areas[22] of each power plant, which places it in very close proximity to a large water resource in almost all cases, except for the Palo Verde site near Phoenix, AZ, which is the only nuclear plant in the world which does not rely on a water resource for cooling[23].

  Thus, moving the waste away from this water resource can decrease the risk that any accident will contaminate and ruin that resource virtually forever. The temporary increased risk of transportation is easily offset by the reduced risk at a location away from such water resources over a much longer period of time.

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[21] https://holtecinternational.com/productsandservices/wasteandfuelmanagement/dry-cask-and-storage-transport/multi-purpose-canisters/

[22] “Exclusion area” is defined in 10 CFR part 100, which unfortunately defines the exclusion area in terms of dosages rather than hard distances. Technical Information Document 14844 (http://www.nucleartourist.com/events/TID-18444.pdf) provides some sample calculations for various reactor sizes. For example, for a 1000 MWth Reactor, they calculate the exclusion area should be 0.67 mi (3537 ft, 1.078 km), low population zone, 10.3mi, and population center distance of 13.7mi. Unfortunately, many plants have been licensed with FAR SMALLER footprints, such as San Onofre which has a minimal exclusion area, but still has a super freeway, rail, and publicly accessible beach area within it.

[23] https://en.wikipedia.org/wiki/Palo_Verde_Nuclear_Generating_Station – “The Palo Verde Generating Station is located in the Arizona desert, and is the only large nuclear power plant in the world that is not located near a large body of water. The power plant evaporates the water from the treated sewage from several nearby cities and towns to provide the cooling of the steam that it produces.”

Also within this consideration is the concern about sea level rise due to climate change. Most on-site ISFSIs are within a few dozen feet of the high water mark and will be easily inundated by the expected rise of sea level. For example, the ISFSI at San Onofre is expected to be fully surrounded by Pacific Ocean water by the end of the century.

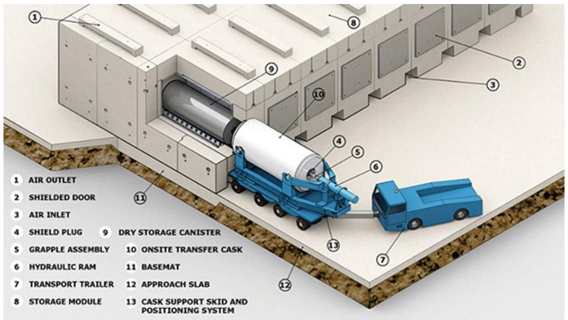
- **Salty Air Results in Rapid Corrosion**
  Furthermore, siting waste storage facilities near salty ocean waters exposes the thin metal containers to the corrosive saltwater air and will reduce the life of storage containers.

  The reality of Chloride-Induced Stress Corrosion Cracking (CISCC) was not fully recognized for more than a decade after MPC started being used. The 2007 NRC Probability Risk Assessment for Dry Storage[24] stated that no corrosion would occur at all. The issue was recognized and more fully understood by the NRC in the period from 2010 to 2016.[25]

  We must recognize that these canisters are not immune from corrosion and over extended periods of time, WILL corrode and deteriorate. The question is not IF, it is WHEN.

  We will assert here that the action investigation into the CISSC should not yet be closed.

- **Spent Fuel Still Hot**
  The BRC Report mentions that the spent fuel is “thermally hot”, but did not quantify how hot they really are. The maximum expected temperature of fuel cladding has been estimated to be 400°C [752°F] at the beginning of storage. This cladding temperature is expected to decrease to around 266°C [510°F] after 20 years and to approximately 127°C [261°F] after 60 years.[26] The cladding is around the fuel rods, and that is inside the canister, but the surface will exhibit similar temperatures. It’s not safe to approach the canister unless it is inside another overpack, but if you could, it is too hot to touch even after 60 years.



Areva (Now Transnuclear) horizontal NUHOMS ISFSI system

- **Dry Storage Types in the U.S.**
  In the common dry storage configurations in

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[24] NUREG-1864, “A Pilot Probabilistic Risk Assessment Of a Dry Cask Storage System At a Nuclear Power Plant” https://www.nrc.gov/docs/ML0713/ML071340012.pdf (2007) – We note this has not been updated subsequent to the recognition of the CISCC issue, and includes many disturbingly optimistic assumptions and no treatment of terrorist threats. On Corrosion, the entirety of its attention to this issue is as follows: “The MPC, which acts as the confinement boundary for the HI-STORM dry cask storage system, is constructed entirely from austenitic stainless steel Types 304, 316, 304L, or316L. All of these stainless steel grades are corrosion resistant in high-humidity and industrial environments. Therefore, coastal and industrial atmospheres should have no effect on the confinement ability of the MPC (Reference 51). The MPC is drained, dried, and filled with helium. Helium is an inert gas; it does not react with the fuel cladding or the internal structures of the MPC.”

[25] Lombard, Mark, “Chloride-Induced Stress Corrosion Cracking (CISCC) Regulatory Issue Resolution Protocol (RIRP) Closure Meeting” (April 28, 2016) – https://www.nrc.gov/docs/ML1611/ML16113A160.pdf

[26] NRC NUREG-2214 Managing Aging Process In Storage (draft) Adams Accessor ML17289A237, Page 3-14

the U.S., there are two major vendors, Areva (now TransNuclear) and Holtec. These storage designs feature concrete surrounding the canisters to absorb radiation. However, atmospheric air freely circulates through openings and then over the canisters to cool them off, and that air is subject to gamma and neutron radiation, and depending on the intensity of that radiation, may become slightly radioactive. Any release of radioactivity would be carried into the atmosphere without restriction. The concrete that surrounds the canisters is needed to absorb the gamma radiation and neutron flux from the radioactive material and will break down over time and therefore eventually will have to be replaced.

- **Airborne Radioactive Release Danger**
  One risk from dry storage is an airborne release caused by an extremely hot fire, that spreads over hundreds or even thousands of square miles. Such a release could be caused by terrorist attack, warfare strike, or industrial accident. Sure, these are not daily events, but we need to plan for the worst case. Dry storage facilities should be in remote locations generally away from dense populations.

- **“Spent Fuel” is extremely dangerous**
  A U.S. Nuclear Regulatory fact sheet states that after 10 years in a cooling pool, the surface radioactivity of a spent fuel assembly is still about 10,000 rem/hour. To understand the danger that poses to health, consider that a 500-rem dose delivered to a whole person in a single exposure is fatal. Close proximity to a single 10-year-old spent fuel assembly would deliver a fatal whole-body radiation dose in about three minutes.[27] After about 150,000 years the spent fuel will be no more hazardous than the parent ore, so any geologic repository should be designed for that period of time.[28] But we must admit, even planning to safely store the waste for 1,000 years is a big challenge.

- **Shallow Defense**
  The nuclear industry usually prides itself by respecting the philosophy of “Defense-in-depth” by providing layers of defense and providing recovery of failures at many levels.

  This philosophy is not well respected in the case of spent fuel, as the spent fuel is encapsulated only two times, once by the cladding of the fuel pellets, and once by a thin canister. However, the cladding of fuel pellets is already cracked in many cases (perhaps about 15% of the time at many nuclear plants). In any accident that deforms the canister itself, and since the zirconium cladding is pyrophoric (flammable)[29], it may actually start to burn, and pouring water on it will split the water into oxygen and hydrogen, only making matters worse. So really the cladding can’t be counted as a defense layer in any conservative

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[27] http://www.psr.org/environment-and-health/environmental-health-policy-institute/responses/the-growing-problem-of-spent-nuclear-fuel.html

[28] John Deutch and Ernest J. Moniz, et al., Massachusetts Institute of Technology Report, The Future of Nuclear Power: An Interdisciplinary MIT Study, 2003, 180 pages, (April 16, 2011). http://web.mit.edu/nuclearpower/pdf/nuclearpower-full.pdf page 161

[29] Review of Zirconium-Zircaloy Pyrophoricity -- https://www.osti.gov/scitech/servlets/purl/5791423

analysis. And the “cans” used around individual damaged fuel assemblies do not fully isolate the spent fuel because they have drains in the bottom to allow the water to drain out when the canisters are loaded from the fuel pool. And so, they don’t provide an isolation boundary either. That leaves only one layer – the thin canister – which if cracked or compromised, and if isotopes exist in in the gas inside the canister, radioactivity can escape directly into the circulating cooling air[30].

In fact, the NRC regulations doe not mandate any “defense in depth.” The only mention of containment boundary is § 72.122 Overall requirements. (h) Confinement barriers and systems.

> (1) The spent fuel cladding must be protected during storage against degradation that leads to gross ruptures or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. This may be accomplished by canning of consolidated fuel rods or unconsolidated assemblies or other means as appropriate.
>
> (2) For underwater storage of spent fuel, (not relevant).
>
> (3) Ventilation systems and off-gas systems must be provided where necessary to ensure the confinement of airborne radioactive particulate materials during normal or off-normal conditions.
>
> (4) Storage confinement systems must have the capability for continuous monitoring in a manner such that the licensee will be able to determine when corrective action needs to be taken to maintain safe storage conditions. For dry spent fuel storage, periodic monitoring is sufficient provided that periodic monitoring is consistent with the dry spent fuel storage cask design requirements. The monitoring period must be based upon the spent fuel storage cask design requirements.
>
> (5) The high-level radioactive waste and reactor-related GTCC waste must be packaged in a manner that allows handling and retrievability without the release of radioactive materials to the environment or radiation exposures in excess of part 20 limits. The package must be designed to confine the high-level radioactive waste for the duration of the license.

We note the following deficiencies:

- “Canning” used to confine a single spent fuel assembly inside a dry canister have drains on the bottom to allow the water to drain out, and thus they do not provide a radiological confinement boundary.

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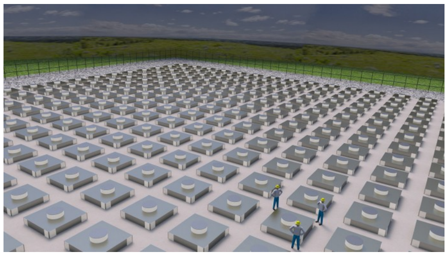
[30] However, if a crack were to occur in a canister and it the cladding was not compromised, then there may not be much of any release, particularly if the cracks are microscopic.

    - Dry cask storage systems used in the U.S. are vented to the outside air, and thus they are all in noncompliance with 72.122(h)(3) (above).
    - Constant monitoring is required for wet storage, but only periodic monitoring is required for dry spent fuel systems. We disagree that this is an appropriate level of monitoring given that electronic monitoring is feasible on 7/24 basis.
    - The short-duration of the license is not realistic and results in designs that are insufficient for “indefinite” storage now allowed by other NRC regulations. The sentence “The package must be designed to confine the high-level radioactive waste for the duration of the license.” is the crux of the problem. The short 20-year license means that dry storage systems will be designed only for that extent, and no more. This is a serious blunder by the NRC and must be corrected.

- **No easy way to deal with cracked canisters**
  If these stainless steel canisters are subjected to the outside air, especially if next to the ocean, they will suffer stress corrosion cracking.

  > In a sheltered environment, deliquescence of airborne salts below the dew point also could generate an aqueous electrolyte initiating general corrosion. These salts may be chloride rich and originate from marine environments, deicing salts, and condensed water from cooling towers, as well as a range of other nonchloride-rich species originating from industrial, agricultural, and commercial activities. Studies have shown that $MgCl_2$, a component of sea salt with a low deliquescence relative humidity, would deliquesce below 52°C [126°F] under realistic absolute humidities in nature (He et al., 2014).[31]

  If a canister becomes compromised due to cracking, the industry has very few actions defined. Apparently, the way to solve this is to replace the canister, and to do that, it needs to be placed in either a spent fuel pool or in a “hot cell”, which is a chamber which can be filled with helium to provide a dry inert environment (without moisture or oxygen), and use remote controlled robotics to cut open the canister, remove the fuel assemblies, and then place them in a new canister, and weld it shut, and pressurize it with helium. This step is so difficult, it should be avoided by design. The HELMS proposal avoids this problem.



Holtec Proposed Consolidated site in New Mexico between Carlsbad and Hobbs could hold waste from all plants storing canisters vertically in underground vaults

- **Consolidated Storage**
  The BRC Report proposes that an interim solution is

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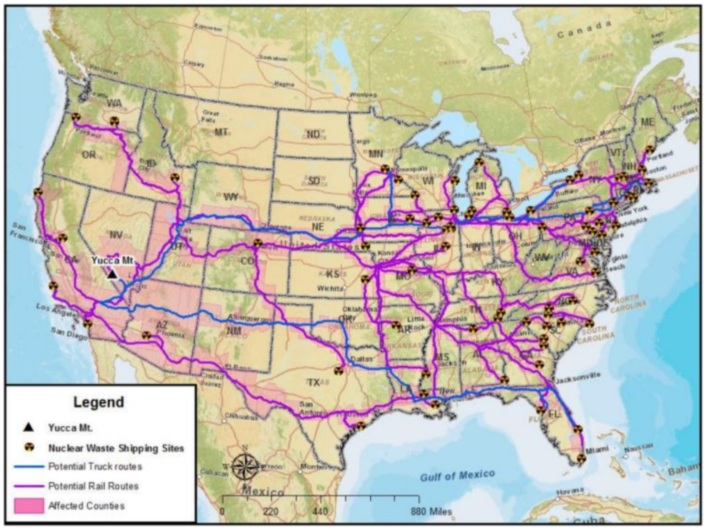
[31] NRC NUREG-2214 “Managing Aging Process In Storage” (draft) Adams ML17289A237, page 3-8

to build one or more large "Consolidated Interim Storage" (CIS) sites[32] designed to operate on the order of 100 years while a permanent geologic repository can be developed. Consolidation can reduce costs of administrative control and security by avoiding duplication. However, they propose the same lousy design similar to what we have now at the local ISFSIs. (It is our position any CIS facilities must comply with the HELMS plan.) Fully consolidated waste means a lot of transportation, which will be covered below.

- **Transportation**
  "Because of the residual hazard it poses, spent fuel must be shipped in containers or casks that shield and contain the radioactivity and dissipate the heat. In the United States, spent fuel has typically been transported via truck or rail; other nations also use ships for spent fuel transport."[33]
  - **Limit Transportation, Limit Risk**
    There is obviously increased risk during handling and transportation compared with not transporting the waste at all, if the two sites (source and destination) have similar risk profiles. The increased risk is due to three factors: human error, in handling the waste containers during transportation; design error, the possibility that the containers do not perform as expected; and terrorist risk, which might be higher if the transportation route is either more accessible to such attack, or if the route exposes dense populations.



Proposed Transportation Routes to YM

  - **High Consolidation Means High Transportation Risk**
    Either a single geologic repository or a single large CIS facility includes the concept that spent fuel would be transported <u>across the country</u> to those consolidated sites, resulting in transportation over very large distances and then requiring a second move to a permanent repository, if and when that ever happens. Residents are rightly concerned about this possibility exacerbated by the fact that rail transportation routes typically run right through the middle of cities. We must say, however, that it is probably quite reasonable to transport spent fuel out of California (and any locations west of the Rocky Mountain range, approximately 104° longitude – approximately along the extension of the Montana-Nebraska border) to locations east of that same line to reduce risk due seismic factors. We

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[32] BRC Report, Page 35
[33] BRC Report, Page 11

do not subscribe to the theory that we can adequately predict seismic risk using the very short history of seismology.[34]

- **No Real Transportation Experience**
  Even though the BRC Report and other documents[35] make it sound like transportation in the United States is routine and has a long history, we have **NO experience** transporting full-sized dry storage canisters containing commercial spent fuel in the U.S.[36]. France and other countries have transported spent fuel but we must remember that France is a much smaller country and has no routes even close to an East-coast to YM route, and there are differences in the types of fuel and canisters being used.

  In December 2016, Oak Ridge National Laboratories started a project to research the concerns regarding transportation.[37] The study and most planning is still around a large transportation campaign to a central site rather than to more local consolidation centers.

- **Rail or Ship Transportation raises fewest issues**
  Rail is said to be the safest approach for transporting spent fuel nuclear waste on land as it avoids most traffic incidents, but those same rails typically go right through the center of many towns and major cities. Ocean-going ships have been designed to accommodate spent fuel in dry cask storage containers and that approach may reduce popular push-back on spent fuel transport. However, transportation by ship likely means we will have much more handling as the canisters are loaded and unloaded, and then transported over land to the final destination, and we have no experience with transporting full-size commercial spent fuel canisters that way.

- **“Local” Siting Important**
  Thus, since transportation is a risky endeavor, it should be minimized while also balancing the need to move the waste from the site of origin and the associated water resource and high population density. In our proposal, we refer to this as “Local” siting, which may usually equate to “within the state of origin,” or among a consortia of nearby states. There is something inherently fair about that concept. Each state that benefited from the power generated by the nuclear plant should also bear the burden of the waste. Since transportation does add risk, why transport very hot spent fuel long distances just to store it on the surface to cool for decades anyway? It makes no sense, but prudent local relocation does.

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[34] Lutz, R, “A Prudent View of Earthquake Risks, Nuclear Plants and Nuclear Waste Along the California Coast” http://copswiki.org/Common/M1731

[35] Kevin J. Connolly, Oak Ridge National Laboratory & Ronald B. Pope, Argonne National Laboratory, “A Historical Review of Safe Transport of Nuclear Spent Fuel” – FCRD-NFST-2016-000474, Rev. 1 (Aug 31, 2016) – https://www.energy.gov/sites/prod/files/2017/03/f34/Enhanced%20safety%20record%20report%20-%20final%20public%20release_0.pdf

[36] Based on an answer to my question at the NRC DSFM REG CON 2017 meeting on Nov 1, 2017.

[37] https://www.ornl.gov/division/rnsd/projects/spent-nuclear-fuel-transportation – This project was started in December 2016 and has no published papers on their web site disclosing any results.

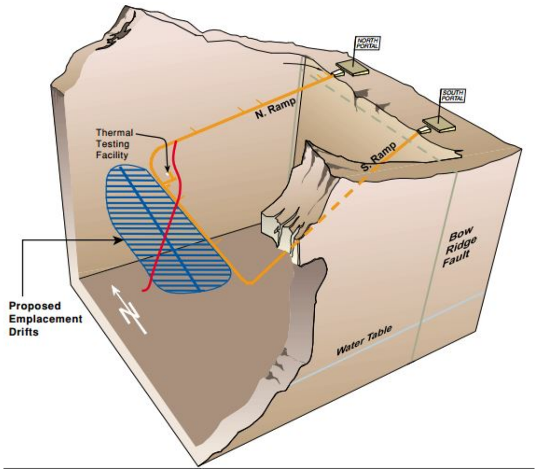
Where exactly should the sites be? That question is beyond the scope of this paper, but some work should be done to look at possible sites generally away from dense populations, water resources, and other concerns, while being mindful of environmental justice issues.

- **Deep Geologic Repository**
  “While several options for disposing of spent fuel and high-level nuclear waste have been considered in the United States and elsewhere, international scientific consensus clearly endorses the conclusion that deep geological disposal is the most promising and accepted method currently available for safely isolating spent fuel and high-level radioactive wastes from the environment for very long periods of time.”[38]

  - **Interim Storage a Reality**
    While the statement in the above paragraph is no doubt true, we believe there are a number of reasons why we must have a better interim solution which can get us through the next few centuries with a design goal of 1,000 years, as follows:

  - **Siting Very difficult**
    Siting and developing a deep geologic repository is a more difficult technical and political challenge than anticipated. There are many unknowns over a long period of time in a geologic repository and it would be very difficult to deal with any significant unanticipated events.

  - **Very few**
    Very few deep geologic repository sites will be developed, if any. Our experience so far is only with YM, and it was perhaps the finalist not because it is the optimal location from a geologic standpoint but because it is near the national atomic weapons testing area, and the planners at the time figured that Nevada put up with all that atomic testing, so why not allow safe storage of some spent nuclear fuel?



Overall diagram of YM as currently proposed

  - **YM Not Viable**
    There are many red flags about the YM site: It is not really “deep” in that it is in a mountain above the saturated zone rather than being deep in the crust. It is not in a highly stable geologic rock formation. It is near cinder cones and has a number of faults running through it. There is recognition that it will be permeated by water. You may hear that “it is the most studied place on earth” from a geologic standpoint, but that only means that we now know how much we really don’t know about

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[38] Massachusetts Institute of Technology, *The Future of the Nuclear Fuel Cycle: An Interdisciplinary MIT Study*, Cambridge, MA, 2011, p. 59 (Referenced by the BRC Report, Page 29, Footnote 52.

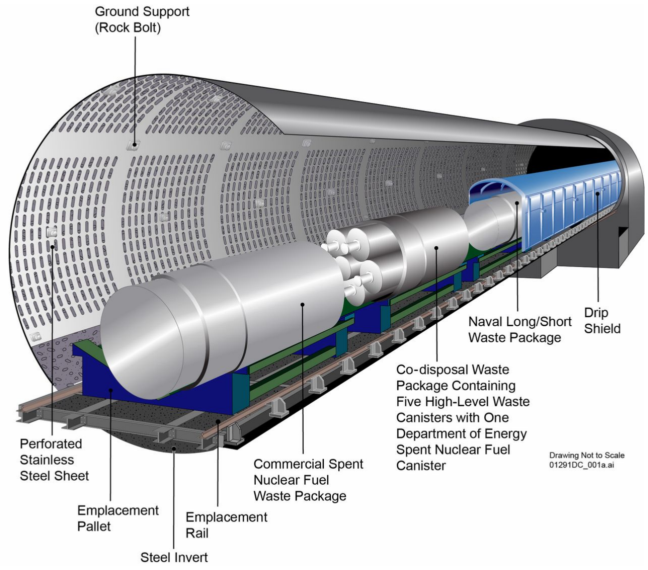
the situation and any notion that it is the best place for such a repository has been hopelessly refuted, particularly when mated with the design philosophy, which relies on the geologic formation for isolation.

- **Science Must Guide Law, not the reverse**

  It is tempting for lawmakers to throw science under the bus and just pass a law saying the YM site will be used no matter what, and then say that “any scientific conclusions to the contrary are now moot” which is exactly what the DOE administrator said in the early 2000s in a recorded interview.[39] We must base our actions regarding this highly toxic waste on science and prudent planning rather than passing an overriding law in desperation while ignoring those real concerns at the site.

- **Spent Fuel Too Hot Anyway**

  There are two approaches to the use of YM, one where the mountain is allowed to get very hot, and another where the temperature is kept below 100°C, so the water will not be boiled out of the rock and its characteristics changed dramatically. It will apparently be necessary to actively ventilate and cool the mountain for up to 200 years before it can be sealed. If that is the case the “deep geologic” part of the proposal is far from real. The air circulated over the waste effectively places it on the surface, or the spent fuel must stay on the surface for a long time (> 60 years) as well to be “aged”[40] which is to say they must cool off.

  YM Emplacement Tunnel As Designed

  Thus, even if we had YM open and ready for business, waste canisters from plants are far too hot, from a thermal perspective, to place in the repository under the cool-mountain scenario.

- **Too Hot for Humans**

  If hot waste is placed into the mountain, then it will be all but impossible to work in that environment without being roasted. We are told that it will be fully automated and there will

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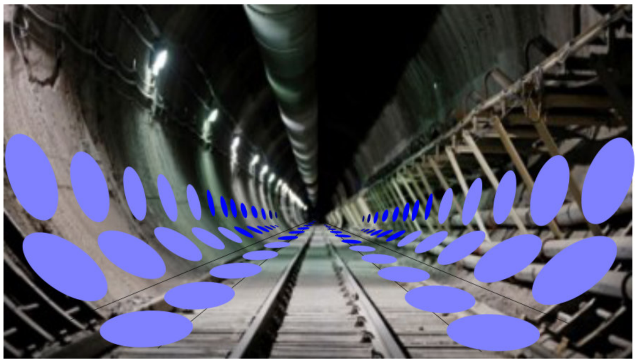
[39] https://www.youtube.com/watch?v=c0emnrflYKE “Subversive Doubt: The Story of Yucca Mountain Nuclear Repository” 36:52 Quote by Edward F. Sproat III, Director, Office of Civilian Radioactive Waste Management, U.S. Dept of Energy – “Whether of not Yucca Mountain is an appropriate site for a repository, it is a moot point because back in 2002, the Department of Energy recommended to the president, the president accepted, and both houses of Congress approved Yucca Mountain as the site for the national high level waste repository.”

[40] NRC Yucca Mountain Report, section 2.1.1.2.3.5.3 “Aging Overpack and Shielded Transfer Casks” page 2-96

be no reason for humans to have to enter it. This is the same sort of broken optimism that got us painted into the corner to begin with. Our conclusion is that a geologic repository is premature until at least several hundred years of cooling has been completed.

- **But A Geologic Repository Does Provide Advantages**
  Despite the technical and political difficulty in siting a deep geologic repository, it does provide exceptional protection against surface warfare and loss of administrative control, as described below.

- **Design of a Repository should be compatible with Surface Storage**
  We believe it is a big mistake to view the geologic repository as a completely different design from that used on the surface. YM design was hatched prior to learning what works best on the surface. Thus, it uses canisters that are much smaller (only 24 PWR fuel assemblies vs. 37 in Holtec UMAX system), where the canisters are placed in a horizontal orientation and rolled down long tunnels, with no means to pull out just one errant cask or deal with any issue down that tunnel, and not double-wall design we propose.



YM-HELM Concept – Radial HELM storage in the YM main tunnel so each cask can be monitored, serviced and replaced, to accommodate 120,000 tons heavy metal waste (roughly 10,000 casks). Each blue circle represents the lid of a below-grade cavity where the cask is interred.

  We suggest it is probably best to rethink the YM emplacement design with the view to make it compatible with surface storage, i.e. a HELMS surface installation moved underground. If we assume nearly vertical, UMAX style emplacement with three tiers on both sides of the main tunnel, and since the main tunnel about 5 mi (8.0 km) long, there is room for about 10,000 casks (about 120,000 tons heavy metal waste).

  With that said, we believe this can be set aside for the next one or two hundred years and focus on the reasonable proposal of HELMS.

Loss of Administrative Control

Although we will not dwell on this consideration at much length, one of the important considerations and the rationale for either the geologic repository or the 1,000 year design criteria we endorse is the potential loss of administrative control and an extended “dark age” when the human culture may lose its technological prowess, or just a loss of funding, industry bankruptcies, and total lack of attention. Such a retreat implies that all inspections, maintenance, and aging management protocols will cease. Optimally, all nuclear installations should then persist in a safe state without releasing radiation into the environment for as long as possible, to hopefully allow the human culture to re-establish technological capability and administrative control.

DISCUSSION

With the HELMS proposal presented and factual context in hand, there are a number of other important points which deserve treatment.

HELMS does not require a geologic repository as a prerequisite

The use of thin, temporary canisters in ISFSIs at nuclear plants was based on the expectation that that the spent fuel would be moved promptly to a more permanent site within the expected service life of those canisters. This expectation is now known to be without merit, both from the likely life of these canisters in corrosive environments, and the likelihood of a repository in the necessary time-frame, which is currently not on the horizon.

The more recent suggestion that these same canisters alone (without the double-wall upgrade of MELO) can be stored in a Consolidated Interim Storage (CIS) facility is also unreasonable. Thus, many communities who are asked to approve such CIS facilities have required that a geologic repository is also available or at least predicted to be available. Indeed, that may cause some to push to approve YM to allow those installations to move forward, even if approval and use of YM may not be supported by scientific inquiry or honest reason.

But worse, as mentioned, even if YM was approved, it would be far from feasible to accept those hot canisters in the facility, and so we are left with a contradiction. This contradiction means that use of the existing thin canisters without using an improved storage technology, is unreasonable and imprudent. Therefore, it is essential that improved storage technology is used, such as the HELMS Storage recommendation.

HELMS: an essential and prudent step to secure commercial nuclear waste

The Waste Bottleneck stopped some new plants and thus reduced the overall waste problem. Given that communities could not block the construction of nuclear power plants based on safety concerns due to the dominance of federal law, many states passed moratoria to block new nuclear plants based on economic concerns unless a permanent solution to the waste problem was established[41].

As the world came to recognize the danger of nuclear power, after witnessing periodic devastating meltdown accidents and other close calls, there was a need to block the threat of new nuclear plants. Since safety was off the table, one valid tactic was to block the approval of any permanent repository site because the moratoria would in turn stop new plants from being built. But the tactic has a downside, as there is now a build-up of waste around the country. The world now recognizes that one

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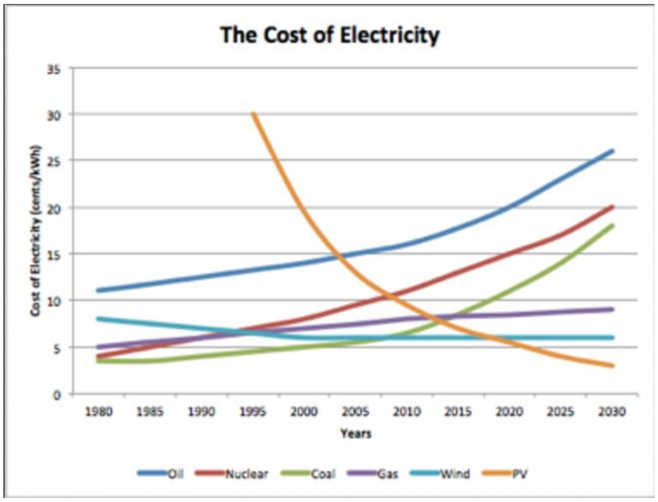
[41] BRC Report, Page 25

of the fatal weaknesses in nuclear energy is the production of long-lasting and highly toxic waste, and that there is no means at hand to dispose of it.

Since operating nuclear plants generate new waste, blocking new plants and expediting shut down of any operating plants becomes the top priority.

We believe we have moved past this quagmire due to the economics of electricity sources and the rapid decline in the cost of electricity from Solar Photovoltaic (SPV) sources.[42] This is a new and important development, and it is unlikely that the nuclear industry can withstand this trend over time, regardless of what utilities may desire.



SPV is a good match to market-based optimization because many manufacturers can compete in the fabrication of PV cells, and since many millions are built each year, there is a great impetus to improve them and compete in the marketplace. Also, we must note that the marketplace cannot be easily controlled or rigged by utility monopolies to reduce this competitive advantage and thus to preserve their existing investment in fossil and nuclear plants.

In contrast, nuclear plants are not a good fit for market-based optimization because there are too few vendors while the design and life cycle of the plants is far too long, so long-term, they will never be able to compete. It matters not what sort of new-fangled “modular” designs may be contemplated.

Thus, it is now time to shift gears and embrace our proposal for prudent storage of the existing commercial nuclear waste, and allow these severe market forces to limit the future generation of waste rather than by continuing the standoff.

Thick vs. Thin Canister Debate

Much has been said of late about the inadequacy of the thin canisters for use on an extended basis at ISFSIs around the country. The concern is legitimate because the thin canisters were designed for short-term use only, and now we are aware that they will corrode and crack over time. The industry has responded in the typical manner with administrative work-arounds – make them work anyway, using even more administrative controls, in the form of aging management[43] and detailed robotic inspections[44]. These steps might work to squeeze every year of life out of the thin canisters, but it

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[42] Chart and data from Zoltan Kiss, “Trends In The Cost Of Energy” https://seekingalpha.com/article/1324411-trends-in-the-cost-of-energy (2013)

[43] NRC NUREG-2214 “Managing Aging Process In Storage” (draft) Adams ML17289A237

[44] https://www.epri.com/#/pages/product/000000003002008234/ “Dry Canister Storage System Inspection and Robotic Delivery System Development”

assumes the aging management and inspections are indeed feasible, performed correctly, and the reports honestly prepared. The simple fact remains that the design of these thin canisters is insufficient for the purpose for which they are now being applied – indefinite storage – and ignores the concern of loss of administrative control.

Some have advocated very strongly that we require the so-called "thick" casks, pointing to the CASTOR design, as an example, made of ductile cast iron instead of stainless steel, and is much thicker, with walls about 10" thick (or more). Then, these are stored without any other shielding, because the shielding is integrated into the cask. These casks are NOT licensed for use in the U.S., and were originally designed for a different use-case, to be reused as spent fuel was sent to be reprocessed.[45] That said, just because they are not licensed does not mean the design elements cannot be adopted to some extent. These do have some very good design features, but we must caution that every design change comes with a trade-off of some sort, and so no design is perfect.

GNS CASTOR cask uses thick single-wall design that provide both containment and shielding

Direct Comparison Inappropriate

Sometimes, the thin canisters (1/2" to 5/8") are compared directly (i.e. without the overpack associated with the thin canisters) with the thicker casks to demonstrate how thin and inadequate they are. But, this is an incorrect comparison, because the thin canisters are part of a *component system* and are always transported and stored with some other additional overpack or enclosure, either concrete, steel with lead (for example the Holtec HI-STAR 190), or sometimes steel with lead and water (Holtec HI-TRAC transfer cask). The overpack would need to be included to make a fair comparison.

The thicker casks have a bolted lid, which has a seal which degrades over time and must be replaced. The hermetically sealed thin canisters have no seals to replace. So the thick casks require periodic maintenance which may require a hot cell to avoid any entry of oxygenated air.

The thicker casks look more robust, but size is not everything. Cast iron, even the most ductile is much more brittle than stainless steel and there is a lot to learn how these options react to neutron bombardment over many decades or centuries. The thick casks are not solid metal, but typically have cavities filled with polymer to provide neutron shielding.

On the other hand, the comparison DOES have merit because the thin canisters ARE exposed directly to the environment and the air. So if any cracks should develop, radioactive particles could escape. The thin casks alone are NOT adequate for the long-haul.

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[45] http://www.npolicy.org/article.php?aid=395&rtid=2 – "U.S. Government policy turned against reprocessing after India, in 1974, used the first plutonium recovered by its U.S.-assisted reprocessing program to make a nuclear explosion. Reprocessing makes plutonium accessible to would-be nuclear-weapon makers – national or sub-national – because it eliminates the protection provided by the lethal gamma radiation emitted by the fission products with which the plutonium is mixed in spent fuel."

No need to inspect fuel assemblies inside the interior canister

We reject the notion that there is a great need to inspect the contents of the canister once it is sealed, and in the thicker design, doing so means removing the bolted lid. If you ever do that, then it will likely require a hot-cell as the cask is completely open. It is better to view the canister as a unit that is never to be opened unless there is no other option.

Heat Load Differences

The other downside of the “thick” cask alternative is the reduction in heat dissipation, since the thicker walls will reduce the transmission of heat, and therefore, those casks will not be able to enclose the very hot fuel assemblies thin canisters commonly allow. This is probably the most important reason the U.S. industry adopted the thin canisters, as they were eager to move extremely hot spent fuel out of fuel pools and canisters that could transfer a lot of heat to the environment.

It also is a concern with the dual-wall canister design because whenever you add another layer, it does limit the transmission of heat.

Thin Component Canister Systems are the Defacto Standard in the U.S.

The design of dry storage systems is a balancing of many trade-offs. Most decisions in this industry were hastily made at the time with cost and expediency in mind, rather than a well-thought out integrated system. The fact remains that the industry has already proceeded down this path and restarting from scratch is not an option.

What we must do now is embrace what we have and make sure we are not doing any additional handling, and make sure the inside sealed canister does not deteriorate. The same interior canister should be compatible with any future geologic repository, probably by replacing the exterior MELO Cask before it is stored in a permanent repository. There was an assumption in the design of YM that the fuel assemblies would be removed from the canisters and placed in smaller YM-compliant canisters. That we see as a waste in all dimensions.

No upgrade path from thin to single-wall thick casks

It is viewed as infeasible to get the industry to adopt single-wall thick casks instead of thin canister component systems because there is no “upgrade path” from the thin canister design to the thick cask design without scrapping the current investment and doing a lot of repackaging. It becomes necessary to prove not only that the thicker cask is better, but also it must be shown that they are so much better that the investment in the thin canisters must be forfeited and obligate the industry through law that they must upgrade, and endure the risk of repackaging all the spent fuel from one type of design to the other.

Since almost all spent fuel in the U.S. is in the thinner canisters (which are combined with other shielding elements), we are hopeful that providing an upgrade path will provide most of the advantages of the thick cask systems without these severe drawbacks.

Both of these alternatives are the single-wall design, and when that wall fails, then the contents of the cask or canisters can be released. How fast and how much of a catastrophe this might be is open to debate.

To be fair, thick casks may provide dual lids with an inert-gas pressurized gap which can provide automated monitoring of the seals that must be replaced periodically, similar to the two-layer system of the MELO Cask over the canister. But this dual layer only exists on the lid and leaks in the rest of the cask cannot be detected through a pressure test.

We should note that NRC regulations DOES require that there are two lids in the thin canisters, and they do provide this: NRC Part 72.236: (e) The spent fuel storage cask must be designed to provide redundant sealing of confinement systems.

However, redundant sealing systems is hardly of much value if you can’t detect when the outside seal becomes breached. These canisters have no mechanism for that, unlike the CASTOR design and the MELO Cask design.

So for these reasons, we suggest that those pushing for the thick cast-iron casks should endorse the MELO Cask two-layer system we are proposing here, so that the sacrificial exterior layer can serve as the warning that the interior canister may now start to corrode, and will eliminate the severe requirement that inspections of the canisters detect minute cracks before they become through-wall holes. The MELO Cask design provides an upgrade path for existing thin-wall canisters and can be readily adopted on a gradual basis, most particularly as new locally consolidated HELMS compliant facilities are built somewhat away from the risk factors that exist at the nuclear plant sites.

The upgrade path

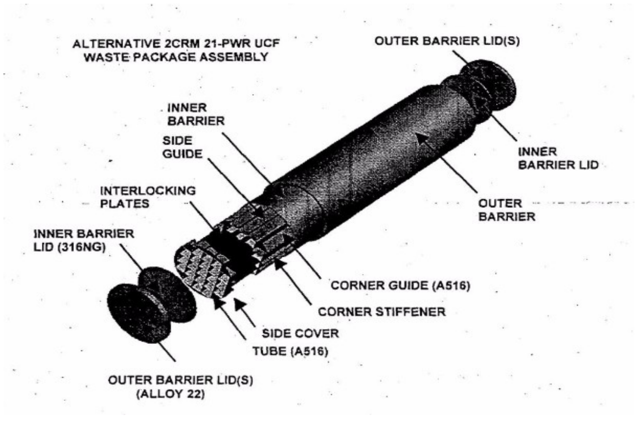
We suggest the following upgrade path from the status quo:

- Any new ISFSI installations should be designed with sufficient space between the internal canister and the outer concrete and or steel shielding cask, so as to accommodate the MELO Cask.
- Older ISFSI installations which are designed to be above-ground, should phase-in a larger overpack, if indeed it is required, and add the MELO Cask to the older canisters and then replace the concrete overpack as these cool to below 52°C and Stress Corrosion Cracking may start.
- Older ISFSI installations which are designed with below-ground vaults should review the applicability of the dual-wall design provided by adding the MELO cask and if necessary, using lower capacity canisters, and then add the MELO Cask as soon as they cool to 52°C. Otherwise, we hope sufficient forethought will be given to any new below-ground ISFSI installations so they will have the capacity for the additional of the MELO Cask.

Comparison with Yucca Mountain

We should note that the cask design at Yucca Mountain (YM) uses a single-wall canister using two layers of different types of steel alloys bonded together, which is about the same thickness as what we envision for the MELO Cask (3”). The two layers in the YM design has no gas-gap to facilitate monitoring for cracks of the outer cask. They also added one more partial layer, in the form of a titanium (and costly) “drip shield” to avoid moisture induced corrosion. We believe there would have been more merit in a slightly different design by enclosing the drip shield as a second layer and making it part of the cask, similar to the facility provided by the dual-layer MELO design.

According to Farmer et al of the Lawrence Livermore Laboratory regarding the waste package proposed for YM[46], “The waste package outer barrier (WPOB) is to be made of Alloy 22 (UNS N06022), while the underlying structural support is to be made of 316NG or 316L (UNS S31603). Alloy 22 is a high-performance nickel-based alloy with substantial amounts of chromium (21%), molybdenum (13%) and tungsten (3%). This particular material contains palladium (0.12-0.25%) to enhance resistance to hydrogen induced cracking.”



Canister design conceptualized for use at Yucca Mountain

Stress Corrosion Cracking

Farmer continues, “There are several modes of failure that could lead to premature breach of the waste package. One of the most threatening is stress corrosion cracking (SCC). Initiation and propagation of SCC can occur at relatively low stress intensity factors. After initiation, through-wall penetration is essentially instantaneous when compared to the 10,000-year time scale of importance to the high-level waste repository at Yucca Mountain.”[47]

The paper by Farmer goes on to say there are a number of strategies to reduce the probability that such cracking will occur, but there is no way to prevent all risk of such cracking. And, as they mention, once it initiates, then cracking is essentially instantaneous (compared with 10,000 years).

We submit that the YM storage container and its associated drip-shield is a poor design. The drip shield provides incomplete encapsulation and is built into the storage cavities rather than being part of the cask itself. There is no means to monitor and detect leakage of the canisters at YM and no way to do much of anything if a breach does occur. The drip shield was a very costly attempt to reduce the flow of water over the canisters but can’t stop inundation from below.

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[46] Farmer, et al, Lawrence Livermore Laboratory, (2000) “Modeling and Mitigation of Stress Corrosion Cracking in Closure Welds of High-Level Waste Container for Yucca Mountain” https://digital.library.unt.edu/ark:/67531/metadc733541/m2/1/high_res_d/791472.pdf

[47] *Ibid*

We believe that the MELO Cask design should be viewed as the cask design that should be compatible with any future geologic repository, so that no repackaging would be necessary, and if any were to be done, it would be restricted to replacing the outer MELO Cask.

Comparison with HOSS

The HOSS proposal has been discussed recently, which means Hardened On-Site Storage. HOSS is similar to HELMS in that surface storage is used. But, in contrast with the "On-Site" of HOSS, HELMS includes the notion of "Local" to imply that an on-site location may be fine in a few instances (such as at Palo Verde nuclear plant in Arizona, as there is no associated body of water next to it), but in general, some local transportation may be appropriate, so as to move it away from the water resource associated with the nuclear plant, move it away from dense populations, and consolidate the waste on a regional basis. For those plants in California – which we now know are in a very seismically active area – moving these off the moving Pacific plate and onto the more stationary North American Plate is advisable to reduce seismic risk. Although no place is safe from seismic risk, 90% of earthquakes occur on the "Ring of Fire" around the Pacific Ocean, and 81% of the largest earthquakes occur there. All of California is considered "very" or "extremely" hazardous.

Comparison with Humboldt Bay Nuclear Plant ISFSI

Humboldt Bay Nuclear Plant was very small and during decommissioning, had the need to store only five multipurpose canisters, and one canister with Greater Than Class-C Waste. PG&E selected the underground Holtec UMAX design, but modified the design not just to accommodate the "thin" canisters, but also to include the Holtec HI-STAR transportation overpack (without the impact limiters installed.)

HI-STAR 190 Transportation Cask showing enclosed MPC canister

This is similar to the MELO design because it includes two containment boundaries, and the gap between the overpack and the canister is purged of oxygenated air and replaced with purified helium. The implementation at Humboldt does provide shielding intended for transportation which is redundant in the storage configuration because it is stored in an underground UMAX facility, but does no harm. The Holtec HI-STAR 190, similar to the units at Humboldt, has walls that are a total of 15.25" thick, including nine inches of lead encapsulated in steel[48]. Other overpacks include concrete and sometimes water encapsulated in a steel jacket. The units at Humboldt can be removed from the ISFSI and (in theory) transported directly after installing the impact limiters.

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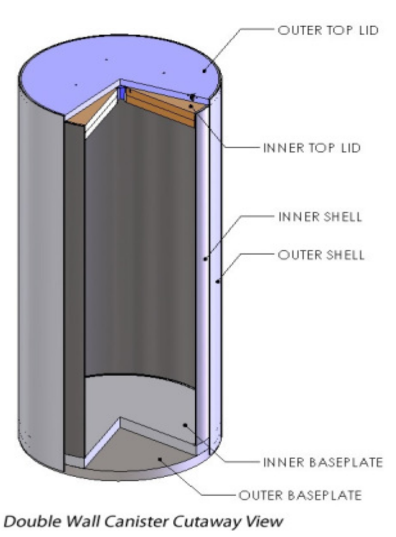
[48] The HI-STAR 190 Transportation cask has an inside diameter of 76" and outside diameter of 106.5", providing an overall wall thickness of 15.25". The walls have an inside steel layer and an outside steel layer, providing structural support, while containing approximately 9" of lead, which is a gamma radiation absorber. Table 1.1.1, page 1.1-4 "Safety Analysis Report, HI-STAR 190 Package", NRC Adams Accessor number ML17166A448

Although the implementation of the Humboldt Bay ISFSI does NOT provide the monitoring features we recommend for the MELO design, we appreciate the effort of PG&E to anticipate the need for the two-layer design. It may be feasible to back-fit monitoring to this configuration by adding the standard monitoring module to the lid.

Comparison with Chernobyl Cask Design

The design of canisters used for storage at the Chernobyl plant use a two-layer canister[49] similar to the MELO Cask design except that they do not have the ability to remove the outer enclosing layer and replace it when it becomes compromised, since the two layers are “bonded” and in substantial contact, with no intervening gas gap.

> "The system consists of an enclosure vessel comprising two welded canisters that form two separate confinement areas to prevent the spread of radioactive materials, an internal basket and fuel tubes. It is designed for the horizontal placement of each canister inside the individual compartments of a concrete storage module."[50]



Double-Wall Canister as approved for Chernobyl.

The new Holtec UMAX type installation recently approved for use for Chernobyl waste will also include a two-layer canister.[51] The Holtec Patent on the design used for the Chernobyl[52] mentions the first pressure vessel (the interior canister) and an outer pressure vessel (what we call the MELO cask) but there is no mention of the gas-gap nor or any facility to detect leaks in the outer canister, and it says they are in “substantial contact” between the two confinement systems. These are minor differences. It is important for NRC regulators to be mindful of the fact that other international regulations apparently are more robust in this regard.

The Holtec patent document describes the fact that the outer shell is bonded to the inner shell:

> In other words, the interface between the inner shell 10 and the outer shell 20 is substantially free of gaps/voids and are in conformal contact. This can be achieved through an explosive joining, a cladding process, a roller bonding process and/or a mechanical compression process that bonds the inner shell 10 to the outer shell 20. The continuous surface contact at the interface between the inner shell 10 and the outer shell 20 reduces the resistance to the trans mission of heat through the inner and outer shells 10, 20 to a negligible value. Thus, heat emanating from the SNF loaded within the cavity 30 can

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[49] https://holtecinternational.com/2015/08/03/the-chernobyl-defueling-project-worlds-largest-makes-major-strides/

[50] http://www.world-nuclear-news.org/WR-Holtec-delivers-first-dry-storage-canisters-to-Chernobyl-site-27111501.html

[51] “In addition to leading the world in size, the ISF-2 project has bestowed new technologies to the nuclear industry that includes the first double wall canister design (now adopted by other users)” – https://holtecinternational.com/2017/08/03/chernobyls-spent-nuclear-fuel-storage-facility-worlds-largest-enters-the-post-construction-integrated-testing-phase/

[52] https://www.google.com/patents/US20160372224 Holtec Patent on Double-Wall Canister.

> efficiently and effectively be conducted outward through the shells 10, 20 where it is removed from the outer surface 22 of the outer shell via convection.

Comparison with Holtec UMAX system with metal liner

It is true that the underground Holtec UMAX system does include a metal cavity liner. This may appear to provide another layer of defense, but it is almost useless because it is not sealed, it cannot be easily replaced, it is not pressurized to detect leaks and to isolate the canister from the corrosive outside air, nor is there any integrated and standardized monitoring package. Thus, it does not – in itself – provide the attributes of the MELO Cask design, and thus we see a need to add the MELO Cask to the UMAX system, which unfortunately may require slightly larger cavities. Yet we are open to discussing how the current UMAX system design may provide some of the advantages of the MELO design by pressurizing the cavity between the metal liner and the enclosed MPC canister with helium once the canister cools to the point that the lid can be sealed, and outfitting the lid with the standard monitoring unit.

Comparison with Maine-Yankee Failed canister enclosure

We understand that the Maine-Yankee plant has a failed canister overpack which exhibits some of the characteristics we are suggesting in the MELO overpack so as to provide a double-wall canister. The image of this component of the larger system does provide a good image which would likely be quite similar to what we have envisioned in this recommendation, albeit with the note that the Failed Canister Overpack does not provide the monitoring features we are recommending.

HELMS for Hanford

Since HELMS is really a set of criteria rather than a final design, it may help us find a better solution for the Hanford, WA site, even though this question is out of the intended scope of our attention.

Much of the waste at Hanford is in the form of liquid waste in tanks, some 149 single-shell tanks (SSTs) and a few dozen double-wall tanks. The SSTs are all unfit for use and decades past their design life.[53] Sum of capacity of all tanks at Hanford is 206,000 cubic meters[54]. Assuming a double-wall cask system similar in size to the Holtec MPC-37 plus the MELO over cask, we end up needing about 15,000 casks. If placed 16 feet on center, 122 units on a side, this would consume an area of about 75 acres – easily sited on the Hanford site. The benefit to using many smaller casks rather than huge tanks is that a) they can be produced in a factory setting with tighter tolerances and quality assurance, b) they

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[53] http://www.ecy.wa.gov/programs/nwp/sections/tankwaste/closure/pages/tank_leak_FAQ.html

[54] Appendix D: Waste Inventories – https://energy.gov/sites/prod/files/EIS-0391-FEIS-Volume2_AppD-G-2012.pdf

can be more easily replaced if there are any leaks, and c) even if one is completely breached, it is not nearly as large a catastrophe as a large tank. That said, this is a much different problem because liquid waste will more easily leak out of a canister system when compared with spent fuel, which is solid in form. And, some of the tanks were filled with grout to absorb the liquid and getting it out is a problem of its own.

Bottom line is that we believe HELMS could be appropriately applied to the Hanford site with positive results, at least for some of the waste there.

Conclusion

We hope that the nuclear industry and community concerned with nuclear spent fuel will consider our recommendations in this document, and hopefully start to make some changes in the planning, most particularly for any new ISFSI installations or CIS proposals.

We appreciate feedback and comments from the community as we progress this plan for national implementation. Please email to the author.

About the Author

Ray Lutz, MSEE, has been involved in nuclear decommissioning and spent fuel issues most particularly regarding the shut down and decommissioning of the San Onofre nuclear plant, and has served in the role as intervenor at CPUC and NRC proceedings, among other endeavors.

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