How to deal with spent fuel fires

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Loading spent fuel canisters into cement overpacks for long-term storage

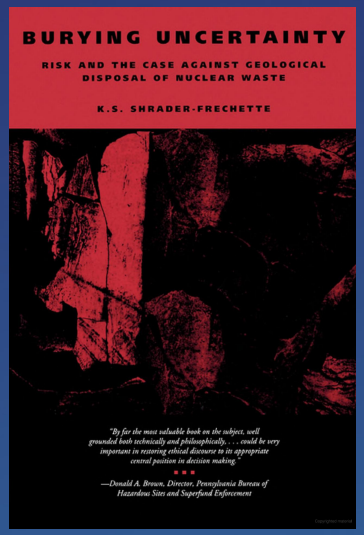
Spent fuel storage by the ocean and near major earthquake faults

Spent nuclear fuel transport in Europe

Unique black frogs have developed near the Chernobyl nuclear disaster

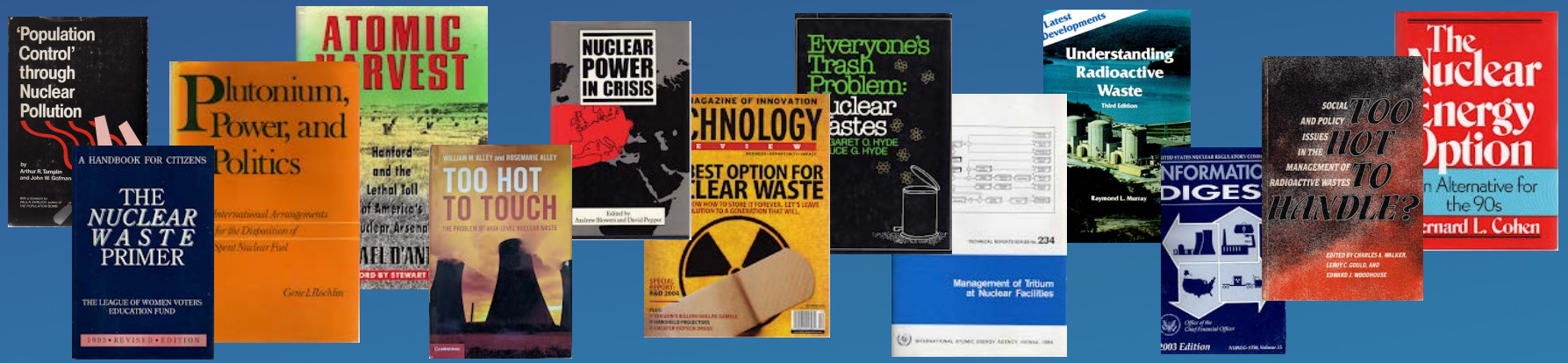
Spent nuclear fuel transport cask

An intractable problem



In 1952, *four years before the United States began commercial generation of electricity by nuclear fission*, James Conant – Roosevelt's wartime advisor on atomic energy and later president of Harvard University – predicted that the world would turn away from nuclear power *because the problem of waste disposal would prove intractable.*

– Burying Uncertainty, K.S. Shrader-Frechette, 1993



70 years later and still nobody has been able to solve this "intractable" problem...

Why worry?

Baltimore Tunnel Fire, July 18th, 2001.
Peak fire temperature estimate during the five day fire was "at least 1000º F to 1500º F

Howard Street (Baltimore, Maryland) Fire, 2001

"Fueled by the strong wind and accumulation of dry autumn vegetation, the fire destroyed hundreds of buildings and homes in less than an hour, with temperatures reported to have reached *2,000º Fahrenheit* in some places."

– sfbayca.com

The Nuclear Regulatory Commission only requires that a dry storage cask must survive an engulfing 1,475º F fire for 30 minutes...

Oakland Hills (California) Wildfire, 1991

Evacuation?

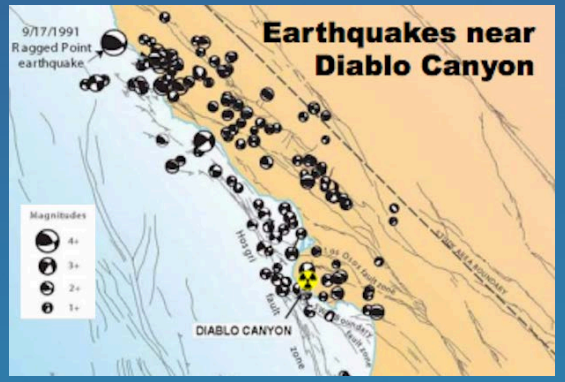
The Baltimore Tunnel fire occurred on the designated route for removing Calvert Cliffs' spent fuel to Yucca Mountain. The local fire department was not alerted for 60 minutes. There goes much of the needed evacuation time!

A tunnel accident involving spent fuel (ONE cask) could have caused 5,000 to 15,000 latent fatal cancers (among Baltimore residents) over the next 50 years, and cost nearly $14 BILLION to remediate.

– Lamb & Resnikoff, RWMA, Sept 2001

Perhaps that is an underestimation. Each dry cask contains roughly as much radiation as was released during the Chernobyl nuclear disaster. The exclusion zone around Chernobyl is over 1,000 square miles...

Diablo Canyon is surrounded by earthquake faults, some only a few hundred yards from the plant. After an earthquake, evacuation and access to the site might both be impossible...



Why use dry casks?

1. Originally, fuel was ONLY supposed to be stored on site for a few months... the reason was weapons, of course – the Pu239 becomes Pu240 if you wait, and that's no good for bombs... Or reactors…

2. No Yucca Mtn.

3. “Trouble with a capital T that rhymes with P and stands for pool.”

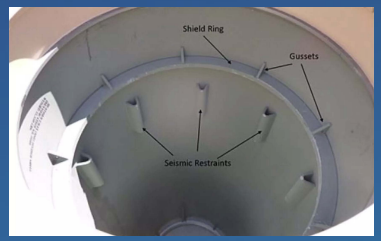
– Elliott Negin, Union of Concerned Scientists

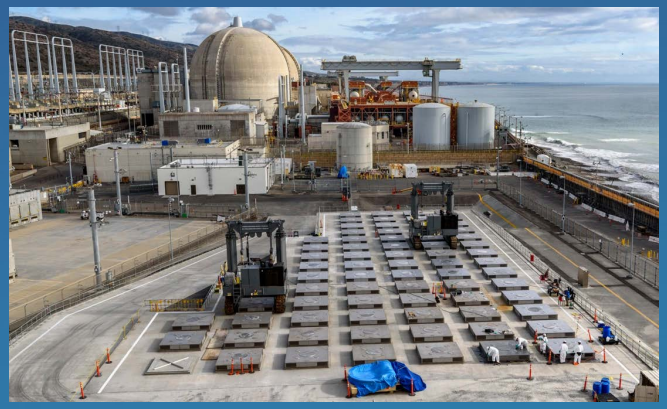
Unsound Logic:

"Plant owners eventually will have to transfer spent fuel to dry casks to ship it via rail or truck to an interim or permanent repository, so it makes the most sense to accelerate the transfer to the less vulnerable dry casks."

– Elliott Negin, UCS, Huffington Post June 2012

But every transfer is risky. In 2018 San Onofre had a "near miss" when it got a dry cask stuck on a protruding ridge. A quarter inch of lip was all the prevented an 18 foot drop of "highly radioactive" spent fuel in a 50 ton container with thin-walled (5/8") sides. Then they tried to cover up the incident.

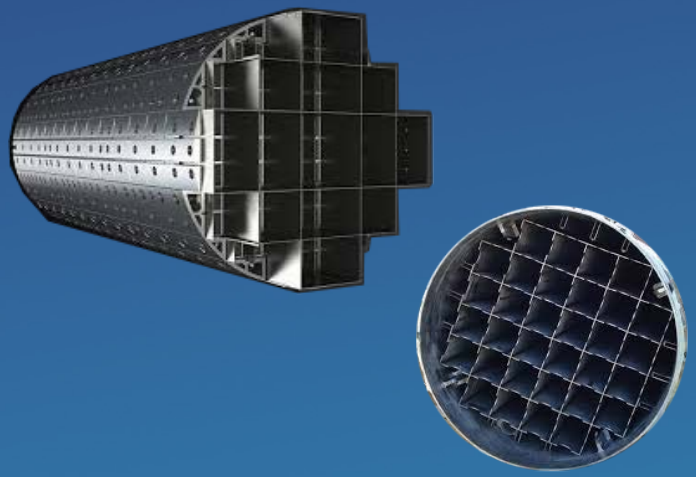




What is a dry cask?

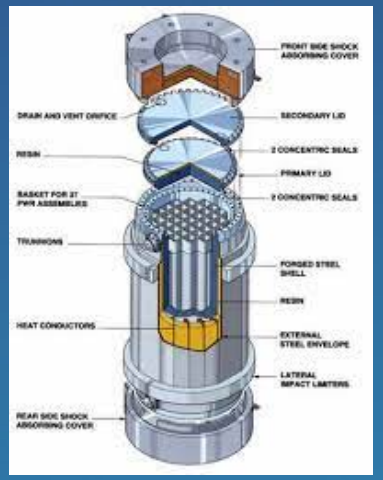
Dry casks are about 20 feet long, 10 feet in diameter, and weight up to 100 tons, including about 15 tons of used reactor core assemblies.

Dry casks are filled with an inert gas, usually helium. One reason is that the zirconium cladding around the fuel pellets is pyrophoric and introducing water and oxygen into the cask would be extremely hazardous. Another reason is they wouldn't want things rusting, since no one's looking...for 40, 60, 100, 200, even 300 years. Guarding the dry casks will become a "family business" for generations to come.



Typical inner structures of dry casks

Impact test - but did not simulate realistic conditions.

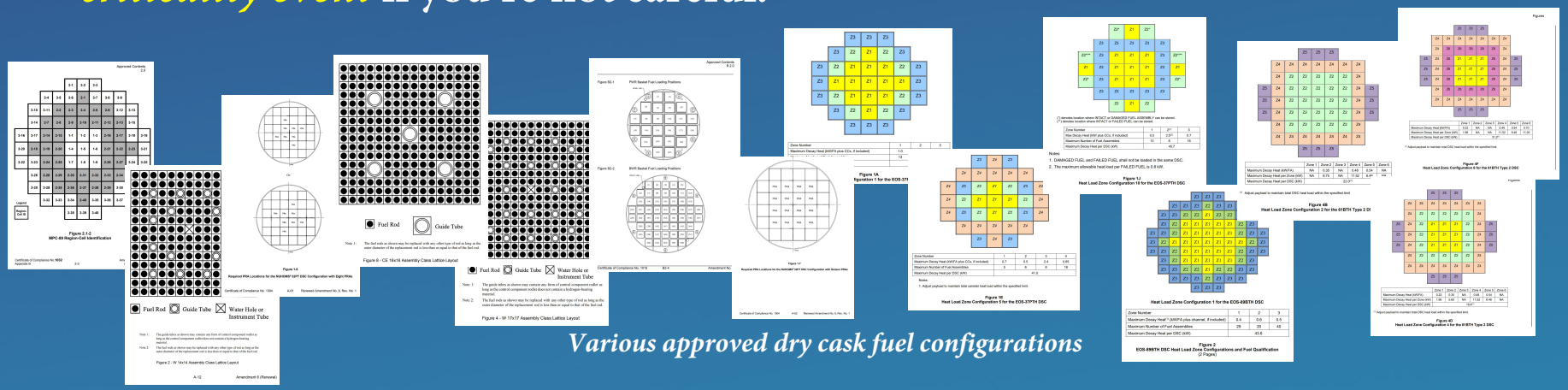


Most dry casks in the USA have 1/2 inch outer shells and are welded shut.

What are they made of?

Dry casks are made of stainless steel, and might also contain lead and be enclosed in additional steel and cement to protect workers and the public from gamma rays. Additional materials such as polyethylene, boron-impregnated metals or resins, and more concrete are also used to shield neutrons. The fuel is usually separated by "baskets" inside the dry cask.

Currently nearly 30 different designs have been licensed by the Nuclear Regulatory Commission. Some of the designs are licensed for both storage and (eventual) transport. Each dry cask must be separated from other dry casks by some distance, because so-called "spent" fuel can have a *criticality event* if you're not careful.



Various approved dry cask fuel configurations

How can that happen?

For a criticality event, spent fuel from Light Water Reactors (such as both US reactor designs) needs a "moderator" (normally water) to slow the neutrons. Water intrusion into a dry cask is possible a number of ways, such as, for San Onofre, a earthquake that splits open one or more dry casks, followed by a tsunami.

One dry cask may not have enough material for a criticality event under most circumstances, but dry casks are never alone. There are currently (as of 2022) over 3,000 dry casks in America, with more added every week. Over 10,000 dry casks will be needed just to hold the nuclear spent fuel that already exists.

Vernon Spent Fuel Installation

Trojan Spent Fuel Installation

Oyster Creek Spent Fuel Installation

Pilgrim Spent Fuel Installation

Things to worry about:

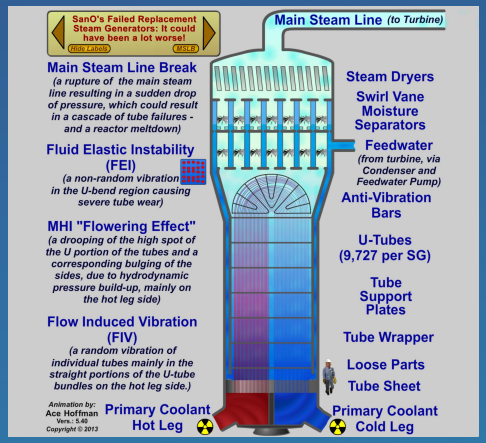
Airplane strikes, terrorists, manufacturing errors, maintenance errors, abandonment, earthquakes, tsunamis, "tornado missiles"… "Skylab"... asteroids…

"There have also been no known or suspected attempts to sabotage spent fuel casks or storage facilities."

– Nuclear Regulatory Commission

Does that mean there never will be?

2011: New replacement steam generators at San Onofre Unit 2 vibrate excessively, leak radioactive primary coolant, forcing shut down of both reactors, which becomes permanent.



2007: Vermont Yankee cooling system collapses after decades of neglect and "failed maintenance." In 2012 the state of Vermont voted 26 to 4 not to renew the reactor's state license.

2002: Davis Besse reactor worker leans against a control rod during refueling operation and it gives way, leading to discovery of a football-sized hole which had rusted all the way through the reactor pressure vessel head. A thin stainless steel liner was all that was preventing a meltdown -- and it was bulging.

Security is warm gun, yeah!

"Dry casks were designed to ensure safe storage of spent fuel, not to resist terrorist attacks.... the protection requirements for these installations are lower than those for reactors and spent fuel pools. The guard force is required to carry side arms, and its main function is surveillance: to detect and assess threats and to summon reinforcements... The protected area is surrounded by vehicle barriers to protect against the detonation of a design basis threat vehicle bomb...."

– National Academies Press 2006

That's not enough to protect against today's terrorists...

(Nigeria)

(Hamas)

(Ghana)

(Afghanistan)

And then there are the domestic terrorists: "On April 2, 1997, Captain Button took off in his single-seat A-10 attack aircraft on a training mission with two other A-10s from Davis-Monthan Air Force Base. His jet was armed with 4 Mark 82 [500 lb] bombs, 60 magnesium flares, and 120 metal chaff canisters, and its GAU-8 Avenger gun was loaded with 575 rounds of 30-millimeter [uranium] ammunition."

– Wikipedia

More things to worry about:

"In general, the analyses show that some types of [aircraft] impacts will damage some types of casks. For some scenarios there could be substantial cask-to-cask interactions, including collisions and partial tipovers"

… but at least Sandia Labs concluded that jet fuel would likely be dispersed over a large area in a low-angle impact… Long-duration fires that could damage the casks or even ignite the cladding of the spent fuel were not seen to be credible for the aircraft impact scenarios considered by Sandia.

But…

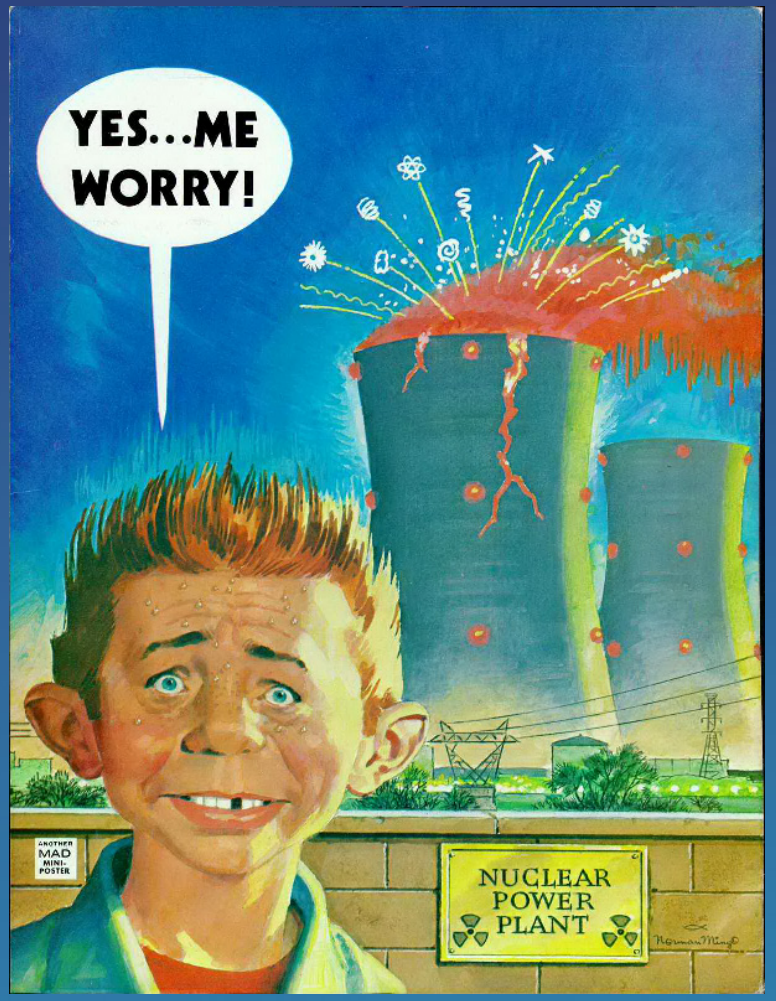
Sandia Labs evidently doesn't know you can barrel-roll a jet airliner of any size… at the top of the roll you can pull back on the controls and you'll dive just like a Stuka…it's a "1-g" maneuver – you just don't pull out.

… and you can practice this maneuver over and over in the comfort of your own home!

What, me worry?

"Additional surveillance could be added to dry cask storage facilities to detect and thwart ground attacks. Certain types of cask systems could be protected against aircraft strikes by partial earthen berms. Such berms also would deflect the blasts from vehicle bombs. Visual barriers could be placed around storage pads to prevent targeting of individual casks by aircraft or standoff weapons. These would have to be designed so that they would not trap jet fuel in the event of an aircraft attack."

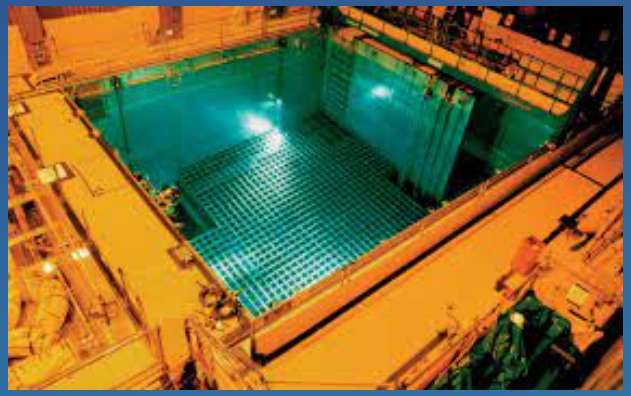
– nap.edu 2006



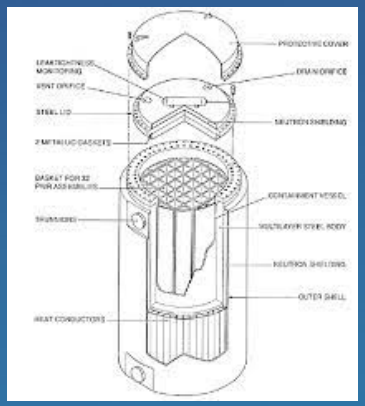
Safer than pools?

1) There is less fuel in a dry cask – but there are many more of them.
2) Measured on a per-fuel-assembly basis, the inventories of radionuclides available for release from a dry cask are lower than those from a spent fuel pool because dry casks store older, lower decay-heat fuel.
3) "It is the potential for zirconium cladding fires in spent fuel pools that gives dry cask storage most of its comparative safety and security advantage."

– nap.edu 2006



Most spent fuel pools are filled with several decades of reactor assemblies stored in overcrowded conditions.



Dry casks can hold up to 32 fuel assemblies, depending on design.

A spent fuel dry cask "farm" is an wide-open target for any terrorist group that can get past a chain link fence.

Dry casks add to the risk:

"All storage cask designs are vulnerable to some types of terrorist attacks for which radionuclide releases would be possible."

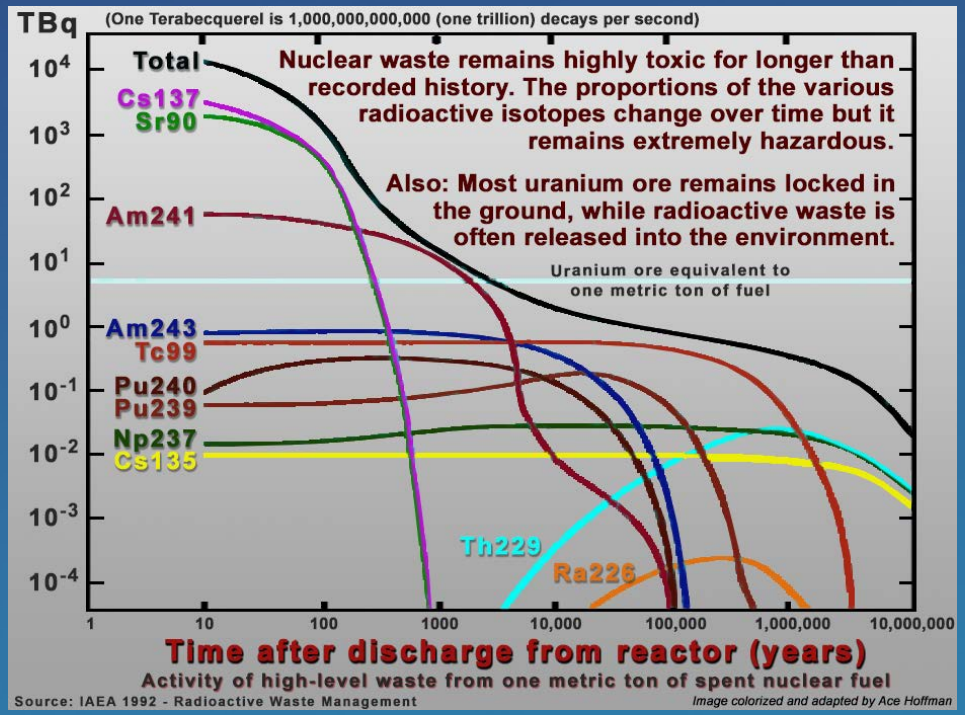
"Dry cask storage does not eliminate the need for pool storage at operating commercial reactors."

– nap.edu 2006

So it's not one or the other.

It's both…

Unless we stop making more nuclear waste…



How risk is calculated:

1. The scenario describing the undesirable event,
2. The probability that the scenario will occur,
3. The consequences if the scenario should occur.

– nap.edu 2006

In other words…

How risk is REALLY calculated:

"The committee expects that cost-benefit considerations would be a part of these analyses."

– nap.edu 2006

In the nuclear industry, #1 is a problem because some "scenarios" are overlooked, missed, or intentionally ignored. #2 is also a problem not only because it is difficult to estimate odds of rare events, but also because items with very low probability of occurrence – sometimes hundreds of items – are often completely ignored. And #3 is particularly troublesome. For example, "expert" estimates of the number of deaths from Chernobyl vary by three to five orders of magnitude (from under 100 to around one million). The NRC ignores multi-generational consequences of nuclear accidents, and minimizes the potential effects of low level radiation in a number of ways.

Consider the following: If you buy a lottery ticket, you'll have about a one in one million chance of winning $10,000.00. If you live in Hayward, California the odds of being in an earthquake in the next hour are also about one in one million. The "odds" may be the same, but the consequences can be substantially different! Should you buy something on credit assuming you'll win enough to pay for it, or should you know what to do in an earthquake?

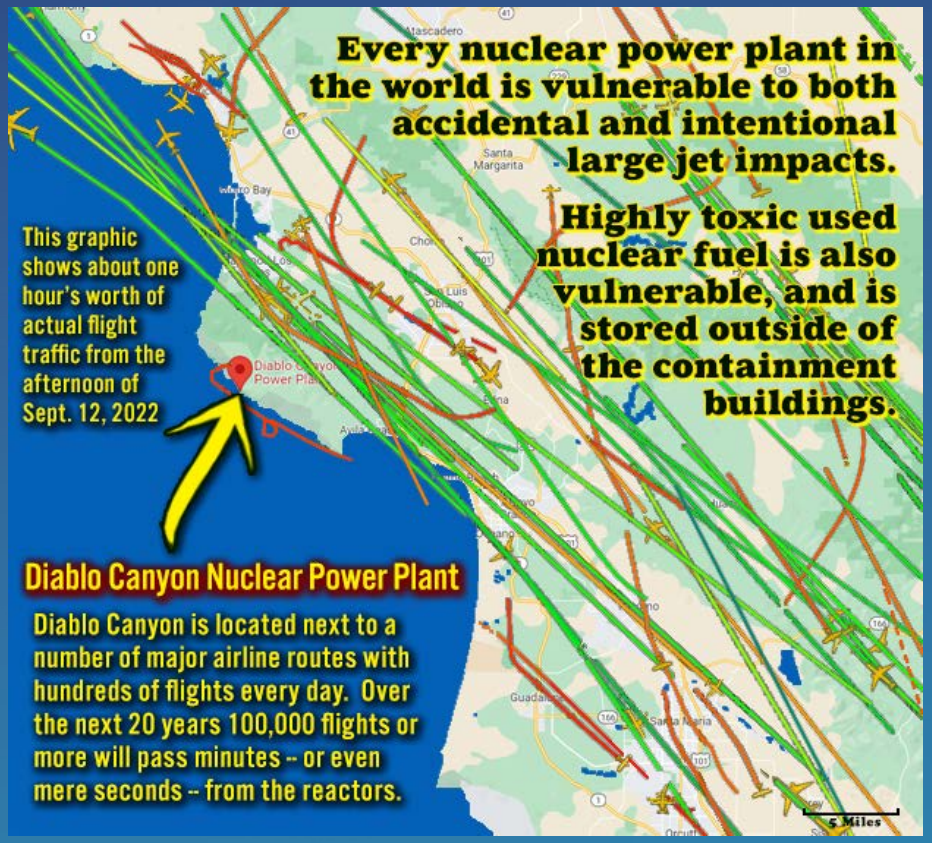
Worst-case scenario:

"The maximum credible scenario for suicide attacks involving civilian passenger aircraft would utilize the largest civilian passenger aircraft widely used in the United States flying at maximum cruising speed and hitting the facility at its most vulnerable point."

– nap.edu 2006

BUT REALLY, THEY DECIDED THE PLANE WOULD CRASH "JUST SO". It's further assumed terrorists cannot get access to military aircraft or "bunker busters" and, of course, can't get hold of a nuclear weapon!!!

Let's hope they're right.



“Reasonable” terrorists?

“[Nuclear] weapons would be relatively difficult for terrorists to build or steal. Even if such a weapon could be obtained, the committee can think of no reason that it would be used against a spent fuel storage facility rather than another target. There are easier ways to attack spent fuel storage facilities, as discussed in the classified report, and there are more attractive targets for nuclear weapons, for example, large population centers.”

– nap.edu 2006

MK153 SMAW (USA)
Shoulder-fired rocket launcher
Can penetrate 8 inches of concrete...

Kestrel (Taiwan)
Shoulder-fired rocket launcher
Can penetrate 2 feet of reinforced concrete...

Did “reasonable” terrorists attack the World Trade Center on 9-11?

What they really worry about is damage to their industry:

"Attacks using rocket-propelled grenades (RPGs) of the type that have been carried out in Iraq against U.S. and coalition forces would not likely be successful if the intent of the attack is to cause substantial damage to the facility. Of course, **such an attack would get the public's attention and might even have economic consequences for the attacked plant and possibly the entire commercial nuclear power industry.**"

– nap.edu 2006

Nuclear power is very profitable...if you're not the one paying for accidents, waste storage, R&D, etc.

Don't think it can't happen:

"The committee judges that it is not prudent to dismiss nuclear plants, including their spent fuel storage facilities, as undesirable targets for attacks by terrorists...Attacks by knowledgeable terrorists with access to advanced weapons might cause considerable physical damage to a spent fuel storage facility, especially in a suicide attack."

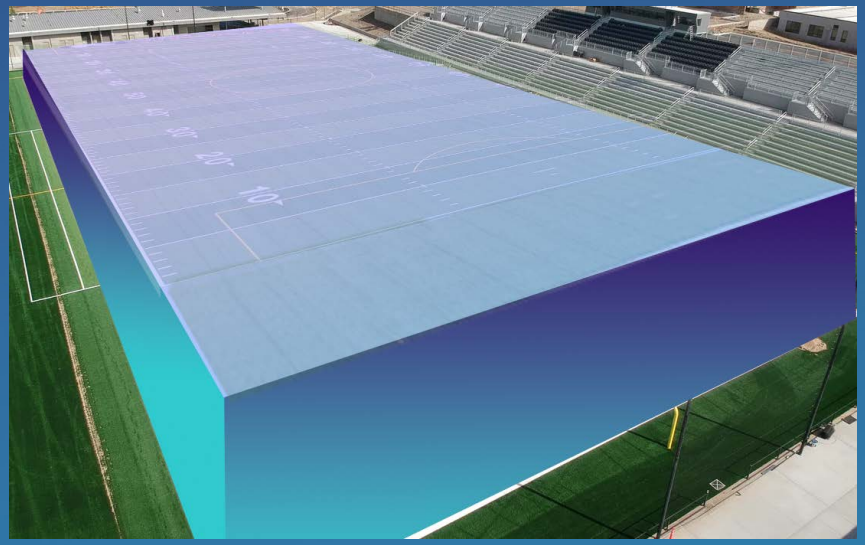
– nap.edu 2006

Too much of a bad thing:

In 1980 it was estimated that the annual production of plutonium exceeded that of platinum. The total volume of nuclear waste is sometimes described as fitting on a football field 7 yards deep if consolidated.* Of course, it would go critical if you tried to do that! But that's actually more than all the gold ever extracted.

The important thing is to stop making more waste. There' s no such thing as a good solution to an intractable problem.

** Industry only as of 2012 (nei.org)*



In 2022 the total amount, if placed on top of a football field, would be "less than ten yards." That is about 1.7 million cubic feet of High Level Nuclear Waste.*

** energy.gov*

Final thoughts:

Extracting Pu-239 and U-235 through "reprocessing" does not destroy the fission products. It is horribly polluting and prohibitively expensive. Transmutation is energy-intensive, incomplete, and technologically challenging to what extent it can be done at all. Other methods of spent fuel "burn-up" are likewise foolhardy.

At Zaporizhzhia Nuclear Power Station there are more than 100 spent fuel casks – in the midst of a war zone.

We don't need a new definition of "intractable".

We need to stop making nuclear waste.