IRSS. INSTITUTE FOR RESOURCE AND SECURITY STUDIES

Declaration of 12 February 2019
by Gordon R. Thompson
for submission to the
US Nuclear Regulatory Commission
regarding an application by
Holtec International
for a license to construct and operate a
Consolidated Interim Storage Facility
in Southeast New Mexico

NRC Docket No. 72-1051

Theme of this declaration:
Holtec Responses to Selected RAIs,
and Wider Implications

I, Gordon R. Thompson, declare as follows:

I. Introduction

(I-1) I am the executive director of the Institute for Resource and Security Studies (IRSS), a nonprofit, tax-exempt corporation based in Massachusetts. Our office is located at 27 Ellsworth Avenue, Cambridge, MA 02139. IRSS was founded in 1984 to conduct technical and policy analysis and public education, with the objective of promoting peace and international security, efficient use of natural resources, and protection of the environment. My professional qualifications and experience are discussed in Section II, below.

(I-2) I have been retained by public-interest organizations to prepare this declaration. The organizations are Don't Waste Michigan et al, and Sierra Club. This declaration addresses a proposal by Holtec International (Holtec) to construct and operate a Consolidated Interim Storage Facility (CISF) in Southeast New Mexico. The proposed CISF would provide interim storage of spent nuclear fuel (SNF).[1] Holtec has submitted a

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[1] The proposed CISF might also store some Reactor-Related Greater than Class C LLRW. This declaration focuses on SNF.

license application to the US Nuclear Regulatory Commission (NRC). A licensing proceeding is under way, before an Atomic Safety and Licensing Board panel.

(I-3) The proposed CISF is a type of facility that is often described as an independent spent fuel storage installation (ISFSI). A number of ISFSIs are in operation in the United States and elsewhere. The proposed CISF, like most existing ISFSIs, would store SNF assemblies in dry conditions inside containers.

(I-4) In this declaration I present information drawn from a number of sources. One of those sources is a generic environmental impact statement (GEIS) prepared by NRC, regarding continued storage of SNF.[2] That GEIS was published in September 2014. Hereafter, that GEIS is referred to as "NRC's GEIS".

(I-5) I provided comments on a September 2013 draft version of NRC's GEIS, in a declaration dated 19 December 2013.[3] That declaration is referred to hereafter as "the Thompson December 2013 declaration". This, my present declaration, incorporates, by reference, the Thompson December 2013 declaration. Moreover, the Thompson December 2013 declaration was accompanied by forty-nine Exhibits, and this declaration incorporates, by reference, those of the forty-nine Exhibits for which I was the sole author.[4] In addition, this declaration cites other documents for which I was the sole author. These documents are incorporated here by reference.

(I-6) In preparing this declaration, I obtained information about the proposed CISF from two major sources, plus other documents as cited. The first major source is the Holtec Safety Analysis Report (SAR).[5] The second major source is the Holtec Environmental Report (ER).[6]

(I-7) This declaration addresses selected issues. Absence of discussion of an issue in this declaration does not imply that I view the issue as insignificant, or that I have no professional opinion on the manner in which others have addressed the issue.

(I-8) The issues addressed in this declaration are pertinent to Holtec's Responses to a selected subset of the Requests for Additional Information (RAIs) that have been made by the NRC Staff, pursuant to Holtec's application for a license for the proposed CISF. I selected this subset of RAIs. Holtec's Responses to the selected RAIs were made in Round 1 Part 2. The selected RAIs, and Holtec's Responses to them, are excerpted here or quoted in full as follows:

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[2] NRC, 2014.
[3] Thompson, 2013.
[4] Exhibits of the Thompson December 2013 declaration for which I was the sole author are: #1, #3, #5, #8, #9, #10, #26, and #27.
[5] Holtec, 2017.
[6] Holtec, 2018.

RAI LA-1 (excerpt):
"Justify the absence of a time limit for a canister to be returned to the nuclear plant of origin, or other facility licensed to perform fuel loading procedures, in Appendix A to the proposed Materials License, "Technical Specifications for the HI-STORE Consolidated Interim Storage (CIS) Facility.""

Holtec Response to RAI LA-1 (excerpt):
"If a canister fails the Krypton-85 test or helium leak test, it shall remain in the sealed HI-STAR 190 transportation cask in the rail spur staging area south of the Cask Transfer Building (CTB), until it is returned to the originating site or other facility licensed to perform fuel loading procedures."

RAI 9-3 (excerpt):
"Clarify the content in Section 9.2.2, "Operational Activities," (Page 9-7) of the HI-STORE SAR."

Holtec Response to RAI 9-3:
"Section 9.2.2 [of the SAR] has been revised to state that "no credible normal, off-normal or accident conditions" could challenge the integrity of the canister confinement integrity and result in a release of any radioactivity."

RAI 17-12 (excerpt):
"Provide additional information to justify the statements in HI-STORE SAR Chapter 18 that the halide content in the air at the HI-STORE site is negligible with respect to the potential to cause stress corrosion cracking of stainless steel."

Holtec Response to RAI 17-12 (excerpt):
"The salts in the surrounding area are not expected to be transported to the canisters due to the design of the system. The canisters are stored within vaults, surrounded by a large amount of solid subgrade. Each canister is also surrounded by a steel CEC, which prevents intrusion through the subgrade to the canister. It should also be noted that although it is not anticipated that significant amount[s] of salts will be transported to the canisters, Holtec has still implemented a full aging management program, as described in Chapter 18. This program involves canister inspections over the life of the canisters. This program will monitor the condition of the canisters for all degradation mechanisms and take corrective actions as necessary."

RAI 17-14 (excerpt):
"Clarify the details of the VVM maintenance activities."

Holtec Response to RAI 17-14 (excerpt):
"The potential for CEC wall thinning will be assessed by visual inspection for any corrosion and/or pitting on the interior surfaces of the CEC. As stated in Section

> 17.7 of this SAR, the CEC is surrounded by a non-aggressive "free-flow" concrete around the structure, isolating it from any possible aggressive corrosion agents in the native soil. As stated in Subsection 17.7.1, the CEC exterior coating is suitable for immersion or below-grade service. Because the CEC is a buried structure, degradation of the coating due to abrasion or other external contact during the life of the CEC is not feasible. Thus, inspection of the CEC internal surface serves as a viable method for determining the potential for any wall thinning due to localized CEC corrosion."

(I-9) This declaration addresses the accuracy and credibility of Holtec's Responses to the selected RAIs. It also addresses some of the wider implications of Holtec's Responses. In addressing these wider implications, this declaration identifies adverse impacts that could arise from construction and operation of the proposed CISF. These adverse impacts would be impacts on:

(i) the general welfare, as stated in the Atomic Energy Act;
(ii) the common defense and security, as stated in the Atomic Energy Act; and/or
(iii) environments and human populations affected by the proposed CISF.

The terms "the general welfare" and "the common defense and security" appear in Sec. 1. (Declaration) of The Atomic Energy Act of 1954, as amended, which says:[7]

> "Atomic energy is capable of application for peaceful as well as military purposes. It is therefore declared to be the policy of the United States that –
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> a. the development, use, and control of atomic energy shall be directed so as to make the maximum contribution to the general welfare, subject at all times to the paramount objective of making the maximum contribution to the common defense and security; and
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> b. the development, use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise."

(I-10) This declaration has the following narrative sections:

I. Introduction
II. My Professional Qualifications and Experience
III. SNF Management as a National Undertaking
IV. Potential Adverse Impacts of ISFSIs
V. Potential Future Operating Environments for ISFSIs
VI. History of Nuclear Power: Lessons Regarding the Proposed CISF
VII. Holtec Responses to RAIs: Accuracy, Credibility, and Wider Implications
VIII. Conclusions

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[7] NRC, 2013, page 15.

(I-11) In addition to the above-named narrative sections, this declaration has two appendices that are an integral part of the declaration. Appendix A contains tables that support the narrative. Appendix B is a bibliography. Documents cited in the narrative or in Appendix A are listed in Appendix B unless otherwise identified.

II. My Professional Qualifications and Experience

(II-1) As stated in paragraph I-1, above, I am the executive director of the Institute for Resource and Security Studies. I am professionally qualified by education and experience to discuss all issues addressed in this declaration.

(II-2) I received an undergraduate education in science and mechanical engineering at the University of New South Wales, in Australia, and practiced engineering in Australia in the electricity sector. Subsequently, I pursued graduate studies at Oxford University and received from that institution a Doctorate of Philosophy in mathematics in 1973, for analyses of plasma undergoing thermonuclear fusion. During my graduate studies I was associated with the fusion research program of the UK Atomic Energy Authority. My undergraduate and graduate work provided me with a rigorous education in the methodologies and disciplines of science, mathematics, and engineering.

(II-3) My professional work involves technical and policy analysis in the fields of energy, environment, sustainable development, human security, and international security. Since 1977, part of my work has consisted of analyses of actual and/or potential adverse impacts from the operation of commercial and military nuclear facilities. These analyses have been sponsored by a variety of non-governmental organizations and local, state and national governments in North America, Western Europe, and elsewhere. Drawing upon these analyses, I have provided expert testimony in legal and regulatory proceedings, and have served on committees advising government agencies.

(II-4) My Curriculum Vitae accompanies this declaration as Exhibit #1.

III. SNF Management as a National Undertaking

(III-1) To provide a context for discussing the proposed CISF, I discuss here some issues related to management of SNF created in the United States. These issues apply to SNF from commercial reactors.

(III-2) NRC has, in the past, argued that a repository for SNF will – with "reasonable assurance" – be available during coming decades.[8] NRC's GEIS, published in 2014, abandons that argument. It evaluates the environmental impacts of continued storage of SNF in three timeframes, one of which is the indefinite future. In discussing the respective likelihoods of the three timeframes, NRC's GEIS says:[9]

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[8] Thompson, 2009, Section 1.

[9] NRC, 2014, Section B.2.

> "Based on the analysis below and elsewhere in this GEIS, the NRC believes that the most-likely scenario is that a repository will become available to dispose of spent fuel by the end of the short-term timeframe (within 60 years of the end of a reactor's licensed life for operation). The NRC's belief is based on the resolution of two questions: whether a repository is technically feasible and, if so, how long will it take to site, license, construct, and open a repository."

In other words, NRC says that storage of SNF for the indefinite future is a plausible outcome, but not the most likely outcome. However, NRC's "belief" that availability of a repository is "the most-likely scenario" is based entirely on considerations of technical feasibility. Experience shows that social and political factors have played important roles in retarding the establishment of a repository in the United States.[10]

In addition, a likely future for nuclear power in the United States is that, over coming decades, commercial reactors will cease operation and not be replaced.[11] If that future occurs, its likely features include:

(i) SNF would be removed from reactor spent-fuel pools and placed in ISFSIs;
(ii) fee revenue from reactor licensees to pay for establishment of a repository would cease;
(iii) reactor and/or ISFSI licensees would fade away; and/or
(iv) the net political momentum for transport of SNF and establishment of a repository would decline over time.

Thus, it is reasonable to conclude that storage of SNF for the indefinite future is a likely outcome in the United States.

(III-3) NRC's GEIS assumes that institutional controls would continue even if SNF were stored for the indefinite future. NRC argues for that assumption as follows:[12]

> "The assumption that institutional controls will continue enables an appropriate and reasonable evaluation of the environmental impacts of continued storage over an indefinite timeframe. Absent the stability and predictability that follows from institutional controls, including but not limited to NRC licensing and regulatory controls, few impacts could be reliably forecast. The "hard look" required by NEPA would quickly become unfocused, highly speculative, and ill-defined. Analyzing the impacts that might result from a permanent and total loss of institutional controls would require NRC to reach unsupportable conclusions about how and when our nation, and its government, institutions, and social cohesiveness might degrade or even collapse. Such speculation would preclude

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[10] Thompson, 2008.
[11] Schneider et al, 2018.
[12] NRC, 2014, Section B.3.4.

> meaningful calculations of impacts for the timeframes envisioned in the GEIS."

NRC's argument that "few impacts could be reliably forecast" for a scenario involving lack of institutional controls is proven false by analysis done by the US Department of Energy (DOE). In 2002, DOE published its final environmental impact statement (EIS) for the proposed Yucca Mountain repository.[13] That document is referred to hereafter as "the Yucca Mountain EIS".

Section 7.2.2 of the Yucca Mountain EIS provides estimates of adverse impacts arising in No-Action Scenario 2, which would involve continued storage of SNF in the absence of institutional controls. That is precisely the scenario for which NRC argues that "few impacts could be reliably forecast". DOE describes its consideration of No-Action Scenario 2 as follows:[14]

> "DOE and commercial utilities intend to maintain control of the nuclear storage facilities as long as necessary to ensure public health and safety. However, Scenario 2 assumes no effective institutional control of the storage facilities after approximately the first 100 years to provide a basis for evaluating an upper limit of potential adverse human health impacts to the public from the continued storage of spent nuclear fuel and high-level radioactive waste. After about 100 years, Scenario 2 assumes that there would be no effective institutional control and that the storage facilities would be abandoned."

(III-4) NRC's GEIS discusses the role of a Dry Transfer System (DTS) or equivalent capability to repackage SNF. As part of that discussion, the GEIS says:[15]

> "Although there are no dry transfer systems (DTSs) at U.S. nuclear power plant sites today, the potential need for a DTS, or facility with equivalent capability, to enable retrieval of spent fuel from dry casks for inspection or repackaging will increase as the duration and quantity of fuel in dry storage increases. A DTS would enhance management of spent fuel inspection and repackaging at all ISFSI sites and provide additional flexibility at all dry storage sites by enabling repackaging without the need to return the spent fuel to a pool. A DTS would also help reduce risks associated with unplanned events or unforeseen conditions and facilitate storage reconfiguration to meet future storage, transport, or disposal requirements (Carlsen and Raap 2012)."

(III-5) NRC's GEIS acknowledges that SNF could be damaged prior to entry into storage, or during storage. The GEIS discusses that issue in connection with the provision of a capability to repackage SNF, saying, in part:[16]

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[13] DOE, 2002.
[14] DOE, 2002, Section 7.2.2.
[15] NRC, 2014, Section 2.1.4.
[16] NRC, 2014, Section 2.2.2.1.

> "As stated in Section 2.1.4, one reason DTSs may be needed in the future is to reduce risks associated with unplanned events (e.g., the need to repackage spent fuel that becomes damaged or that becomes susceptible to damage while in dry cask storage). The NRC defines damaged spent fuel as any fuel rod or fuel assembly that can no longer fulfill its fuel-specific or system-related functions (NRC 2007). These functions include criticality safety, radiation shielding, confinement, and retrievability of the fuel. Appendix B of this GEIS describes spent fuel degradation mechanisms that could occur during continued storage. These include a mechanism (i.e., hydride reorientation) in which high-burnup spent fuel cladding can become less ductile (more brittle) over time as cladding temperatures decrease. Taking actions (e.g., repackaging or providing supplemental structural support) can reduce risks posed by damaged fuel by maintaining fuel-specific or system-related safety functions."

A similar statement could be made in regard to damage to SNF containers.

NRC's GEIS acknowledges that the DTS design it describes, to illustrate present or anticipated capability to repackage SNF, "does not have the capability to handle damaged spent fuel." Nevertheless, says the GEIS, "international experience provides a broad understanding of the technical feasibility of various methods for handling damaged fuel".[17] In other words, the GEIS does not identify any available design of a DTS or equivalent system that could repackage SNF in the event of damage to SNF and/or an SNF container.

(III-6) NRC's GEIS discusses the establishment of a DTS or equivalent system at an away-from-reactor ISFSI, such as the proposed CISF. In that context, the GEIS says:[18]

> "Should storage at an away-from-reactor ISFSI continue for a long enough time for bare fuel handling to be required for inspection or maintenance, then a DTS could be constructed at the facility."

A differing perspective is evident in a 2012 report, prepared at Idaho National Laboratory (INL), that is cited in NRC's GEIS. The INL report discusses, among other matters, the establishment of a DTS or equivalent system at an ISFSI, such as the proposed CISF, where SNF from across the United States would be "consolidated". In that context, the INL report says:[19]

> "**Recommendation 2:** A repackaging and remediation capability should be integrated into the design of future facilities where UNF [used nuclear fuel = SNF] will be consolidated.

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[17] NRC, 2014, Section 2.2.2.1.
[18] NRC, 2014, Section 2.2.1.4.
[19] Carlsen and Raap, 2012, page 24.

> *A key objective is to ensure that UNF is transported to its final destination, or a destination with the necessary repackaging capabilities, before the need for repackaging arises. Although presently small, the likelihood of the need for a DTS to enable retrieval of UNF for inspection or repackaging will increase as the duration and quantity of fuel in dry storage increases. Stored fuel will eventually require remediation and/or repackaging for transport. Any large-scale repackaging operations that may eventually be necessary can be more safely and effectively conducted at a consolidated facility.*"

While the GEIS envisions the establishment of a DTS at a consolidated-storage ISFSI as a potential future requirement, the INL report says that a DTS or equivalent system should be "integrated into the design" of such an ISFSI. Thus, the INL report goes beyond the GEIS by calling for design of a DTS during the design of a consolidated-storage ISFSI. Neither document, however, calls for pro-active deployment of a DTS.

Here, I use the term "pro-active deployment" to mean that licensing preconditions for receipt of SNF at a consolidated-storage ISFSI would include the establishment at the site of a DTS or equivalent system, and the successful testing of that capability using actual damaged SNF.

Several factors, additional to those discussed in the GEIS and the INL report, call for pro-active deployment of a DTS at a consolidated-storage ISFSI. These additional factors include:

(i) storage of comparatively aged SNF at the site;
(ii) likely receipt at the site of damaged SNF assemblies and/or damaged SNF containers;
(iii) likely occurrence, at the site, of damage to SNF assemblies and/or SNF containers; and
(iv) the substantial lead time required to design, construct, and successfully test a DTS or equivalent system that could repackage SNF, including damaged SNF.

(III-7) The United States lacks a coherent national strategy for managing SNF.[20] A UK-based team of researchers has described that lack in the following terms:[21]

> "Examples of countries without any current long-term vision or plan include Germany and the USA. These countries have (in the past) had plans, but for various reasons, mainly political, the plans have been disrupted and spent fuel management is now much more reactive, responding to external factors rather than based on a well-defined vision or strategy."

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[20] Thompson, 2008.
[21] Hambley et al, 2016, Section 4.

One manifestation of the United States' lack of a coherent SNF strategy is the lack of standardization of SNF containers. In 1992, the US Secretary of Energy promised the rapid development of a standardized container for SNF assemblies. In 2005, DOE announced that most of the SNF sent to the proposed Yucca Mountain repository would be delivered to the site "in standard canisters which are then placed in a waste package for emplacement, without handling individual fuel canisters". That arrangement would replace a previously-envisioned process in which SNF would be re-packaged after delivery to Yucca Mountain.[22]

Neither promise was fulfilled. There is no standardization of SNF containers. Table III-1 illustrates the extent to which present SNF containers are non-standardized and are incompatible with the disposal packages that were proposed for emplacement in the Yucca Mountain repository.

Most containers used for dry storage of SNF in the United States are similar to the two examples described in Table III-1. A typical SNF container has a comparatively large capacity for holding SNF assemblies, and a thin wall. Clearly, these containers were designed to minimize licensees' short-term expenditures on SNF storage. They were not designed to:

(i) maximize container lifetime;
(ii) be highly robust during transportation or storage;
(iii) facilitate monitoring of container integrity or the condition of SNF inside a container; or
(iv) be suitable for direct emplacement in a repository.

A coherent national strategy for managing SNF would strive to correct and/or offset these deficiencies in design. The strategy would take a long-term approach to all aspects of SNF management, including each phase of storage, transport, and disposal. An important expression of that approach would be the early establishment of capability to repackage SNF, including damaged SNF. That capability could be provided by a DTS or equivalent system.

If a coherent national strategy included the establishment of a consolidated-storage ISFSI, the strategy would also include the pro-active deployment of a DTS or equivalent system at that ISFSI. Successful testing of that DTS or equivalent system, using actual damaged SNF, would be a licensing precondition for receipt of SNF at the ISFSI.

As stated above, a coherent national strategy for managing SNF would take a long-term approach to all aspects of SNF management. In that context, the "long term" for an ISFSI could extend for centuries. Every ISFSI would be designed with that temporal perspective in mind. The design of an ISFSI would involve balanced consideration of

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[22] Thompson, 2006, Section V.

three types of risk: (i) program risks; (ii) radiological risks; and (iii) proliferation risks. Among the program risks would be the potential for the ISFSI to become a "repository by default". In a 2018 report, I have discussed these design considerations in the context of storing SNF at the Pickering site in Ontario.[23]

IV. Potential Adverse Impacts of ISFSIs

(IV-1) A substantial body of analysis and experience shows that operation of an ISFSI, such as the proposed CISF, would create a significant potential for adverse impacts. Some items of information pertaining to that potential are discussed here.

(IV-2) NRC's GEIS summarizes findings from two studies that estimated radiological consequences of potential accidents at an ISFSI.[24] The GEIS says that one study – NUREG-1864 – found that the radiation dose to an individual at a distance less than 1 mile (1.6 km) could be as high as 185 rem (1.85 Sv). The GEIS says that another study – by EPRI – found that the radiation dose to an individual at a distance of 0.25 miles (0.4 km) could be as high as 19.4 rem (0.194 Sv).[25]

The GEIS contends that the probabilities of accidents leading to such doses would be small. In that context, the GEIS says:[26]

> "Therefore, although the consequences would exceed NRC public dose standards contained in 10 CFR Part 20 (e.g., 100-mrem/yr dose limits for members of the public), the likelihood of the event is very low."

In the above-quoted statement, the term "likelihood" refers to an annual probability. That probability would accumulate over time, and an ISFSI could operate for many years, potentially into the indefinite future. Thus, even a comparatively small annual probability of an adverse impact could imply a substantial likelihood of that impact over the operating lifetime of an ISFSI.

(IV-3) One type of scenario for atmospheric release from an SNF container would involve mechanical loading of the container in a manner that creates a comparatively small hole. The loading could arise, for example, from the air blast produced by a nearby explosion, or from the impact of an aircraft or missile. Thus, the scenario could apply to an accident or an attack. If the loading were sufficient to puncture the SNF container, that loading would also shake the SNF assemblies and damage their cladding.

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[23] Thompson, 2018.

[24] NRC, 2014, Section 4.18.2.2.

[25] NRC's GEIS does not state the modes of exposure leading to the individual radiation doses estimated in NUREG-1864 and by EPRI. Presumably, the exposure would include an inhalation component.

[26] NRC, 2014, Section 4.18.2.2.

Table IV-1 addresses the "blowdown" (i.e., escape of helium and other gases) of an SNF container that has been subjected to a loading pulse sufficient to cause a comparatively small hole. The table shows, for example, that if a hole with an equivalent diameter of 2.3 mm were created, radioactive gases and particles released during the blowdown would yield an inhalation dose (CEDE) of 6.3 rem (0.063 Sv) to a person 900 m downwind from the release. Most of that dose would be attributable to release of two-millionths (1.9E-06) of the SNF container's inventory of radioisotopes in the "fines" category.[27] This finding illustrates the hazardous nature of SNF.

(IV-4) NRC's GEIS discusses potential attacks on ISFSIs. In that context, the GEIS discusses analyses done by the NRC Staff for the Diablo Canyon ISFSI. The GEIS quotes findings from those analyses, including the statement:[28]

> "Based on these considerations, the [radiation] dose to the nearest affected resident, from even the most severe plausible threat scenarios – the ground assault and aircraft impact scenarios – would likely be below 5 rem."

I have critiqued the NRC Staff's analyses of potential attacks on the Diablo Canyon ISFSI. I have said, for example:[29]

> "The NRC Staff reluctantly prepared an EA [environmental assessment] that examines the potential for an attack on the Diablo Canyon ISFSI. Most of the analyses and assumptions underlying the EA are secret. However, it is clear that the Staff limited its examination to Type III releases. The Staff may have been misled by the comparatively dramatic appearance of the attack scenarios associated with Type III releases, leading to the false conclusion that Type IV releases would yield comparatively small environmental impacts."

Table IV-2 explains the types of atmospheric release that I refer to in the above-quoted statement. At an ISFSI, a Type IV release could take the form of a "cask fire", which I discuss below.

A 2003 paper by German experts – Pretzsch and Maier – provides a perspective that differs from the NRC Staff's analyses of potential attacks on the Diablo Canyon ISFSI.[30] Two manifestations of these differing perspectives are especially relevant here. First, Pretzsch and Maier show that technical analysis regarding potential attacks on ISFSIs can be openly published without assisting potential attackers. By contrast, the NRC Staff's analyses were secret. Second, Pretzsch and Maier show how radiation dose to an

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[27] The overall release fraction would be the product of the Fuel Release Fraction, the MPC Blowdown Fraction, and the MPC Escape Fraction.
[28] NRC, 2014, Section 4.19.2.
[29] Thompson, 2009, Section 7.5.
[30] Pretzsch and Maier, 2003.

exposed individual could vary by distance. By contrast, the NRC Staff hid that information.

Pretzsch and Maier consider a Type III release, involving an attack on an SNF container using a comparatively small shaped charge. They estimate the conditional probability of a downwind individual experiencing a given level of inhalation dose at a given distance. They find, for example, that an individual at a distance of 500 m would have a 2% conditional probability of experiencing an inhalation dose of 30 rem (0.3 Sv). Distances up to 5 km are considered.

(IV-5) As mentioned above, a Type IV attack-induced release at an ISFSI could take the form of a "cask fire". That event would involve sustained burning in air of the zircaloy cladding of SNF, causing release from SNF to the atmosphere of radionuclides including cesium-137 (Cs-137). That isotope accounts for most of the offsite radiation exposure attributable to the Chernobyl and Fukushima reactor accidents.

I have discussed the potential for a cask fire in various documents that I have authored.[31] For example, in the Thompson December 2013 declaration, I say:[32]

> "A successful attack on an ISFSI, in which attackers expended an effort roughly the same as the effort needed to successfully attack a spent-fuel pool and cause a pool fire, could cause a cask fire in one or perhaps two casks. For illustration, let us assume that two casks would experience a fire and the fractional release of Cs-137 to the atmosphere would be 50%. In that case, the total atmospheric release from two typical casks holding 32 PWR fuel assemblies per cask would contain 67 PBq of Cs-137. That would be a substantial release [of Cs-137], with a magnitude between the Fukushima release (36 PBq) and the Chernobyl release (85 PBq), as shown in Table V-1."

(IV-6) As discussed in Section III, above, the Yucca Mountain EIS provides estimates of adverse impacts arising in No-Action Scenario 2, which would involve continued storage of SNF in the absence of institutional controls.[33] Those estimates were made on a US-wide basis. Similar estimates could be made for specific ISFSIs, such as the proposed CISF.

(IV-7) NRC's GEIS acknowledges that SNF assemblies could be removed from an ISFSI for the purpose of extracting plutonium for use in nuclear weapons. In that context, the GEIS says:[34]

> "In general, the potential for theft or diversion of light water reactor spent fuel

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[31] See, for example: Thompson, 2009, Sections 6 and 7.
[32] Thompson, 2013, paragraph XI-10.
[33] DOE, 2002, Section 7.2.2.
[34] NRC, 2014, Section 4.19.2.

> from the ISFSI with the intent of using the contained special nuclear material for nuclear explosives is not considered credible because of (1) the inherent protection afforded by the massive reinforced concrete storage module and the steel storage canister; (2) the unattractive form of the contained special nuclear material, which is not readily separable from the radioactive fission products; and (3) the immediate hazard posed by the high radiation levels of the spent fuel to persons not provided radiation protection (NRC 1991c, 1992)."

The GEIS concedes that the "radiation barrier" surrounding SNF would decline over time. In that context, the GEIS says:[35]

> "Thus, additional security requirements may be necessary in the future if spent fuel remains in storage for a substantial period of time. Under those circumstances, it is reasonable to assume that, if necessary, the NRC will issue orders or enhance its regulatory requirements for ISFSI and DTS security, as appropriate, to ensure adequate protection of public health and safety and the common defense and security."

The above-quoted statement assumes the continuation of institutional controls. Yet, those controls could fade away at some future time. DOE considered that situation in the Yucca Mountain EIS.

Similar arguments can be made regarding the removal of SNF assemblies, and/or components of SNF assemblies, from an ISFSI for the purpose of constructing radiological weapons. One difference in this case is that the radionuclides responsible for SNF's radiation barrier would be sought after by malevolent actors, for use in radiological weapons.

In the absence of institutional controls, SNF containers, and the concrete overpacks or structures that surround these containers during storage, would be comparatively minor obstacles to well-equipped groups seeking to remove SNF assemblies, and/or components of SNF assemblies, from an ISFSI.

The effectiveness of the radiation barrier surrounding SNF could be partially offset by makeshift shielding, tools, and procedures. In that way, the radiation doses to intruders could be kept below levels that would cause mortality or disabling morbidity in the short term. Experience in the modern world, where suicide attacks have become routine, suggests that sufficiently-skilled intruders could be recruited to work under these conditions.

(IV-8) Development of a coherent national strategy for managing SNF would necessarily involve the systematic identification and analysis of: (i) potential modes of attack on SNF facilities or transport operations; and (ii) options for reducing the likelihood and/or

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[35] NRC, 2014, Section 4.19.2.

consequences of attack. Productive analyses of these matters can be conducted in the public domain, without access to secret information or public disclosure of information that would assist an attacker. I have participated in analyses of this kind, conducted by the Committee on Radioactive Waste Management (CoRWM), an advisory body created by, and responsible to, the UK government. These analyses are illustrated by a 2005 report that I prepared as a consultant to CoRWM.[36]

V. Potential Future Operating Environments for ISFSIs

(V-1) NRC's GEIS concedes that SNF could remain in interim storage for the indefinite future. Holtec's ER assumes (at page 1-1) that SNF could be stored at the proposed CISF for about 120 years (i.e., until about 2140). Given such a potential for long periods of ISFSI operation, it is important to consider the operating environments that ISFSIs could face in the future.

(V-2) Climate change will expose the proposed CISF, if it is established, to an operating environment that changes over time. A credible compendium of present knowledge about future climate change in the United States is a 2017 report by the US Global Change Research Program (GCRP).[37]

One of the key findings in the GCRP report is:[38]

> "The frequency and intensity of heavy precipitation events are projected to continue to increase over the 21st century (*high confidence*)."

A more detailed finding about heavy precipitation events is as follows:[39]

> "*Heavy Precipitation Events*
> Studies project that the observed increase in heavy precipitation events will continue in the future (e.g. Janssen et al. 2014, 2016). Similar to observed changes, increases are expected in all regions [of the USA], even those regions where total precipitation is projected to decline, such as the southwestern United States. Under the higher scenario (RCP8.5) the number of extreme events (exceeding a 5-year return period) increases by two to three times the historical average in every region (Figure 7.6) by the end of the 21st century, with the largest increases in the Northeast."

The extent of future climate change will be heavily affected by the magnitude of humanity's collective emissions of greenhouse gases over the coming decades.

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[36] Thompson, 2005.

[37] US Global Change Research Program, 2017.

[38] US Global Change Research Program, 2017, Chapter 7, page 207.

[39] US Global Change Research Program, 2017, Section 7.2.2, page 218.

Substantial change is inevitable, however, even if national governments initiate serious programs of emissions reductions.

For any trajectory of future greenhouse-gas emissions, but especially for high-emissions trajectories, estimates of future climate change will be accompanied by uncertainty. On this subject, the GCRP report says:[40]

> "While climate models incorporate important climate processes that can be well quantified, they do not include all of the processes that can contribute to feedbacks, compound extreme events, and abrupt and/or irreversible changes. For this reason, future changes outside the range projected by climate models cannot be ruled out (*very high confidence*). Moreover, the systematic tendency of climate models to underestimate temperature change during warm paleoclimates suggests that climate models are more likely to underestimate than to overestimate the amount of long-term future change (*medium confidence*)."

(V-3) Climate change is just one manifestation of the stresses that humanity is placing on Earth's biosphere. Scientists studying these stresses argue that we must change our practices if human civilization is to be sustainable. For example, a group of scientists examining the "safe operating space for humanity" has said: [41]

> "The exponential growth of human activities is raising concern that further pressure on the Earth System could destabilize critical biophysical systems and trigger abrupt or irreversible environmental changes that would be deleterious or even catastrophic for human well-being. This is a profound dilemma because the predominant paradigm of social and economic development remains largely oblivious to the risk of human-induced environmental disasters at continental to planetary scales."

(V-4) As natural-resource constraints tighten over the coming decades, humanity will face a growing challenge.[42] Continued pursuit of the currently predominant economic paradigm would degrade our life-support systems, widen gaps between rich and poor, and promote conflict within and between nations, potentially leading to a retrograde civilization that has been dubbed "Fortress World".[43]

(V-5) Humanity could correct its present course, and pursue practices that lead to a peaceful, prosperous future through the 21st century and beyond. It would, however, be imprudent to assume such a favorable outcome when designing an ISFSI such as the proposed CISF. Instead, the ISFSI should be designed to accommodate a future that

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[40] US Global Change Research Program, 2017, Chapter 15, page 411.
[41] Rockstrom et al, 2009.
[42] Laybourn-Langton et al, 2019.
[43] Raskin et al, 2002.

involves degradation of societal institutions, increased violence, and reduced technological capability.

VI. History of Nuclear Power: Lessons Regarding the Proposed CISF

(VI-1) The commercial nuclear power industry in the United States began in the 1950s. Other countries also developed nuclear power, and the industry is now global. The history of this industry provides important lessons regarding the proposed CISF. A few highlights of this history, and some of the lessons regarding the proposed CISF, are discussed here. This discussion focuses mostly on light-water reactors and their SNF.

(VI-2) From the beginning, the nuclear power industry has been characterized by optimism about cost, technical performance, and safety. Experience has showed repeatedly that this optimism is unwarranted. A possible response to that experience would have been to slow down, reconsider the prevailing designs, and adopt a precautionary approach to potential hazards. Instead, nuclear vendors, licensees, and regulators have repeatedly ignored or suppressed inconvenient information until forced by events to respond to that information. Even then, their response has typically been reluctant and partial.

(VI-3) One illustration of this behavior is the industry attitude regarding the potential for a reactor-core-melt event. That attitude is addressed, among other matters, in two books published in the early 1980s. One book is by David Okrent.[44] The other is by Daniel Ford.[45]

Okrent and Ford show that reactor vendors and licensees were reluctant to consider core-melt events. Safety regulators exhibited the same behavior. In the United States, regulation was initially done by the Atomic Energy Commission (AEC), and from 1975 onward by NRC. The regulatory position for many years was that core-melt events are "Class 9" events, not considered credible for licensing purposes. NRC began to change that position in 1976, but did so incrementally.[46]

One of the unfortunate results of ignoring core-melt events was that reactor containments were not designed to accommodate such events. Instead, their design was determined by a stylistic loss-of-coolant accident. Until recently, no commercial reactor in the world was equipped with a containment designed to accommodate a core melt or comparable event. That design flaw has led to adverse outcomes, as discussed below.

(VI-4) The core-melt event at the Three Mile Island (TMI) site in 1979 demonstrated that such events are credible. Fortunately, the "large-dry" containment surrounding the affected reactor was not breached directly, although it was not designed to accommodate

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[44] Okrent, 1981.
[45] Ford, 1982.
[46] Okrent, 1981, Chapter 2.

a core melt. However, containment breach did occur during the core-melt event at Chernobyl in 1986 and the three core-melt events at Fukushima in 2011, reflecting design flaws in these reactors' containments.

(VI-5) After the TMI event in 1979, NRC took various actions. For example, in 1980 NRC introduced regulations that substantially upgraded off-site emergency planning. Also, NRC mandated numerous changes in the design and operation of existing reactors and reactors under construction. Those changes were costly. If AEC and NRC had adopted a forward-looking, precautionary approach to regulation, instead of responding to events as they occurred, much of that expenditure could have been avoided.

(VI-6) The lack of a forward-looking, precautionary approach to regulation has been accompanied by a tendency of regulators to ignore or suppress inconvenient information. Daniel Ford discusses that tendency as follows:[47]

> "The AEC and the NRC, which was made from it, were able to ignore what they did not wish to believe and were inclined to cover up everything discreditable…………The problems did not go away, of course, merely because they were ignored and have accumulated, uncorrected, in the [nuclear power] plants now operating around the country. In many cases it was difficult to fix them even if anybody wanted to, since many of the most serious problems involve basic design mistakes. Other problems, which could have been corrected – and still could be – remain uncorrected because the cost of fixing them is more than the economically depressed nuclear industry thinks it can afford."

(VI-7) The lack of a precautionary approach to regulation has led to deployment of reactors and other nuclear facilities that are vulnerable to a variety of foreseeable threats, including accidents and attacks. Nuclear vendors, licensees, and regulators have developed arguments to support continuation of this deployment. One argument is that adverse outcomes have low probability. An analytic art known as probabilistic risk assessment (PRA) has been developed to support that argument.

Experience shows, however, that PRA findings, while valuable for certain, limited purposes, do not constitute a complete, objective assessment of risk. For example, credible retrospective investigations of the core-melt events at TMI, Chernobyl, and Fukushima have identified dominant risk factors that were not susceptible to PRA analysis. These factors included deep-rooted, systemic deficiencies in the responsible organizations.[48]

(VI-8) My professional experience has involved me in various issues where PRA findings, or subjective judgments of probability, have been used to block or delay actions

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[47] Ford, 1982, page 237.

[48] Thompson, 2014, Section 5.1.

that would protect the public. One such issue is the potential for a "fire" in a densely-packed SNF pool if water were lost from the pool.

In the period 1978-1979 I served on an international team of experts advising the government of Lower Saxony, a German province, regarding the licensing of a proposed nuclear complex at Gorleben. The complex would have included six densely-packed SNF pools. I identified a potential for a fire in one or more of these pools, identified lower-risk options for storing SNF, and presented my findings to the Lower Saxony government. In May 1979 the government issued a ruling denying a license for the proposed complex. The ruling stated that one reason for the government's denial of a license was that the potential for an SNF pool fire was unacceptable. Subsequently, all German facilities for apart-from-reactor storage of SNF have employed dry storage.

Since that time I have written and contributed to various technical documents, and been involved in various NRC licensing proceedings, regarding the potential for an SNF pool fire in the United States. NRC's GEIS concedes that an SNF pool fire is a credible event, and that its consequences could be large. The GEIS says, however, that the probability of such a fire, whether induced by accident or attack, is low.[49] A practical outcome of that finding is that SNF continues to be stored in densely-packed pools at nuclear power plants across the United States.

I have argued at length that NRC is mistaken in asserting that the probability of an SNF pool fire is low.[50] My arguments are supported by investigations showing that a fire in the SNF pool of Fukushima #1 Unit 4 was narrowly avoided during the Fukushima accidents of 2011. In a 2016 paper, Frank von Hippel and Michael Schoeppner discuss that near-miss event. They say:[51]

> "This article reviews the case of the spent fuel fire that almost happened at Fukushima in March 2011, and shows that, had the wind blown the released radioactivity toward Tokyo, 35 million people might have required relocation."

(VI-9) Unjustified optimism, weak regulation, and the ignoring or suppression of inconvenient information are discussed above. Another prominent aspect of the history of nuclear power is the use of political influence. Ironically, that influence can be counterproductive. I identified such an outcome while preparing a 2008 paper about the US effort, over the period 1957-2007, to develop a repository for SNF and related waste. I concluded that, if the effort to develop a repository did not succeed, the stakeholders most responsible for that outcome would be the nuclear vendors and licensees and the factions in the federal government (e.g., in national laboratories) that favor increased use of nuclear power. My paper says:[52]

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[49] NRC, 2014, Section 4.18.2.1 (Accidents) and Section 4.19.1 (Attacks).
[50] Thompson, 2013.
[51] von Hippel and Schoeppner, 2016, Abstract.
[52] Thompson, 2008.

> "Those stakeholders have been intent on developing a repository, and determined to use their political influence to that end. Through their political influence, the principles underlying the NWPA [Nuclear Waste Policy Act of 1982] have been successively relaxed. Now [in 2008], the Yucca Mountain project and the institutions supporting it lack the credibility that the NWPA sought to create."

(VI-10) Unjustified optimism in the nuclear industry can have substantial consequences. For example, as of August 2018, a total of 108 commercial reactors had been cancelled in the United States prior to or during construction.[53] These cancellations involved large financial loss and a diversion of national effort away from productive activities. Holtec's proposal to establish a CISF should be viewed in light of this experience.

VII. Holtec Responses to RAIs: Accuracy, Credibility, and Wider Implications

(VII-1) Here, I address the accuracy and credibility of Holtec's Responses to selected RAIs. I also address some of the wider implications of Holtec's Responses. The selected RAIs, and Holtec's Responses, are excerpted or quoted in full in paragraph I-8, above. The information set forth in Sections III through VI, above, supports the discussion here.

(VII-2) Holtec's Response to RAI 9-3 says that "no credible normal, off-normal or accident conditions could challenge the integrity of the canister confinement integrity and result in a release of any radioactivity". One could reasonably infer that this statement covers potential attacks. Thus, Holtec asserts that no credible event, whether accident or attack or slow degradation of a canister boundary, could ever release any amount of radioactive material from an SNF canister at the proposed CISF.

This assertion is remarkably optimistic. In the context of accident or attack, this assertion is also inconsistent with statements in NRC's GEIS, as mentioned in paragraphs IV-2 and IV-4, above. The GEIS concedes that a credible accident or attack could release radioactive material, albeit with low probability.

Holtec makes an equivalent assertion in its ER (at Section 4.13.2). Then, the ER (at Section 4.13.3) makes a false claim that Holtec's assertion is consistent with NRC's GEIS and with NUREG-1864, which is cited in the GEIS (see paragraph IV-2, above). The claim is false because Holtec says that the probability of a release is zero, while the GEIS says that this probability is low.

In the context of slow degradation of a canister boundary, Holtec's assertion is inconsistent with DOE's consideration, in the Yucca Mountain EIS, of a scenario involving loss of institutional control of an ISFSI after about 100 years of service (see paragraph III-3, above). That loss would eventually lead to failure of the boundary of each canister at the ISFSI, resulting in a release of radioactive material.

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[53] NRC, 2018, Appendix D.

(VII-3) NRC's GEIS is itself optimistic about the probability and magnitude of a release of radioactive material from an SNF canister at an ISFSI. For example, the GEIS assumes that the operating environment for an ISFSI will remain stable and benign throughout the indefinite future. As discussed in Section V, above, that assumption is imprudent. It is even imprudent for the storage period – until about 2140 – that is contemplated in Holtec's ER.

Thus, NRC's GEIS carries forward a longstanding tendency of NRC to ignore or suppress inconvenient information (see Section VI, above). That behavior makes NRC an impediment to the development of a coherent national strategy for managing SNF (see Section III, above).

As discussed in paragraph VII-2, above, Holtec compounds NRC's failure to consider inconvenient information. Holtec refuses to acknowledge any possibility that radioactive material could be released from an SNF canister. By taking this unreasonable position, Holtec obstructs the development of a coherent national strategy for managing SNF.

(VII-4) The proposed CISF would involve placement of SNF canisters in below-ground cavities. I acknowledge that incorporation of this design feature would reduce the probability of an attack-induced release of radioactive material of a given magnitude, when compared to an above-ground ISFSI using established Holtec technology, if all other factors remained equal.

In the context of attack resistance, a questionable feature of the design of the proposed CISF is that the top lid of each below-ground cavity is, apparently, held in place by gravity. That design feature is implied by a statement in the Holtec SAR (at Section 17.6) that the only bolts employed in the vertical ventilated module (VVM) system are those used to secure the vent flue to the inlet and outlet plenums.

The proposed CISF could be vulnerable to a Type IV attack, as specified in Table IV-2 of this declaration. The outcome of such an attack could be a cask fire, as discussed in paragraph IV-5, above. If the below-ground configuration of the proposed CISF is compared to an above-ground ISFSI using established Holtec technology, induction of a cask fire would be more difficult for the below-ground configuration, although still possible. The difference in difficulty would be lessened if the top lid of the below-ground cavity could be readily removed.

The below-ground configuration of the proposed CISF could adversely affect the performance of the facility in areas of concern other than attack resistance. Two issues are salient. First, water entering the below-ground cavities from above or below could accumulate and contribute to degradation of the external boundaries of SNF canisters. Second, the lack of visible structure above grade level could contribute to the CISF becoming a repository by default (see paragraph III-7, above).

(VII-5) Holtec's Response to RA 17-12 says that salts in the surrounding area are not expected to reach the SNF canisters. Holtec's Response to RA 17-14 says that the cavity enclosure containers (CECs) would be isolated from corrosion agents in the native soil. Both statements exhibit unwarranted optimism, especially in view of foreseeable effects of climate change.

Holtec's SAR says (at Section 6.5.2.6) that the Design Basis Flood for the proposed CISF is 5 inches. The SAR also says (at Section 2.4.3) that the estimated maximum flood would be 4.8 inches. Thus, it appears that the CISF design has a small margin of safety (0.2 inches) regarding flooding of the below-ground cavities.

Holtec's SAR says (at Section 2.6.1) that CISF construction would involve excavation to a depth of 25 feet below grade. Holtec's ER says (at Section 2.2.2.1) that the CISF would store SNF to a total depth of about 22.5 feet. Holtec's SAR says (at Section 2.5) that an onsite well showed water depth of 34 feet below grade. Artesian head was estimated at 50 feet. Water in the well was highly mineralized brine. Thus, the CISF design has a modest margin of safety (11-12 feet) regarding highly mineralized groundwater reaching the elevation of SNF canisters.

It appears that Holtec has not considered climate change. Discussion of meteorology in Holtec's SAR (at Section 2.3) is confined to historical observations. Yet, as discussed in Paragraph V-2, above, effects of climate change at the CISF site are foreseeable.

The GCRP report predicts substantial increases in the frequency and intensity of heavy precipitation events across the United States. The report notes that such increases are expected even in regions where total precipitation is projected to decline, such as the southwestern United States. Moreover, the GCRP report notes that present climate models probably under-estimate the scale of future climate change.

Thus, over coming decades, the CISF site is likely to experience greater drought, interspersed by episodes of heavy precipitation with increasing frequency and intensity. Episodes of high wind speed could also occur with increasing frequency and intensity.

The expected trend in heavy precipitation could substantially increase the potential for flooding of the below-ground cavities at the proposed CISF, especially in view of the CISF's small margin of safety against flooding. Such flooding might, in principle, be corrected by pumping water out of the cavities. Such correction would rely, however, on continuation of institutional control. Loss of such control is a foreseeable outcome. Moreover, flooding could occur after the accumulation of corrosive particulates – salt dust – in the below-ground cavities. In that event, water would distribute the corrosive material across surfaces including the exterior boundaries of SNF canisters. Removal of that material could be difficult.

Cooling of SNF canisters at the proposed CISF would occur by thermosiphon action, with air intake at about grade level. Corrosive particulates in the local environment could be drawn into the below-ground cavities by the incoming air. Transport of particulates into the cavities could be exacerbated by increased air concentrations of particulates and/or by increased deposition of particulates near the air intakes. Those increases could arise from increased incidence of drought and/or high wind speed, attributable to climate change.

The expected trend in heavy precipitation could substantially increase the level of highly mineralized groundwater at the CISF site, episodically or permanently, potentially reaching the elevation of SNF canisters. In that event, mineralized groundwater could reach the exterior surfaces of CECs. The resulting corrosion could, over time, allow mineralized groundwater to enter the below-ground cavities and come into contact with SNF canisters.

Holtec's SAR says (at Section 17.11) that corrosion of structural steel (i.e., rebar) embedded in concrete structures would not be a problem at the proposed CISF, because the VVM would contain no rebar. However, Holtec's ER says (at Section 2.2.2.8) that the support foundation pad (SFP) would contain rebar. If mineralized groundwater rose to the level of the SFP, the presence of rebar could exacerbate degradation of the SFP, allowing groundwater access to the exterior surfaces of CECs.

Discussion here shows that Holtec has not properly accounted for mechanisms that could allow corrosive material to reach CECs and/or SNF canisters. In this regard, Holtec's Responses to RA 17-12 and RA 17-14 exhibit unwarranted optimism.

(VII-6) Holtec's Response to RA 17-12 says that Holtec's Aging Management Program (AMP) would conduct inspections of SNF canisters and take corrective actions as necessary. Holtec's Response to RA 17-14 says that inspection of CEC interior surfaces would suffice to detect wall thinning due to corrosion. Holtec's SAR says (at Table 18.6.1) that SNF canisters would be inspected every 5 years, and VVMs – which include CECs – would be inspected every 5 years.

Holtec has withheld important information about its AMP, asserting that this information is proprietary. The information withheld includes Attachment 10 to Holtec's license application letter.[54] Also, much of the content has been removed from Chapter 18 of the non-proprietary version of Holtec's SAR that is available to me. By withholding information of this kind, Holtec obstructs the development of a coherent national strategy for managing SNF.

Partial information available in Holtec's SAR (at Chapter 18 and page xviii) suggests that Holtec's inspection of SNF canisters would rely on visual examination, accelerated coupon testing, and eddy current testing.

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[54] Manzione, 2017.

NRC has, in recent years, recognized the need to inspect SNF canisters at ISFSIs. One manifestation of that recognition is a study done by Pacific Northwest Laboratory for NRC, which yielded a 2013 report.[55] The report identified two options for deploying sensors to inspect SNF canisters that remain within their overpacks. One option would be a flexible wand. The other option would be a robotic crawler.

In a September 2014 presentation, Steve Marschman, of DOE's Idaho National Laboratory, summarized the state of the art of inspecting SNF canisters that remain within their overpacks.[56] Marschman identified three such inspections:

- "EPRI [Electric Power Research Institute] led three examinations (partly funded by DOE); Calvert Cliffs, Hope Creek, Diablo Canyon
- Inspections generally consisted of:
  - Temperature measurements of cask at points inside the annulus between the cask and canister
  - SaltSmart™ measurements in similar locations
  - Dust collection from the cask lid
  - Visual inspection"

Marschman explained that experience with these inspections was unsatisfactory, saying:

> "Conclusion
> - We conclude that we couldn't conclude much about the potential for ClSCC [chloride-induced stress corrosion cracking]
> - We need a better way to gather information from canisters"

DOE sponsored a research project, through its Nuclear Energy University Programs, to help find a better way to gather information from SNF canisters. The project team was led by Cliff Lissenden. The team assumed that SNF canisters would remain within their overpacks. The team succeeded in building a working prototype of a robotic crawler, and described their work in a 2018 report as follows:[57]

> "While the project team met all milestones and exceeded our own expectations in some areas (e.g., sensitivity of LIBS [laser-induced breakdown spectroscopy] to chlorides), there is still room for significant further development. Our goal was to build a working prototype, which was accomplished. However, there is a [sic] still much effort [needed] to transform the working prototype into a reliable product for commercial use."

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[55] Meyer et al, 2013.
[56] Marschman, 2014.
[57] Lissenden et al, presumed 2018, Part III.

The technical challenge of performing this type of robotic inspection is discussed by Sungho Choi and colleagues in a 2018 paper. They say:[58]

> "In addition to a constricted tortuous access path, the vertical guide channels (nominally 50-mm deep, 150-mm wide, and at 214-mm intervals) block access to portions of the circumferential and bottom welds under the channels. Moreover, if the axial weld is located at a channel, it is completely inaccessible. Consequently, this limited accessibility to welds prevents the use of nondestructive inspection (NDI) techniques that rely on point-wise scanning, such as visual testing, eddy current testing, and ultrasonic testing using bulk waves, as much of the welds can be hidden by guide channels. The most appropriate technique would be guided wave ultrasonic testing because it can be considered as a line scan method and can potentially inspect all the welds."

Clearly, this area of research has not matured to the point of developing a reliable, proven system for inspecting SNF canisters at functioning ISFSIs. For example, Lissenden et al's working prototype was not tested on a canister containing actual SNF. Ongoing research, development, and field testing – if properly funded and done with active cooperation by vendors and licensees – might yield a reliable, proven system in about a decade.

The work described above is primarily directed toward inspecting SNF canisters. This work could eventually yield, as a byproduct, a system that uses an internal sensor to detect wall thinning of the exterior surface of a CEC due to corrosion. Such detection is not possible today.

Discussion here shows that Holtec lacks a capability to perform credible inspections of SNF canisters or CECs. In this regard, Holtec's Responses to RA 17-12 and RA 17-14 exhibit unwarranted optimism.

(VII-7) Holtec's Response to RA 17-12 says that Holtec's AMP would conduct inspections of SNF canisters and take corrective actions as necessary. A credible plan for taking such corrective actions should be a precondition for licensing the proposed CISF. Indeed, NRC should require – as a licensing precondition – the articulation of a credible, coherent, long-range plan for responding to foreseeable contingencies affecting the proposed CISF, including emergencies and slowly-developing situations.

Holtec says little about its preparations for contingencies affecting the proposed CISF. Holtec has withheld the CISF Emergency Response Plan, contending that it is proprietary.[59] I see no justification for withholding this Plan.

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[58] Choi et al, 2018.

[59] Manzione, 2017.

Holtec's SAR says (at Section 18.14) that Holtec could deploy "a highly conductive sequestration canister with a gasketed lid that can be used to isolate a leaking [SNF] canister from the environment". This statement suggests that Holtec does not believe its own assertion (see paragraph VII-2, above) that no credible event could ever release any amount of radioactive material from an SNF canister at the proposed CISF.

A sequestration canister of the type described might be an appropriate element of a coherent, long-range plan for responding to foreseeable contingencies. Holtec has not articulated such a plan. The brief, casual mention of a sequestration canister suggests that Holtec is not serious about contingency planning.

(VII-8) Holtec's Response to RAI LA-1 says that an SNF canister arriving at the site, and found to be leaking, would be held onsite in a transportation cask for an indeterminate time period and then sent somewhere else.

An underlying assumption is that the leakage would be small and the canister largely intact. That assumption allows Holtec to imagine a process in which the canister is received, tested, repackaged, stored, shipped, and received somewhere else without any difficulty. Yet, Holtec's ER (at Section 1.0) envisions receipt of 10,000 canisters of SNF at the proposed CISF. Holtec's assumption that none of these canisters exhibits substantial damage or leakage is highly optimistic.

Holtec's position on this matter is troubling on two counts. First, the position reflects unwarranted optimism about canister damage, as mentioned above. Second, the position suggests that Holtec accepts no responsibility for what happens to SNF at any location other than the site of the proposed CISF. (Other ISFSIs using Holtec technology might be partial exceptions.)

In a coherent national strategy for managing SNF, the entities and facilities involved in the strategy would function synergistically, seeking to enhance the general welfare and support the common defense and security (see paragraph I-9, above). For example, an ISFSI providing consolidated storage would have responsibilities related to shipment of SNF to its location. One manifestation of those responsibilities would be the establishment of an onsite DTS that could handle SNF canisters damaged en route to the site, and those damaged at the site. Holtec seems to be oblivious to such responsibilities.

VIII. Conclusions

(VIII-1) Holtec asserts that no credible event, whether accident or attack or slow degradation of a canister boundary, could ever release any amount of radioactive material from an SNF canister at the proposed CISF. This assertion exhibits unwarranted optimism. Also, this assertion is inconsistent with findings in NRC's GEIS and in DOE's Yucca Mountain EIS. Moreover, by taking this unreasonable position, Holtec obstructs the development of a coherent national strategy for managing SNF.

(VIII-2) Below-ground placement of SNF canisters at the proposed CISF would reduce the probability of an attack-induced release of radioactive material of a given magnitude, when compared to an above-ground ISFSI using established Holtec technology, if all other factors remained equal. However, below-ground placement could have adverse effects in other respects.

(VIII-3) Holtec states that corrosive material on the surface or below ground, in the vicinity of the proposed CISF, is not expected to reach SNF canisters or CECs. This statement exhibits unwarranted optimism, especially in view of foreseeable effects of climate change. Holtec has not considered climate change.

(VIII-4) Holtec asserts that it can perform credible, in situ inspections of SNF canisters and CEC interior surfaces. This assertion exhibits unwarranted optimism. Proven technology for performing credible inspections of this kind is not yet available.

(VIII-5) Holtec has not articulated a coherent, long-range plan for responding to foreseeable contingencies affecting the proposed CISF, including emergencies and slowly-developing situations. Such a plan should be a precondition for licensing the facility.

(VIII-6) Holtec states that an SNF canister arriving at the proposed CISF, and found to be leaking, would be held onsite in a transportation cask for an indeterminate time period and then sent somewhere else. This statement exhibits unwarranted optimism about the extent of damage to SNF canisters. Also, this statement suggests that Holtec does not accept the nation-wide responsibilities that would arise from establishment of the proposed CISF.

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I declare, under penalty of perjury, that the facts set forth in the foregoing narrative, and in the two appendices below, are true and correct to the best of my knowledge and belief, and that the opinions expressed therein are based on my best professional judgment.

Executed on 12 February 2019.

G. R. Thompson

Gordon R. Thompson

APPENDIX A: Tables

List of Tables

Table III-1
Characteristics of BWR-Spent-Fuel Storage Canisters or Disposal Packages Proposed for Use at the Monticello or Skull Valley ISFSIs, or at Yucca Mountain

Category	**Characteristics of Storage Canister or Disposal package**		
	NUHOMS 61BT storage canister (proposed for the Monticello ISFSI)	**HI-STORM 100 MPC-68 storage canister (proposed for the Skull Valley ISFSI)**	**Proposed disposal package for emplacement in Yucca Mountain**
Vendor	Transnuclear West	Holtec	Unknown
Capacity (number of BWR fuel assemblies)	61	68	24 or 44
Wall thickness	0.5 in. (stainless steel)	0.5 in. (stainless steel)	2.0 in. (stainless steel) plus 0.8 in. outer layer (Alloy 22)
Length	196.0 in.	190.3 in.	201.0 in. (for 24 assemblies) or 203.3 in. (for 44 assemblies)
Diameter	67.2 in.	68.4 in.	51.9 in. (for 24 assemblies) or 65.9 in. (for 44 assemblies)
Neutron absorber material	Boral	Boral	Borated stainless steel
Fill gas	Helium	Helium	Helium
Presence of aluminum thermal shunts to transfer interior heat to wall of vessel ?	No	No	No for 24 assemblies, Yes for 44 assemblies

Notes:
(a) NUHOMS data are from: Xcel Energy's Application to the Minnesota PUC for a Certificate of Need to Establish an ISFSI at the Monticello Generating Plant, 18 January 2005, Section 3.7; and Transnuclear West's FSAR for the Standardized NUHOMS system, Revision 6, non-proprietary version, October 2001.
(b) HI-STORM data are from Holtec's FSAR for the HI-STORM 100 system, Holtec Report HI-2002444, Revision 1.
(c) Characteristics of the Yucca Mountain package are from the Yucca Mountain Science and Engineering Report, DOE/RW-0539, May 2001, Section 3.
(d) This table reproduces Table V-4 of: Thompson, 2006.

Table IV-1
Estimated Atmospheric Release of Radioactive Material and Downwind Inhalation Dose for Blowdown of the MPC in a Spent-Fuel-Storage Module

Indicator		**MPC Leakage Area**		
		4 sq. mm (equiv. dia. = 2.3 mm)	**100 sq. mm (equiv. dia. = 11 mm)**	**1,000 sq. mm (equiv. dia. = 36 mm)**
Fuel Release Fraction	**Gases**	3.0E-01	3.0E-01	3.0E-01
	Crud	1.0E+00	1.0E+00	1.0E+00
	Volatiles	2.0E-04	2.0E-04	2.0E-04
	Fines	3.0E-05	3.0E-05	3.0E-05
MPC Blowdown Fraction		9.0E-01	9.0E-01	9.0E-01
MPC Escape Fraction	**Gases**	1.0E+00	1.0E+00	1.0E+00
	Crud	7.0E-02	5.0E-01	8.0E-01
	Volatiles	4.0E-03	3.0E-01	6.0E-01
	Fines	7.0E-02	5.0E-01	8.0E-01
Inhalation Dose (CEDE) to a Person at a Distance of 900 m		6.3 rem	48 rem	79 rem

Notes:

(a) Estimates are from: Gordon Thompson, *Estimated Downwind Inhalation Dose for Blowdown of the MPC in a Spent Fuel Storage Module*, IRSS, June 2007.
(b) The assumed multi-purpose canister (MPC) contains 24 PWR spent fuel assemblies with a burnup of 40 MWt-days per kgU, aged 10 years after discharge.
(c) The following radioisotopes were considered: Gases (H-3, I-129, Kr-85); Crud (Co-60); Volatiles (Sr-90, Ru-106, Cs-134, Cs-137); Fines (Y-90 and 22 other isotopes).
(d) The calculation followed NRC guidance for calculating radiation dose from a design-basis accident, except that the MPC Escape Fraction was drawn from a study by Sandia National Laboratories that used the MELCOR code package.
(e) CEDE = committed effective dose equivalent. In this scenario, CEDE makes up most of the total dose (TEDE) and is a sufficient approximation to it.
(f) The overall fractional release of a radioisotope from fuel to atmosphere is the product of Fuel Release Fraction, MPC Blowdown Fraction, and MPC Escape Fraction.
(g) For a leakage area of 4 square mm, the overall fractional release is: Gases (0.27); Crud (0.063); Volatiles (7.2E-07); Fines (1.9E-06). Fines account for 95 percent of CEDE, and Crud accounts for 4 percent.
(h) This table reproduces Table 6-1 of: Thompson, 2009.

Table IV-2
Types of Atmospheric Release from a Spent-Fuel-Storage Module at an ISFSI as a Result of a Potential Attack

Type of Event	Module Behavior	Relevant Instruments and Modes of Attack	Characteristics of Atmospheric Release
Type I: Vaporization	• Entire module is vaporized	• Module is within the fireball of a nuclear-weapon explosion	• Radioactive content of module is lofted into the atmosphere and amplifies fallout from nuc. explosion
Type II: Rupture and Dispersal (Large)	• MPC and overpack are broken open • Fuel is dislodged from MPC and broken apart • Some ignition of zircaloy fuel cladding may occur, without sustained combustion	• Aerial bombing • Artillery, rockets, etc. • Effects of blast etc. outside the fireball of a nuclear weapon explosion	• Solid pieces of various sizes are scattered in vicinity • Gases and small particles form an aerial plume that travels downwind • Some release of volatile species (esp. cesium-137) if incendiary effects occur
Type III: Rupture and Dispersal (Small)	• MPC and overpack are ruptured but retain basic shape • Fuel is damaged but most rods retain basic shape • No combustion inside MPC	• Vehicle bomb • Impact by commercial aircraft • Perforation by shaped charge	• Scattering and plume formation as for Type II event, but involving smaller amounts of material • Little release of volatile species
Type IV: Rupture and Combustion	• MPC is ruptured, allowing air ingress and egress • Zircaloy fuel cladding is ignited and combustion propagates within the MPC	• Missiles with tandem warheads • Close-up use of shaped charges and incendiary devices • Thermic lance • Removal of overpack lid	• Scattering and plume formation as for Type III event • Substantial release of volatile species, exceeding amounts for Type II release

Note: This table reproduces Table 7-8 of: Thompson, 2009.

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