Position White Paper by Citizens' Oversight

A New Strategy: Storing Spent Nuclear Fuel Waste

Featuring HELLMSS-MELO:

"Hardened Extended-Life Local Monitored Surface Storage"

and

"Monitored Extended-Life Overcask" containers

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Ray Lutz, MS Engineering
Founder, Citizens Oversight, Inc.

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 of this plan is the "HELLMSS-MELO" plan, allowing graceful upgrade of the investment in dry storage to date. 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.

HELLMSS stands for Hardened, Extended-Life, Local, Monitored Surface Storage, and implies that waste should be moved away from water resources in the vicinity of the waste, but stored locally, probably within state, 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 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 HELLMSS-MELO 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.

WASTE CONFIDENCE? NO!

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 (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 Installation" or "ISFSI") – 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.

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

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 85°C (185°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.

The waste problem is still not solved, and it still getting more expensive. It is almost never included in any 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 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,” published in January, 2012 (“BRC Report”), primarily Chapter 3, “Technical and Historical Background.”[4]

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. That document also includes the definition of many acronyms in use in the field.

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.”[5]

4 “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

5 BRC Report, Executive Summary, page vi

- **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 at alll what will happen even 1,000 years in the future is no more than a wild guess, let alone 10,000 or one 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 problem of Not In My BackYard (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, so much so that we should not expect it to happen at all. Our “plan B” needs to be good enough to be considered “permanent” rather than a temporary and interim fix.

- **After the Fukushima disaster**
  “...Americans became newly aware of the presence of tens of thousands of tons [(actually 76,430 metric tons and increasing)] 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.”[6]

  - **Terrorism now a reality**
    The issue was further compounded by the post-9/11 recognition that the nuclear fuel at these sites represents more more than 70 terrorist targets, which would result in a nuclear dirty bomb without any need to obtain or handle nuclear materials by terrorists.

  - **Water resources in danger**
    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. We do not support moving waste from **operating plants** because it does not improve the risk situation unless the plant is shut down. However, we hope stakeholders will plan ahead and implement the

6 BRC Report, Executive Summary, Page vii

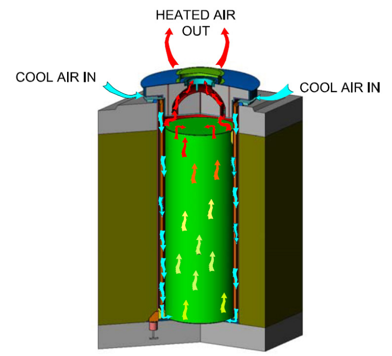
HELLMSS-MELO plan so there is no need to upgrade in the future, and then begin the process to systematically shut down these plants.

- **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."[7]

  - **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 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.

- **Dry (cask) storage**
  "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."[8]

  - **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.



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

7 BRC Report, page 10
8 BRC Report, page 11 (as of 2012)

- **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.

- **Water Resource at Risk**
  As mentioned, storing the nuclear waste in dry storage at the site of the reactor will leave 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[9]. Thus, moving the waste away from this water resource can decrease the risk that any accident will contaminate and ruin that resource virtually forever, and 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.

- **Salty Air Results in Rapid Corrosion**
  Furthermore, siting waste storage facilities near salty ocean waters exposes the metal containers to the corrosive moist ocean air and will reduce the life of storage containers. Thus, moving the waste away from the default location next to the associated plant will be an important part of any reasonable plan.

- **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.[10] 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.

- **Component System Uses Thin, Single Layer Canisters**
  The canisters used predominantly in the U.S. is a component system with relatively thin (1/2” to 5/8”) welded stainless steel internal canisters, surrounded by 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.

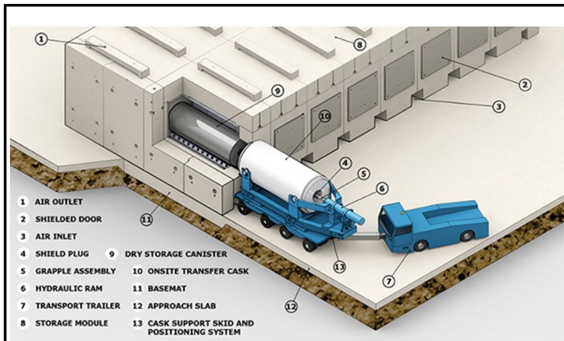
- **Dry Storage Types in the U.S.**
  In the common dry storage configurations in the U.S., there are two major vendors, Areva (now TransNuclear) and Holtec. These storage designs feature concrete surrounding the

9 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.”

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

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**
  Probably the highest 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. Dry storage facilities should be in remote locations generally away from dense populations.



Areva (Now Transnuclear) horizontal NUHOMS ISFSI system

- **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. (In an accident that deforms the canister itself, since the cladding is flammable, it provides no defense at all.) So really the cladding can’t be counted as a defense layer in any conservative analysis. That leaves only one layer which if cracked or compromised, radioactivity can escape directly into the circulating cooling air.

- **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.

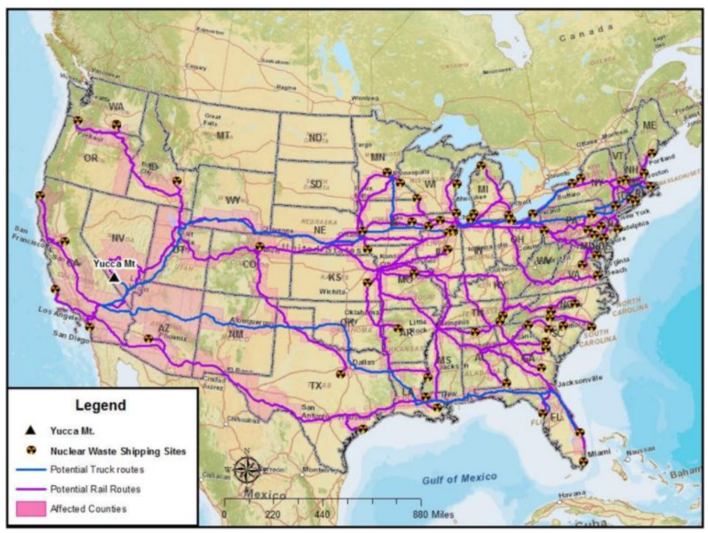
> In a sheltered environment, deliquescence of airborne salts below the dew point also could generate an aqueous electrolyte initiating general corrosion. These salts may be chloride rich and originate from marine environments, deicing salts, and condensed water from cooling towers, as well as a range 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).[11]

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, and our proposal does that.

- **Consolidated Storage**
  The BRC Report proposes that an interim solution is to build one or more large “Consolidated Interim Storage” (CIS) sites[12] 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 HELLMSS 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.”[13]



Proposed Transporation Routes to YM

  - **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.

11 NRC NUREG-2214 “Managing Aging Process In Storage” (draft) Adams ML17289A237, page 3-8
12 BRC Report, Page 35
13 BRC Report, Page 11

- **High Consolidation Means High Transportation Risk**
  Either a single geologic repository or the recent CIS proposal by Holtec at the Eddy-Lea site midway between Carlsbad and Hobbs NM[14] (which may be a good place for a HELLMSS-MELO compliant facility) includes the concept that spent fuel would be transported across the country to those consolidated sites, resulting in transportation over very large distances and then requiring a second move to a permanent repository, wherever that may be in the future. Residents are rightly concerned about this possibility exacerbated by the fact that rail transportation routes typically run right through the middle of cities.

- **No Real Transportation Experience**
  Even though the BRC Report and other documents[15] 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 spent fuel in the U.S.[16]. 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.[17] 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 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 is loaded and unloaded, and then transported over land to the final destination.

- **"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." There is something inherently fair about that

14 http://www.eddyleaenergyalliance.com/

15 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

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

17 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.

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.

- **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."[18]

  - **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 any review of that experience will reveal that it was only recommended because it is close to the atomic testing area which is already hopelessly ruined with high levels of radioactivity.

  - **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 the situation and any notion that it is the best place for such a repository has been hopelessly refuted.

  - **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

18 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.

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.[19] 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”[20] which is to say they must cool off.

  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 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.

Loss of Administrative Control

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. Such a retreat implies that all inspections, maintenance, and aging management protocols will cease. Optimally, all nuclear

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19 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.”

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

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.

Thus, even if a geologic repository is eventually established and begins to accept spent fuel, any remaining spent fuel on the surface should be in compliance with a 1000-year design so as to minimize exposure with complete loss of administrative control.

HELLMSS-MELO Proposal

We turn now to explain our recommendation, for which the acronym **HELLMSS-MELO** has been coined. It is primarily a conceptual plan and a set of criteria to which any proposal can be measured rather than a specific detailed plan. We can split this into two logical phrases, **HEL** for **Hardened Extended-Life**, regarding the design of the facility and canisters coupled with our proposal for **MELO – Monitored, Extended Life Overcask** containers, and **LMSS**, for **Local, Monitored Surface Storage**, regarding where it is located and monitored. It will be easier to start with the second part in our explanation here to create the context and use-case for the canister design.

Local, Monitored Surface Storage (LMSS)
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 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.

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.

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.

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.[21] 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 approach will be available in the future. But the proposal is not predicated upon a repository. We must consider that a HELLMSS facility is permanent in the human time scale.

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.

21 BRC Report, Page 47

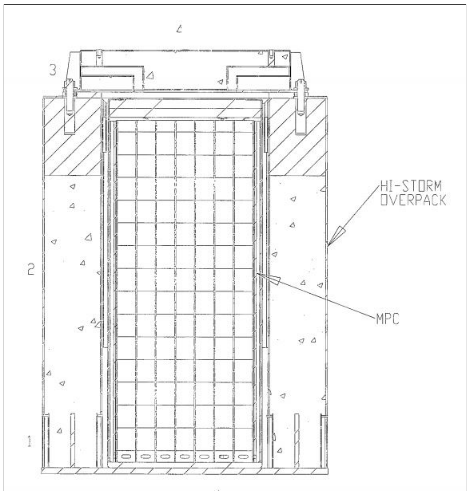
Although there maybe various approaches to achieve this, we suggest the following for purposes of explanation. Our suggestion includes only a single change to the existing modular canister design we see today, while still allowing the design to accommodate sealed canisters without the need to fiddle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

Monitored Extended-Life Overcask (MELO Cask)

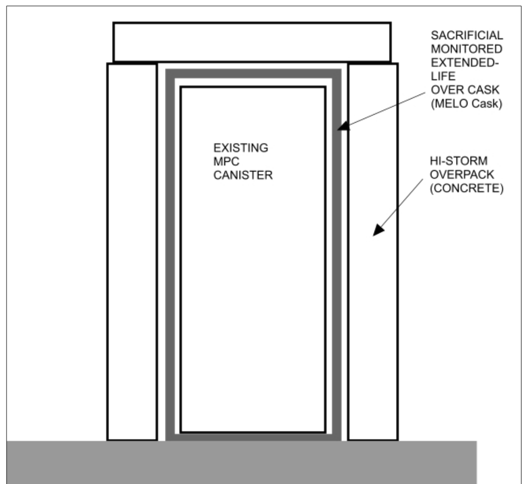
For sake of description, we propose a specific mechanism for obtaining the Extended-Life criterion. Conceptually, each of the relatively thin canisters (1/2” to 5/8” thick) generally used today would be **encapsulated** by an additional “MELO Cask.” We suggest that we consider the MELO cask be similar 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 “air 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. Any leak 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.

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.



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



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 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 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 bolting 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 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 an 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, 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 prior to failure to avoid a release of radioactivity. 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. At that point, 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.

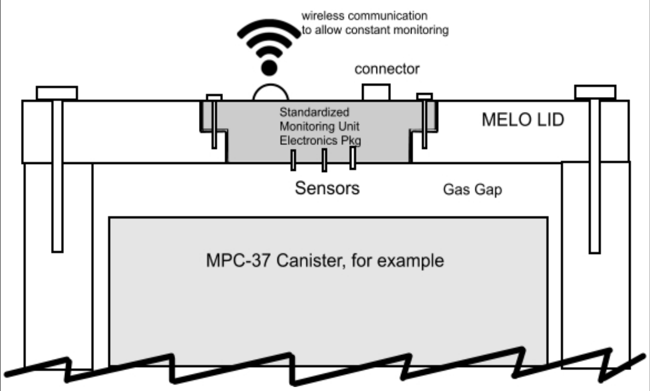
- **Confinement Barrier**
  The MELO Cask as envisioned here is intended as a secondary confinement barrier, not as a neutron or gamma radiation shield, although it would provide some shielding. Uranium and radioactive isotopes are physically held inside the fuel rod cladding (if they are not compromised) 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.

- **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.

- **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 once the lid is bolted to the top, which is at the storage location (i.e. the destination rather than the source).

- **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 even the canisters in YM will be monitored to the extent that “they’ll know exactly what is going on.”[22] 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.

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.[23]

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 this 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.

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

Hardened

The “Extended Life” attribute relates to the design of the dry storage system itself so that it will remain

22 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”

23 Please provide more information on this if you have such knowledge.

intact for a design life of 1,000 years (with maintenance, such as replacing the MELO Cask), while 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. A surface facility will require special effort to provide some measure of protection through 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. The current design of surface ISFSIs provides no real resistance to low-technology explosive attacks, and the provision of a bunker can make sense once the temperature is low enough to allow full enclosure. The bunker could be ventilated, probably just by convection until the temperature is low enough to fully enclose it.

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.

Summary of HELLMSS

Thus in summary, the HELLMSS 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,
2. Siting surface storage installations locally, near the nuclear plant of origin but away from the water resource, high population densities, known fault lines, tsunami risk, 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.

DISCUSSION

With the HELLMSS proposal now presented, there are a number of other important points which deserve treatment.

HELLMSS 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 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 HELLMSS-MELO recommendation.

Funding and Ownership

It is our position that HELLMSS 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[24].) The installations should be owned and operated by the federal government. With this said, HELLMSS storage is not a deep geologic repository and so it is not considered “disposal,” but is an <u>interim</u> solution for the next 1,000 years.

HELLMSS-MELO: an essential and prudent step to secure commercial nuclear waste

The Waste Bottleneck stopped some new plants and thus reduces 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[25].

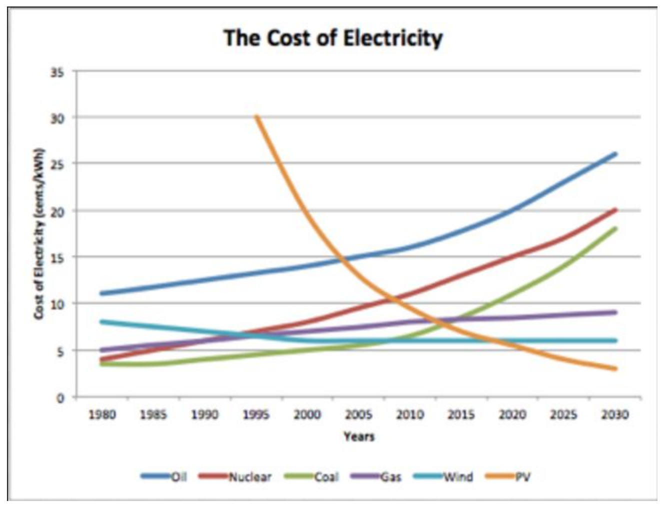
24 E&E News, “U.S. ends fee collections with $31B on hand and no disposal option in sight” (May 16 ,2014) https://www.eenews.net/stories/1059999730

25 BRC Report, Page 25

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 build. That wasn't difficult since YM was such as bad choice. But the tactic has a downside, as there is now a build-up of waste around the country. The world now recognizes that one 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.[26] 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.

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. The industry has responded in the typical manner by finding ways to make them work anyway, using even more administrative controls, in the form of aging management and detailed

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

robotic inspections. These steps might work to squeeze every year of life out of the thin canisters, but it assumes the aging management and inspections are indeed feasible, performed correctly, and the reports honestly prepared. The simple fact is 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 in buildings 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, which is not currently an option in the US.[27]

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) 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 have cavities filled with polymer to provide neutron shielding.

On the other hand, the comparison does have some 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.

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

27 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."

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.

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.

No upgrade path to thick casks

It is therefore infeasible to get the industry to adopt the 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 proposed bolted lid of the MELO Cask. But this dual layer only exists on the lid and leaks in the rest of the cask cannot be detected through a pressure test.

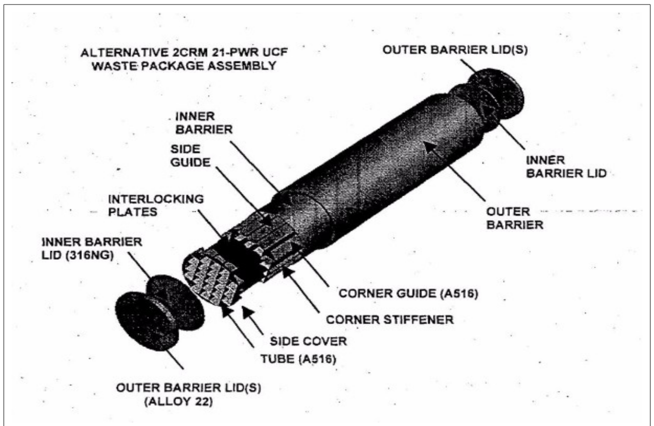
So for these reasons, we suggest that those pushing for the thick cast-iron casks should endorse the MELO Cask two-layer system we are proposing here, so that the sacrificial exterior layer can serve as the warning that the interior canister may now start to corrode, and will eliminate the severe requirement 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 HELLMSS-MELO 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 more 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 the larger overpack, and add the MELO Cask to the older canisters and then replace the concrete overpack as these cool to below 85°C and Stress Corrosion Cracking may start.
- Older ISFSI installations which are designed with below-ground vaults should consider using smaller capacity canisters, as they are added, 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



Canister design conceptualized for use at 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[28], “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.”

28 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

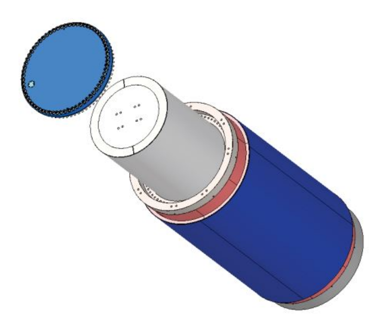
"***Stress Corrosion Cracking***
There are several modes of failure that could lead to premature breach of the waste package. One of the most threatening is stress corrosion cracking (SCC). Initiation and propagation of SCC can occur at relatively low stress intensity factors. After initiation, through-wall penetration is essentially instantaneous when compared to the 10,000-year time scale of importance to the high-level waste repository at Yucca Mountain."[29]

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.

Comparison with HOSS

The HOSS proposal has been discussed recently, which means Hardened On-Site Storage. HOSS is similar to HELLMSS in that surface storage is used. But, in contrast with the "On-Site" of HOSS, HELLMSS 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.



HI-STAR 190 Transportation Cask showing enclosed MPC canister

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

29 *Ibid*

include the Holtec HI-STAR transportation overpack (without the impact limiters installed.) 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[30]. 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.

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 with a gas-gap, apparently 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 (apparently) connected together, and welded shut.

> "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."[31]

The new Holtec UMAX type installation recently approved for use for Chernobyl waste will also include a two-layer canister.[32] We need more information on the exact details of the Chernobyl configuration.

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

30 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

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

32 “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/

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 that UMAX system 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.

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 85°C – 185°F).
- ISFSI vendors should determine an upgrade path so as to provide a dual-layer MELO-Cask design 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. 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 HELLMSS 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 HELLMSS-MELO compliant CIS facilities to be built, and restart the collection from ratepayers who are still receiving power from nuclear plants. No matter what we collect, it will definitely run out before 1,000 years have passed.
    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.

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.

Ray Lutz, raylutz@citizensoversight.org / 619-820-5321
Citizens Oversight
771 Jamacha Rd, #148, El Cajon, CA 92019