Hi all,

Below is my review of the National Academy of Science Safety and Security of Commercial Spent Nuclear Fuel Storage, Public Report, distributed by SCE for last Friday's scoping meeting...

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October 11, 2018

Note to Readers:

The report is specifically about "**maximum credible scenarios.**" I'm sure prior to 9-11 multiple large airplane attacks were not considered credible. And because of TSA, they still aren't, because it's assumed TSA will stop such attacks (a ridiculous assumption).

Additionally, the report uses the term "**potential consequences**" in such a way that numerous assumptions can be made about mitigating factors which might reduce the impact of an attack. The entire report, therefore, should be taken with a grain of salt.

Lastly, the Note to Readers cautions that policy will need to balance "**costs, risks and benefits,**" which basically means nothing needs to be done if it's deemed too expensive to implement. The Note also states that alternative energy infrastructure, which might be far safer, was not considered.

Summary for Congress:

Most important highlights: "**2) The committee judges that successful terrorist attacks on spent fuel pools, though difficult, are possible. 3) If an attack leads to a propagating zirconium cladding fire, it could result in the release of large amounts of radioactive material.**"

Executive Summary:

The authors do not appear to be experts in terrorist thought processes or their sociological idealism, but rather in physical, engineering and associated technical issues. They are therefore incapable of determining the RISK of a terrorist attack of any particular magnitude.

The impetus for the report appears to be that others (a report by Bob Alvarez et al. is mentioned specifically on page 12) have "**suggested**" that spent fuel older than five years should be moved to dry cask storage in order to allow reactor companies to continue making more spent fuel while reducing the risk of a spent fuel pool fire. This appears to ignore the risk of continuing to operate reactors, especially older reactors and ADDING dry cask vulnerabilities on top of all the other risks. Not an out-of-the-frying-pan-into-the-fire situation, because the risk in the frying pan continues while adding additional risks.

The report mentions that the study was time-limited and that in several instances the Nuclear Regulatory Commission failed to provide proper documentation. Both of these constraints (excuses) seem strange for a study by more than two dozen participants, on such an important topic.

The Executive Summary then summarized the following sections. In Finding 2A it states:

"**Spent fuel storage facilities cannot be dismissed as targets for such attacks because it is not possible to predict the behavior and motivations of terrorists, and because of the attractiveness of spent fuel as a terrorist target given the well known public dread of radiation.**"

It is interesting that "p**ublic dread of radiation**" rather than public health impacts of radiation is what they feel might make spent fuel storage facilities attractive targets to terrorists. As stated above, they do not seem to understand terrorist's motives. (Which might include such things as: To bankrupt the country, kill hundreds of thousands of Americans, destroy our infrastructure, etc..)

The report incredibly then states that an attack on a nuclear power plant would not "**necessarily**" result in the release of "**any radioactivity to the environment.**" It can only be said that a poorly planned, unsuccessful attack would not result in "**any**" release. A successful attack would, by definition, result in a massive release. That would be the purpose of the attack. Terrorists have proven time and again that they are willing to properly prepare for their action.

Finding 2B is regarding stealing nuclear material. There is probably little reason to do that, since in situ destruction of the facility and release of the material would be considered a successful terrorist attack. However, claiming "**the amount of material would be small**" that could be successfully removed by "**knowledgeable insiders**" is absurd, since one single pellet of spent nuclear fuel, roughly the size of a finger bone, contains enough radiological material to make a large number of city blocks permanently uninhabitable, and contains hundreds of thousands or even millions of potentially lethal doses of radioactive poison.

Finding 2C was that the NRC did not provide enough information to the committee to evaluate the security at nuclear power plants. This seriously diminishes the usefulness of the report.

Finding 3A notes that freshly discharged spent fuel is thermally very hot and also that putting it in dry cask after less than three to five years would require extensive radioactive shielding. Surprised it didn't note that water is wet.

Finding 3B gets down to brass tacks. The committee finds that "**under some conditions**" terrorists could start a zirconium cladding fire in a spent fuel pool.

Finding 3C suggested that the risk could be reduced by configuring the spent fuel in the pool so that high decay-heat assemblies are surrounded by low decay-heat assemblies. My understanding is that this is normally done now. Also, don't offload entire reactor cores into the pools. This would occur, for example, when a reactor pressure vessel head (RPVH) is being replaced or other RPV maintenance needs to be performed, or when the reactor is permanently closed. However, the preferred alternative might be extremely expensive for the utility. Also very expensive is the committee's suggestion of longer shutdown periods before reactor fuel is offloaded. Because of the cost, I find it inconceivable that these options have been implemented. Another suggestion was to increase security during offloading procedures, but without any knowledge of what is actually being implemented this is a pretty hollow suggestion. Lastly, developing more ways to mitigate or prevent a loss-of-coolant event were urged. The Executive Summary was not specific about what these measures might be, let alone what they might cost.

Finding 3D does not mention specifics, but concludes that some spent fuel pools are more dangerous than others. One presumes they feel the Fukushima-style pools above the reactors are especially risky.

Finding 3E suggests that more research needs to be done "**urgently**" by the NRC. The summary claims that specific suggestions are made in the classified version of their report, but notes that "**cost-benefit**" needs to be part of the process. The committee strongly recommends reconfiguring the fuel assemblies as noted in 3C, and adding water-spray systems so that even if the pool drains, and continues to drain, some method of cooling the fuel assemblies can be maintained. This author finds it questionable whether such a technique would work at all, since it can be very difficult to ensure complete coverage after the building has been damaged by terrorism or an earthquake.

Finding 4A suggests that different cask designs do not offer significantly different safety margins. They claim that "**the quantity of radioactive material releases predicted from such [terrorist] attacks is relatively small.**" There is no reason to believe that is correct, or that "**These releases are not easily dispersed in the environment.**" A zirconium fire would disperse radionuclides very effectively.

Finding 4B suggests there are "**relatively simple steps**" that could be taken to make dry casks less vulnerable. The NRC apparently told the committee they are considering such steps. Knowing the NRC's typical time frame, a dozen years later they are probably still "**considering**" these steps.

Finding 4C mentions that dry cask storage does not eliminate other risks at nuclear facilities. It should be noted that switching to renewable energy DOES eliminate the other risks at nuclear facilities, and saves ratepayers money.

Finding 4D makes the mistake of thinking that 10,000 dry casks spread out at nuclear facilities around the country (or at a centralized interim storage facility) somehow reduces the risk. Unless the plants are closed, it only INCREASES the risk. This finding suggests that dry casks can prevent "**large-scale releases**" but that is certainly not the case at a centralized facility, which could be struck by a jumbo-jet filled with fuel and explosives, rendering dozens, or even hundreds, of dry casks cracked and burning. A single reactor site might have 150 or more dry casks.

Finding 4E indicates the authors think terrorists would choose EITHER to attack a single dry cask OR a spent fuel pool, but not both, and that dry casks can reduce the consequences of a terrorist attack on a spent fuel pool. Perhaps a little, but terrorists are (as the committee seems to realize) most likely to strike a reactor facility shortly AFTER a fuel swap operation, and they would probably then attack both the reactor itself (a relatively easy target with numerous weak links) AND the spent fuel pool. And maybe a dry cask just for good measure. Once again the committee stresses that "**cost-benefit considerations**" would be needed. But the cost-benefit of permanently shutting the reactor seems to be completely ignored.

Finding 5A indicates that, due to security considerations, nothing particularly useful can be discussed in this report. Worse than that, the NRC can't, or won't even discuss important topics with its own licensees. It laments that this might undermine confidence.

Introduction and Background:

Again, the committee is overly worried about people's perceptions:

"**From the outset the committee believed that safety and security issues must be addressed quickly to determine whether additional measures are needed to prevent or mitigate attacks that could cause grave harm to people and cause widespread fear, disruption, and economic loss. The information gathered during this study reinforced that view. Any concern related to nuclear power plants has added stakes: Many people fear radiation more than they fear exposure to other physical insults.**"

1.1 Context for this Study:

The committee states that the NRC disagrees with the Alvarez report (also with Marsh and Stanford, 2001; Thompson 2003). Then the report claims that nuclear power is "**critical**" to America's "**future energy security**" which is utterly false. Such bias causes the entire report to be suspect, since they think it's a given that nuclear power is necessary at all. Despite their claims, the issue is not considered "**carefully, wisely, and with a balanced view.**"

1.2 Strategy to Address the Study Charges:

Some members of the committee visited Germany, but there does not appear to be any discussion of relative safety of the thick German Castor ductile cast iron casks versus stainless steel thin-walled American dry cask storage containers, which are about 1/30th as thick, and barely thicker than an egg shell, in proportion to their contents.

This section mentions that an "**accidental drop of a cask on the pool wall...could lead to the loss of pool coolant.**" This risk seldom sees the light of day, although the report refers to this and several other risks (such as dropping a dry cask elsewhere) as "**well known.**"

The committee did not "**pursue in-depth examinations**" of human factors in responding to a terrorist attack, the plume behavior and effects after a release, economic consequences of an attack (cleanup costs, for example), or the cost of mitigation measures to reduce vulnerabilities. Also, transport vulnerabilities were not investigated (another Academies report is available on that subject, from 2005).

1.4.1 Nuclear Fuel:

On the contents of spent fuel after the first year, the report notes that during the first year, short-lived decay products produce about 90% of the decay heat in the spent fuel. After that:

"**Longer-lived radionuclides persist in the spent fuel even as the decay heat drops further. Cesium-137 decays to barium-137, emitting a beta particle and a high-energy gamma ray. The cesium-137 half-life of 30.2 years is sufficiently long to ensure that this radionuclide will persist during storage. It and other materials present in the fuel will form small particles, called aerosols, in a zirconium cladding fire.**"

1.4.2 Storage of Spent Nuclear Fuel:

The three primary objectives for storage of spent fuel are given as:
1) Prevent heat-up to "**high temperatures**" (for years the fuel is well above the boiling point of water, so this refers to even higher temperatures than that).
2) Shield workers and the public from radiation
3) Prevent criticality events.

I would put #3 first, as would Tom Palmisano, based on his comments at multiple CEP meetings.

This section notes that spent fuel pools do not keep radioactive noble gases from the environment. It credits the "**geometry**" of the fuel assemblies in the spent fuel pool and in dry casks, along with neutron absorbers, for preventing criticality events.

Causing a criticality event would undoubtedly be a major goal of any terrorist attack.

1.4.3 Spent Fuel Inventories:

As of 2003, the report says approximately 50,000 metric tons of spent fuel had been generated by commercial nuclear reactors. The total is closer to 80,000 metric tons today. A "**typical**" nuclear power plant produces about 20 metric tons per year.

When the report was published about 6,200 metric tons of spent fuel was in dry storage. There are now about 2,000 dry storage canisters in use, holding probably more than 20,000 metric tons of spent fuel.

1.2.4 History of Spent Fuel Storage:

This section starts by noting that spent fuel pools were not designed to store a lifetime of reactor spent fuel. It was assumed that the fuel would be removed for offsite reprocessing after about five years in the pools. Later reactors had larger pools, but then operating licenses were extended with no space left in the pools to put the fuel.

Dry cask storage was introduced, along with denser racking of the spent fuel (accomplished in part by improving the water circulation systems). But it was assumed that a permanent geologic repository would eventually open up. The report predicted that the permanent repository would open in 2010 (eight years ago) which was poppycock.

Denser racking is much more risky than the previous "**open-rack**" design in the event of a loss-of-pool-coolant accident or terrorist attack.

The report then mentions industry plans submitted to the NRC for 16 offsite ISFSIs (Independent Spent Fuel Storage Installations), none of which came to fruition.

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2 Terrorist Attacks on Spent Fuel Storage:

This section covers RISK, defined as:

Scenario (such as a suicide attack); and
Probability (of success); and
Consequences (if successful).

Risk equals probability times consequences.

One risk they seem to harp on is: "**severe psychological consequences that could drive changes in public acceptance of commercial nuclear energy.**"

The report next identifies the mechanism for estimating risk, namely the dreaded, inaccurate, easily fudged "**Probabilistic Risk Assessment**" (PRA). The report claims it is possible to estimate the risk of industrial accidents at nuclear power facilities, but this was before Fukushima. It states that quantitative risk assessments cannot be done for terrorist attacks, because neither their size nor their likelihood can be estimated.

The report quotes a 2002 National Research Council report that suggests that there are other, more easily-attacked targets for terrorists to strike, making reactors therefore less risky. Strange logic. Once again, at the end of this section, the report worries that a terrorist attack could "**threaten the viability of commercial nuclear power.**"

2.2 Terrorist Attack Scenarios:

The committee ruled out attacks by large commercial aircraft against a facility "**located below ground level or protected by surrounding hills or buildings.**" This, however, is untrue because even a large jet can be flipped over on its back, or knifed into a steep dive, and the maneuver can be practiced thousands of times on a flight simulator. Regardless, most facilities are NOT protected by being below ground level (something Edward Teller had advocated for, back in the day) or surrounded by hills or buildings.

As to terrorists getting hold of nuclear weapons or "**bunker busters,**" they might yet get their hands on the former (the report admits this), and can build reasonable versions of the latter.

The committee states that: "**if the consequences of such attacks were severe, policy makers might still decide that prudent mitigating actions should be taken regardless of their low probabilities of occurrence.**" However, in reality, the nuclear industry is allowed to ignore "**low probability**" events entirely, regardless of severity. "**Low probability**" is defined (for example, in official Yucca Mountain documentation this author has seen) as something in the neighborhood of one in 8 million, although the method of calculating the odds is usually just wild guesswork.

The committee points out that the NRC's (classified) report on terrorist attacks does "**not consider maximum credible scenarios. Instead, the analyses employ reference scenarios that are based either on the characteristics of previous terrorist attacks or on qualitative judgments of the technical means and methods that might be employed in attacks against spent fuel storage facilities.**" The committee points out that the NRC's classified report scenarios are not "**bounding.**" Furthermore, the committee considers the NRC's analyses to be a "**best-estimate**" scenario, not a "**maximum-credible**" scenario. It considers NUREG-1738 (USNRC, 2001 a) and Alvarez et al. (2003a) to be "**maximum-credible**" scenarios.

Once again, the committee seems to worry more about the public's perception after an attack than any other consequences: "**Of course, such an attack [an RPG against a nuclear facility] would get the public's attention and might even have economic consequences for the attacked plant and possibly the entire commercial nuclear power industry**" even if it did little or no actual damage.

2.2.1 Air Attacks:

Recently an employee of an airline company stole a medium-size turboprop airplane, flew it around for an hour or so, then crashed it into an island in the state of Washington. A few years ago a GermanWings copilot locked the pilot-in-command out of the cockpit when he went to the bathroom, and flew the plane -- full of passengers -- into a mountain. It is probable that MH370 was also the result of a suicide/murder by someone in the cockpit. An EgyptAir crash may also have been a suicide/murder, as well as many other incidents. In 2005 this author was the victim of an attempted suicide/murder by his own Congressman days after the Congressman had agreed to resign from Congress on bribery charges (Randall Cunningham, who was an "ace" pilot in Vietnam (America's last "ace")). TSA can do little, if anything, to protect against a suicidal pilot.

The committee considered air attacks to continue to be a valid threat, and this author completely agrees. And the committee points out that an Airbus 380 is a much larger aircraft than the planes used in the 9-11 attacks. An Airbus A380-800 weighs 1.2 million pounds and can carry nearly 85,000 gallons of fuel -- plus many tons of explosives. A Boeing 767-400ER maximum weight at takeoff is less than half that, and its maximum cruising speed is also less than an Airbus A380's. A Boeing 757 is significantly smaller, but still a very large airplane which could do enormous damage to a spent fuel dry cask or other parts of a nuclear power facility.

Due to the many variations in site arrangements, and in the methods of attack by aircraft, the committee did not try to make any general statements about the consequences of such an attack, but pointed out that "**U.S. commercial nuclear power plants are not required by the Nuclear Regulatory Commission to defend against air attacks.**" The NRC and the nuclear industry simply assume that other elements of the federal government will protect against such attacks. That is absurd.

2.2.2 Ground Attacks:

The committee was not able to assess these dangers very carefully due to not being able to obtain classified information. But various NRC documents and statements have been analyzed by others, indicating that the maximum threat a facility must be expected to repel is not more than five attackers, including one insider.

2.2.3 Attacks Having Both Air and Ground Components:

The details are classified, but: "**The committee judges that some scenarios are feasible.**"

2.2.4 Terrorist Theft of Spent Fuel for Use in a Radiological Dispersal Device (RDD):

While theft of an entire spent fuel assembly would be difficult to carry out, many plants have smaller pieces of fuel assemblies in the spent fuel pools, which would be easier to obtain. However, aerosolizing the fragments would be difficult, making this overall an unlikely scenario.

2.3: Risks of Terrorist Attacks on Spent Fuel Storage Facilities:

The NRC told the committee that it believes such an attack would "**unfold slowly enough**" that mitigative actions could be taken to prevent a large release of radioactivity. The NRC also believes that because nuclear power plants are, in their opinion, "**robust and well protected**" they would be unlikely targets compared to various other chemical and industrial sites.

However, the Committee points out that Al-Qaida initially included nuclear power plants as potential targets for the 9-11 attack. They were only eliminated when the organization scaled back the number of aircraft it planned to use that day.

Once again, the Committee felt an attack could have "**severe adverse psychological**

effects" and "**considerable economic consequences.**" They also said a well-planned and executed attack could "**cause considerable damage to a spent fuel storage facility, especially in a suicide attack.**"

2.4 Findings and Recommendations:

(See Executive Summary, above, for a discussion of the committee's findings and recommendations.)

Spent Fuel Pool Storage:

The committee felt that a criticality event would not necessarily be catastrophic "**offsite**" but an oxidation reaction of the zirconium alloy ("**zircaloy**") could become self-sustaining at high temperatures (above about 2,000 degrees F).

The Zirconium alloy (zircaloy) cladding is capable of extremely exothermic reactions when exposed to air or steam, and when unprotected by circulating water (in a spent fuel pool) or an inert gas such as helium (in a dry cask) those conditions can be achieved. When reacting to steam, the zircaloy oxidizes and hydrogen gas is released, which is explosive. When reacting to air, the zircaloy oxidizes.

As fuel rod temperatures increase during such an event, the gases inside the fuel rod expand, at first ballooning out the cladding and then rupturing it. This will release large quantities of radioactive isotopes such as cesium, as an aerosol.

Temperatures can become high enough (approximately 3300 degrees F) to cause the zircaloy cladding to react with the uranium fuel pellet in a molten phase.

3.1: Background on Spent Fuel Pool Storage:

Spent fuel pool superstructures are generally not designed to protect against tornado-born missiles (e.g. cars, telephone poles, etc.). The pools themselves are more robust, but not "**designed to resist terrorist attacks.**" BWR spent fuel pools are especially vulnerable for several reasons: The location above the reactor, and the lack of substantial superstructure surrounding them. (This author notes that since they are generally the oldest operating reactors, their pools are likely to be densely packed with spent fuel assemblies.)

Some PWR spent fuel pool walls "**also serve as external walls of the spent fuel pool buildings.**" The fuel is usually at or slightly below grade.

"**Pools are potentially susceptible to attacks from above or from the sides depending on their elevation with respect to grade and the presence of surrounding shielding structures.**"

3.2: Previous Studies On Safety And Security of Pool Storage:

A 1975 "**Reactor Safety Study**" by the Atomic Energy Commission did not consider terrorism in regards to spent fuel pool safety. Later studies (1979 through 2003) by or commissioned by the NRC all concluded that a loss-of-coolant event in a spent fuel pool "**could trigger a zirconium cladding fire in the exposed spent fuel.**" However, the NRC concluded such loss-of-coolant events are "**unlikely.**"

A 2001 study, NUREG-1738 (which used PRAs) "**suggested that large earthquakes and drops of fuel casks from an overhead crane during transfer operations were the two event initiators that could lead to a loss-of-pool-coolant accident.**" If the pool cooling mechanisms were shut off for any reason, the study concluded that after about four days the fuel could reach ignition temperatures, if nothing were done to restart the system.

The 2001 study predicted large consequences but very low probability of catastrophic accidents at spent fuel pools. It indicated that freshly discharged fuel would spontaneously ignite within a few hours of becoming uncovered.

In 2003 Alvarez et al. and Thompson, extended the NUREG-1738 analyses by considering an 9-11 style airplane strike that drained the pool, concluding that rapid heat-up and fire would occur (starting with the freshest fuel, but extending to old assemblies), releasing "**many of the fuel's fission products, particularly Cesium-137.**" and that the long-term consequences would be "**worse than Chernobyl,**" with "**10 to 100 percent**" of the cesium-137 "**mobilized in the plume**" causing "**tens of thousands of excess cancer deaths, loss of tens of thousands of square kilometers of land, and economic losses in the hundreds of billions of**

dollars." A subsequent analysis by Beyea at al. (2004) revised the death toll downward to between 2000 and 6000, based on their accounting for population densities around reactors (which have since increased substantially).

Author's note: The Alvarez report became one of the main impetuses for rapid transfer to dry cask storage, which allowed the utilities to keep operating and continue making more nuclear waste. The NRC, however initially concluded that the risk did not justify the cost. The committee states that in the classified version of their report, they judge "**some of [Alvarez's] release estimates to be justified.**"

A 2003 NRC staff publication agreed with Alvarez's conclusions. Another NRC 2003 study concluded, ominously, that a seismic event posed the greatest risk. It apparently did not include a subsequent tsunami event, and the expected frequency was no greater than for a beyond design basis seismic event that would result in reactor core damage. (And apparently two wrongs make a right.)

A 1997 NRC study showed that there have been "**several partial-loss-of-coolant events**" caused by human error, including two events where more than five feet of water was lost.

3.3 Evaluation of the Potential Risks of Pool Storage:

Prior to 9-11, NRC analyses invariably concluded that spent fuel pool risks "w**ere no greater (and likely much lower)**" than operating reactor core risks. So again, two wrongs make a right.

And once again, the committee discusses how an accident (or in this case, a terrorist attack) could spread "**fear and panic among civilian populations**" rather than actual death and destruction. It has been a theme throughout the report.

The NRC informed the committee that thwarting future 9-11 style attacks was (other departments of) the federal government's job and the NRC assumed those departments would be successful, therefore safety measures against such attacks did not need to be developed. (That is still the NRC's and the nuclear industry's assessment today.)

The committee report notes that nuclear power plants were not designed with security as a primary consideration. For example, the reason the containment buildings are "**robust**" is to contain an internal pressure buildup of about four atmospheres, in case steam is released in an accident. The committee also notes, again, that other "**critical infrastructure**" is less robust.

3.3.1 Could a Terrorist Attack Lead to a Loss-of-Pool-Coolant Event?

Most information is "**classified**" but: "**The committee has concluded that there are some scenarios that could lead to the partial failure of the spent fuel pool wall, thereby resulting in the partial or complete loss of pool coolant. A zirconium cladding fire could result...**"

3.3.2: What would be the Radioactive Releases if a Pool Were Drained?

"**An explosion or high-energy impact directly on the spent fuel could mechanically pulverize and loft fuel out of the pool. This would contaminate the plant and surrounding site with pieces of spent fuel. Large scale offsite releases of the radioactive constituents would not occur, however, unless they were mobilized by a zirconium cladding fire that melted the fuel pellets and released some of their radionuclide inventory. Such fires would create thermal plumes that could potentially transport radioactive aerosols hundreds of miles downwind under appropriate atmospheric conditions.**"

Computer analysis of zirconium cladding fire potential strongly indicates that surround high-decay-heat fuel assemblies with older, relatively low-decay-heat fuel assemblies is an important method of reducing risk. (Author comment: It is therefore extremely important that fuel assembly arrangements be properly configured within a spent fuel pool or dry cask.)

A partial pool drain can be more dangerous than a complete pool drain because air flow under the fuel assemblies would not occur with a partial pool drain (there is a gap between the bottom of the spent fuel pool and the bottom of the fuel assemblies).

Once ignition of the fuel occurs in a partially-drained pool, steam would create hydrogen gas, which could cause a "**deflagration of hydrogen,**" which could "**enhance the release of radioactive material in some scenarios.**" PWR pools, being generally larger than BWR pools with higher burn-up fuel assemblies, could have more severe releases than BWR pools in the event of a zirconium fire.

The committee recommends water spray systems capable of spraying at least 50 to 60 gallons per minute be installed above the spent fuel pools, and that the systems be designed to function even if the building is "**severely damaged in an attack.**" The committee also recommended: Limiting full-core offloads and/or delaying full-core offloads after a reactor shutdown; strengthening the walls of the spent fuel pools; increasing security during outages that involve core offloads. It noted that "**cost considerations might be significant.**"

3.3.3 Discussion:

Studies were ongoing at the time the report was completed. Aircraft attack scenarios involved lighter aircraft than what might actually be used. Modeling was greatly simplified for reasons of computational complexity (some models still took 10 to 12 days to complete on a typical personal computer of that era). Ballooning of the cladding was not considered. Radiative heat transfer was not modeled, etc. etc.. An attack "**that ejects spent fuel from the pool**" was not considered. No assessment of the probability of attacks was made.

3.4 Findings and Recommendations:

(See Executive Summary, above, for a discussion of the committee's findings and recommendations.)

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4 Dry Cask Storage and Comparative Risks:

As footnoted: "**The Nuclear Waste Policy Act of 1982 and the Amendments Act of 1987 laid out a process for identifying a site for a geologic repository. That repository was to be opened and operating by the end of January 1998. The federal government now hopes to open a repository at Yucca Mountain, which is located in southwestern Nevada, by the end of 2010.**" It is now the last quarter of 2018...

The committee asserts that dry cask storage was developed because: "**By the late 1970s, the need for alternatives to spent fuel pool storage was becoming obvious to both commercial nuclear power plant operators and the Nuclear Regulatory Commission.**" This presumes that there was a "**need**" for nuclear reactors at all -- an utterly false assumption.

The first dry cask storage site opened in 1986 at the Surry Nuclear Power Plant in Virginia.

4.1 Background on Dry Cask Storage:

The report states that "**typically, concrete, lead and steel are used**" in dry casks to shield gamma radiation. (This author does not believe lead is included in today's dry cask storage containers.) Polyethylene, concrete and boron-impregnated metals or resins are used to shield neutron radiation.

Criticality control is provided by a lattice structure within the dry cask. Additional reduction of the possibility of a criticality event is provided because there is no water to moderate (slow down) the neutrons (slow neutrons are more easily captured by fissile atoms). The lattice structure is designed to maintain the fuel in a fixed geometry, however, earthquakes, high explosives or airplane strikes can alter the configuration. A subsequent tsunami or fire fighters trying to put out a zirconium fire can provide the water necessary for a criticality event to occur.

"**Single-purpose cask systems are licensed only to store spent fuel. Dual-purpose casks are licensed for both storage and transportation. Multi-purpose casks are intended for storage, transportation, and disposal in a geologic repository. No true multi-purpose casks exist in the United States (or in any other country for that matter) because specifications for acceptable containers for geologic disposal have yet to be finalized by the Department of Energy. Current plans for Yucca Mountain do not contemplate the use of multi-purpose casks. Nevertheless, some cask vendors still refer to their casks as "multi-purpose." These are at best dual-purpose casks, however, because they have been licensed only for storage and transport.**"

A typical cask weighs 100 tons or more when fully loaded with 10 to 15 metric tons of spent nuclear fuel. Typical dimensions are nearly 20 feet high and about 8 feet in diameter.

4.2 Evaluation of Potential Risks of Dry Cask Storage:

Dry casks were NOT designed to resist terrorist attacks. Their design purpose is to provide adequate heat dissipation, to survive potential accidents during loading or transport. This author notes that their main purpose is to allow the spent fuel pool inventories to be reduced so the reactors can continue to produce more nuclear waste.

NRC regulations for protection requirements are significantly less than for spent fuel pools and reactors: Guards carry side arms (pistols) and their main function is surveillance.

A terrorist attack against a dry cask could "**potentially**" cause a mechanical dispersion of fuel particles or fragments, and/or a release of radioactive aerosols.

Details on large aircraft impact scenarios are classified, but something about hitting the fan is unquestionable.

4.2.1 Large Aircraft Impacts:

Boeing aircraft were modeled. As noted above, the Airbus A380-800 is much larger than the largest Boeing aircraft that might have been modeled. The casks were assumed to be filled with high burnup, 10-year old spent nuclear fuel. The effects of jet fuel were NOT considered, because Sandia labs concluded that the fuel would disperse over a wide area and any subsequent fire would last less than about 15 minutes. This author notes that the sunken island configuration being promoted by Holtec for future dry cask storage and currently used at San Onofre and other reactor sites would actually allow the jet fuel to surround the casks and burn for a much longer period of time. Such burn times were not considered credible in the Sandia study, but IF they occurred, the study indicated that the casks could be damaged and the zirconium cladding could be ignited.

Although the final reports are classified, some scenarios could cause "**substantial cask-to-cask interactions, including collisions and partial tip-overs.**"

Predicted releases were considered to be small (presumably because cracked canisters and zirconium fires were not evaluated, even though clearly they are possible).

4.2.2 Other Assaults:

No details were provided, but publicly-available literature makes it clear that weaponry is available to terrorists that has enough kinetic energy to easily breach a dry cask, and there are numerous high explosives that could ignite a zirconium fire.

4.2.3 Discussion:

The committee concluded that: "**cask provides complete protection against all types of terrorist attacks. The committee judges that releases of radioactive material from dry casks are low for the scenarios it examined with one possible exception as discussed in the classified report.**" This author notes that terrorists can think up their own scenarios and do not need to rely on classified reports.

The committee recommended: Increased surveillance, earthen berms to deflect vehicle bomb blasts and protect against aircraft strikes. (Note: There is no room for such berms at San Onofre.) They also recommend visual barriers, that the ISFSI should NOT be designed so that it would trap jet fuel (unlike at San Onofre), that the space between casks be widened and/or spacers be placed between dry casks (there is no rebar between casks in the San Onofre island, only cement (there is rebar only at the top and bottom of the island structure)).

4.3 Potential Advantages of Dry Storage over Wet Storage:

The committee judged dry cask storage to have "**several potential safety and security advantages over pool storage.**" Their reasons are specious at best if dry cask storage is ADDED to an operating reactor and spent fuel pool, aside from some reduction in inventory levels of the oldest fuel assemblies in the pool.

Among their reasoning is that less fuel is in each dry cask, which ignores at least two factors: First, there are dozens of dry casks at each ISFSI (in some cases more than 100 already exist, and more than 100 are planned at each site). Second, the footprint of vulnerable areas is greatly increased, making an airplane strike at the facility more likely to succeed, and giving ground attackers more options as well.

They also reasoned that the fuel in the dry casks is older, so the radioactivity of each assembly is less than the average in the spent fuel pool or in the reactor. They assumed there would not be a zirconium fire in a dry cask, and little or not damage to the cladding structure, therefore any releases would be mainly in particle form, not aerosol form, and would not travel very far from the site.

Lastly, they assumed that: "**recovery from an attack on a dry cask would be much easier than the recovery from an attack on a spent fuel pool.**" This was based on the idea that a dry cask breach could be temporarily plugged. They thought a cask could be repaired, although recently, the CEO of Holtec has publicly denied that makes any sense and has stated that millions of Curies could be released from even a small crack in a dry cask.

4.4 Findings and Recommendations:

The committee did not see any significant advantage to any specific design of dry cask over any other "**even in a breach.**" The considered ALL designs to be vulnerable "**to some types of terrorist attacks.**" They considered the risks to be small, even though they are not capable of out-thinking a determined terrorist or assigning a probability to an attack actually occurring.

(See Executive Summary, above, for additional discussion of the committee's findings and recommendations.)

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5 Implementation Issues:

The committee notes that "**a large number of parties**" would have to cooperate to implement their recommendations.

5.1 Timing Issues:

9-11 caused the NRC to reexamine security and issue "**numerous directives**" to increase protection. However, at that time the NAS report was submitted, the NRC's spent fuel storage studies had not been completed. The committee considered the pace to be "**slow.**"

5.2 Communication Issues:

The committee noted that nuclear industry representatives had made "**numerous**" comments to the committee about the lack of information sharing by the NRC on the vulnerabilities discussed by the committee, resulting in "**missed opportunities**" to increase protection. Additionally, access to reports created by EPRI and ENTERGY was sometimes restricted in such a way that even the authors could not access their own reports later. Since the industry is responsible for implementing better protection, they need to know what the studies say, to know what to do.

Not surprisingly, the committee does not feel that information "**that could prove useful to terrorists**" should be released. This author notes that not releasing information about the consequences of a terrorist attack will inevitably lead to the public not knowing the full extent of the danger being imposed on them. The committee notes that "**[s]haring information with the public is essential in a nation with strong democratic traditions...**"

5.3 Finding and Recommendation:

(See Executive Summary, above, for additional discussion of the committee's findings and recommendations.)

The above notes written October 10 - 11, 2018 by Ace Hoffman, Carlsbad, California
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