From: "David Henkin" <dhenkin@earthjustice.org>
To: <NRCREP@nrc.gov>
Date: Fri, Feb 9, 2007 4:10 AM
Subject: Docket 030-36974

Here are Earthjustice's comments, with select enclosures, on behalf of Concerned Citizens of Honolulu re: the Draft Environmental Assessment and Finding of No Significant Impact for Proposed Pa'ina Hawaii, LLC Irradiator in Honolulu, Hawaii. A hard copy of our comments, with a complete set of enclosures, has been sent by priority U.S. mail.

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February 8, 2007

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Re: Docket No. 030-36974
Draft Environmental Assessment and Finding of No Significant Impact for Proposed Pa'ina Hawaii, LLC Irradiator in Honolulu, Hawaii

To Whom It May Concern:

Earthjustice submits these comments on behalf of the Concerned Citizens of Honolulu in response to the Nuclear Regulatory Commission's ("NRC's") December 28, 2006 request for comment on the Draft Environmental Assessment and Finding of No Significant Impact for Proposed Pa'ina Hawaii, LLC Irradiator in Honolulu, Hawaii ("DEA"). See 71 Fed. Reg. 78,231 (Dec. 28, 2006). In preparing these comments, Earthjustice was assisted by Drs. George Pararas-Carayannis, Marvin Resnikoff, Mete Sozen, and Christoph Hoffmann, who prepared separate reports critiquing aspects of the DEA and the Draft Topical Report on the Effects of Potential Natural Phenomena and Aviation Accidents at the Proposed Pa'ina Hawaii, LLC, Irradiator Facility ("Draft Topical Report") within their respective areas of expertise. We have enclosed copies of these reports, together with resumes from the report preparers. In addition, we have enclosed declarations from Drs. Gordon Thompson and William Au, which were previously submitted in the Pa'ina proceeding, addressing potential impacts associated with the proposed irradiator the DEA failed entirely to consider: the risk of terrorist attack and the potential health impacts associated with human consumption of irradiated food.

For the following reasons, the DEA falls far short of the basic requirements of the National Environmental Policy Act ("NEPA"), contravening the statute's mandates to "insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken" and "to help public officials make decisions that are based on understanding of environmental consequences." 40 C.F.R. § 1500.1(a), (b) (emphasis added).

Failure to Disclose Basis of Conclusions

The DEA's cursory discussion of the potential environmental impacts associated with Pa'ina's proposed irradiator fails to satisfy NEPA's mandate to take a "hard look" at environmental consequences. Ocean Advocates v. U.S. Army Corps of Engineers, 402 F.3d 846, 864 (2005). The DEA devotes less than four pages to potential impacts, in which it offers nothing more than "generalized conclusory statements that the effects are not significant." Klamath-Siskiyou Wildlands Center v. Bureau of Land Management, 387 F.3d 989, 996 (9th Cir. 2004). Specifically, the DEA fails to provide:

- Any discussion of the public and occupational health regulatory standards that apply to the irradiator (DEA at 7);
- Any calculations, analysis or data substantiating its claim "the maximum dose at the pool surface would be well below 1 mrem/hour" (Id.);
- Any calculations, analysis or data substantiating its claim "it is improbable that an employee could receive more than the occupational dose limit" or discussion or quantification of what it means by "improbable" (Id.);
- Any calculations, analysis or data regarding its analysis of "expected dose rate" inside and outside the irradiator (Id.);
- Any calculations, analysis or data substantiating its claim "it is unlikely that a member of the public could receive more than the public limit" or discussion or quantification of what it means by "unlikely" (Id. at 8);
- Any calculations, analysis or data substantiating its claim "[t]ransportation impacts from normal operations would be small" or discussion or quantification of what it means by "small" (Id.);
- Any calculations, analysis or data substantiating its claim "[t]he proposed irradiator would potentially have small beneficial impacts to socioeconomics" or discussion or quantification of what it means by "small" (Id.);
- Any calculations, analysis or data substantiating its claim "the probability of an aircraft crash into the proposed facility is 2.1×10^{-4}" (Id.);
- Any discussion or quantification of the "significant forces" the Co-60 sources are allegedly tested to withstand (Id. at 9);
- Any calculations, analysis or data substantiating its claim "[i]t is highly unlikely that a Co-60 sealed source would be breached in the event that an aircraft crashes into the proposed facility" or discussion or quantification of what it means by "highly unlikely" (Id.);
- Any calculations, analysis or data substantiating its claim "a seismically-induced radiological accident is considered negligible" (Id.);
- Any calculations, analysis or data used in the stylized fluid dynamic calculations that purportedly quantify tsunami and hurricane risk (Id. at 9-10);
- Any calculations, analysis or data quantifying hurricane storm surge risk (Id. at 10).

Even if the statements in the DEA represent the conclusions of agency experts, it is well-established that "NEPA documents are inadequate if they contain only narratives of expert opinions." Klamath-Siskiyou Wildlands Center, 387 F.3d at 996. Because public scrutiny of an agency's analysis is vital to accomplishing NEPA's goals, "NEPA requires that the public receive the underlying environmental data from which [the NRC's experts] derived [their] opinion[s]." Idaho Sporting Cong. v. Thomas, 137 F.3d 1146, 1150 (9th Cir. 1998). The DEA fails to comply with this mandate.

The DEA's constant refrain that potential impacts are "described in more detail in the Safety Topical Report (CNWRA, 2006)" and its citations to documents in internal agency files do not remedy this fatal flaw. DEA at 8-10. The data and analysis that purportedly support the DEA's conclusions must be contained in the DEA itself. See Idaho Sporting Cong., 137 F.3d at 1150-51. The NRC cannot legally force the public to hunt down various documents to verify the accuracy of – or unearth the flaws in – the DEA's conclusory statements.[1]

Conclusions Based On Inaccurate Factual Contentions And Improper Assumptions

The NRC cannot cure the DEA's shortcomings merely by cutting-and-pasting from the Draft Topical Report. As discussed in detail in the attached expert reports, the Draft Topical Report's numerous factual and analytic deficiencies render it fatally flawed to support a valid NEPA analysis. "A patently inaccurate factual contention can never support an agency's determination that a project will have 'no significant impact' on the environment." Ocean Advocates, 402 F.3d at 866. Examples of the flaws in the Draft Topical Report our experts have identified include:

- Inaccurate statements that Honolulu International Airport is above the tsunami evacuation zone, when the State Civil Defense maps show the reef runway and various airport facilities are within the zone of potential tsunami inundation. Notably, the Draft Topical Report fails to recognize that the proposed irradiator site itself is in a tsunami evacuation zone.
- Reliance on inaccurate information provided by the State of Hawai'i's Department of Transportation that "the south shore of O'ahu has never sustained more than a 3 [foot] wave from any tsunami since 1837." Draft Topical Report at 3-4. Contrary to this assertion, the historic runup record shows that a 1946 tsunami reached a maximum runup on O'ahu's southern coast of 31 feet; the O'ahu Tsunami Runup Maps show that the 1957 and 1960 tsunamis had maximum runups of 9 feet along O'ahu's south shore; and three Chilean earthquakes generated tsunamis with runup in Honolulu of over 8 feet in 1837, over 5 feet in 1868, and nearly 5 feet in 1877.
- Improper reliance on tide gauge recordings as evidence of low tsunami runup. Tide gauges filter out short period waves, resulting in substantial underestimates of runup heights.

[1] Notably, while the EA claims the Draft Topical Report contains "more detail" regarding the fluid dynamic calculations to determine impacts from potential tsunami-generated wave run-ups, in fact, the report presents only a summary of the results, with no actual data or calculations. Draft EA at 9; see also Draft Topical Report at 3-4. Thus, even if it were proper to require the public to track down a copy of the report, there would be no meaningful opportunity to critique the NRC's analysis.

- Failure to take into account resonance effects or cumulative pile-up that could occur within Ke'ehi Lagoon and cause higher runup at the proposed Irradiator site than on the open coast.
- Incorrect assumption that hurricane storm waves are less damaging than tsunamis, when in fact, potential hurricane surges could result in longer and more extensive flooding at the site than tsunamis.
- Incorrect assumption that, because Hurricane Iniki's storm surge was measured at under 30 inches at a tide gauge at the end of a pier inside Honolulu Harbor, a hurricane surge could not reach above 30 inches in the future at the proposed site. Tsunami tide gauges do not give accurate or realistic measurements of expected hurricane surge inundation, because they filter out the short-period storm waves that significantly contribute to greater maximum water level heights. This is illustrated by the fact that, along the Wai'anae coast, Iniki's hurricane surge reached the second story of apartment buildings and houses, a height far in excess of 30 inches.
- Failure to consider the proximity of the proposed site to the Ke'ehi Lagoon shoreline and the long fetch of the Keehi Lagoon along which hurricane wind frictional effects could add to other surge height components.
- Substantial underestimate of the likelihood of aviation accidents at the facility, due to the Draft Topical Report's reliance on obsolete data, failure to account for unusually elevated crash rates at Honolulu International Airport and for the fact that landings have a higher crash rate than takeoffs, and use of an unreasonably low number of aircraft operations at the Honolulu airport during the term of Pa'ina's license.
- Incorrect assumption that, even if the pool were breached, infiltrating sea water or groundwater would adequately shield the Co-60 sources. The Draft Topical Report ignores the fact the water table is 2 meters (6.6 feet) below the facility floor, which marks the minimum water level necessary to retain shielding integrity for the Co-60 sources. Thus, any break in the pool lining below the floor level – whether from an aviation accident or natural disaster – could severely reduce shielding, threatening radiation exposure.
- Failure to provide any data or calculations to substantiate its claim the standards set forth in 10 C.F.R. § 36.21 would ensure that Co-60 sources at the Pa'ina irradiator would be robust enough to survive an aviation accident without being breached, including, but not limited to, the failure to calculate the impact and temperatures associated with an airplane crash to compare them with the section 36.21 performance criteria.

Failure To Take A "Hard Look" At Potential Impacts

While the DEA purports to consider impacts from natural disasters, aviation accidents and transportation of sources to and from Pa'ina's irradiator, it fails to analyze many potential consequences, violating NEPA's command to take a "hard look at the effects from proceeding with [the proposed irradiator]." Klamath-Siskiyou Wilderness Center, 387 F.3d at 1001. For example:

- While the DEA mentions (albeit only briefly and without quantification) minor flooding due to hurricane surges, it fails completely to consider potential impacts associated with major flooding. As discussed in Dr. Pararas-Carayannis' report, a maximum probable hurricane could cause flooding of up to 7 feet, and storm surge deposits at the proposed irradiator site confirm that major flooding has happened in the past. Potential hurricane surge heights can be accurately predicted and quantified using mathematical models, yet the NRC has failed to quantify this risk.
- As Dr. Pararas-Carayannis explains, there is a 100% statistical probability that a future major Pacific-wide tsunami will impact the Hawaiian Islands, and the proposed site is in a tsunami zone. The risk of flooding due to a tsunami is a foreseeable impact the DEA improperly ignores. The NRC must either quantify this risk through numerical modeling or, at a minimum, analyze "the range of environmental impacts likely to result in the event" of a major tsunami. San Luis Obispo Mothers for Peace v. Nuclear Regulatory Comm'n, 449 F.3d 1016, 1034 (9th Cir. 2006), cert. denied sub nom, Pacific Gas & Elec. Co. v. San Luis Obispo Mothers for Peace, 75 U.S.L.W. 3365 (U.S. Jan 16, 2007); see also 40 C.F.R. § 1502.22(b). Potential consequences of flooding the NRC must consider include the failure of peripheral equipment, power and back up generators, dispersal of leaking pool water, and grounded aircraft or equipment carried and crushing against the irradiator facility, which could affect the integrity of the pool, draining the water below the minimum level needed to shield the Co-60 sources when the flood waters recede.
- The DEA fails completely to consider the impact on the irradiator pool integrity of increased buoyancy, which can be caused by a temporary rise in sea level due to hurricane surges. The range of consequences that must be analyzed include the risk that increased buoyancy will lift or tilt the irradiator pool, compromising the pool's integrity and/or allowing shielding water to drain into the surrounding environment.
- The DEA fails to analyze the full range of potential impacts from hurricane-force winds, including fires from nearby fuel depots and grounded aircraft or equipment crushing against the Irradiator facility.
- As discussed in expert reports prepared by Drs. Resnikoff, Sozen and Hoffmann, the DEA fails to consider credible scenarios under which an aircraft crash might result in exposures above regulatory limits, including, but not limited to, damage to the irradiator pool structure under the floor level, resulting in a loss of irradiator pool shielding water, and release of water contaminated with radioactive cobalt through a tear in the pool lining, contaminating groundwater and nearby Ke'ehi Lagoon.
- The DEA also ignores the potential consequences should the force of the impact from an air crash into the facility or the ensuing fire and explosion of aviation fuel destroy all monitoring equipment and/or incapacitate irradiator personnel, rendering it impossible to implement necessary emergency procedures to protect emergency responders and the public at large.
- The DEA considers only "[t]ransportation impacts from normal operations," failing to examine the likelihood and consequences of accidents involving transportation of Co-60 sources to and from the proposed irradiator, without which the facility could not function.

Failure To Consider Potential Impacts From Terrorism

The DEA improperly fails to analyze potential threats to the public and the environment associated with Pa'ina's proposal to place a major sabotage target in the middle of urban O'ahu, near to attractive terrorist targets like the international airport, Hickam Air Force Base, and Pearl Harbor (a particularly symbolic target). As recognized by the National Nuclear Security Administration, Co-60 is an attractive target for terrorists because it can be used to make dirty bombs. See April 13, 2005 press release from the National Nuclear Security Administration (enclosed). It is also well-known that, in general, nuclear facilities are potential targets of the Al Qaeda organization. If Co-60 were stolen from the proposed facility and then used in a dirty bomb, or if the facility were directly attacked, Co-60 could be released into the environment, causing adverse health effects and spreading contamination.

Pa'ina seeks a license to store up to a million curies of Co-60 at its irradiator. The Federation of American Scientists ("FAS") has analyzed the effect of a terrorist incident involving a much smaller quantity of Co-60, only 17,000 curies. See Public Interest Report, vol. 58, No. 2, March/April 2002 (enclosed). The FAS report estimates that, if a single Co-60 "pencil" were dispersed by an explosion at the lower tip of Manhattan, an area of approximately one-thousand square kilometers would be contaminated, and tens of thousands of New York City residents could die. Similarly disastrous consequences would occur in Hawai'i in the event of dispersal of Co-60 from Pa'ina's proposed irradiator.

The DEA assumes that Co-60 sources would be shipped to Pa'ina's facility approximately once per year. Such sources, in transit from Canada or Russia to the Pa'ina Hawaii plant, would not be well-protected from a terrorist attack. The NRC does not require armed escorts for Co-60 sources, and potential saboteurs have significant fire power at their disposal. The TOW2 and MILAN anti-tank missiles have a range of one kilometer or more and can penetrate one meter of steel, far more steel and lead than the walls of a shipping cask. The newer Russian Koronet missile, used by former Iraqi armed forces, can penetrate 1.2 meters of steel and can be aimed precisely at a distance up to five kilometers. These weapons have the ability to penetrate a shipping cask and disperse its contents.

A Co-60 cask shipment, attacked within a city, could cause major environmental pollution and cancer fatalities. Local residents would clearly have a greater risk than other persons. While shipments could leave Canada or Europe by a number of routes, once they get close to the facility, the route options are decidedly limited. Such an accident would subject the airport passengers and workers and residents of neighboring communities to irreparable harm. In addition to adverse health effects caused by contamination, such an accident would have significant economic impacts, disrupting the major port of entry to the entire state of Hawai'i.

The DEA's complete failure to consider the potential impacts associated with terrorist attacks on Co-60 stored at, or in transit to, the Pa'ina facility is inexcusable. While the NRC historically has refused to analyze terrorist threats in its NEPA documents, the Ninth Circuit Court of Appeals, whose decisions bind NRC activities in Hawai'i, squarely rejected the NRC's policy last year. Consequently, the DEA must analyze "the range of environmental impacts likely to result in the event of a terrorist attack" on the Pa'ina irradiator. San Luis Obispo Mothers for Peace, 449 F.3d at 1034. Even if the NRC cannot precisely quantify the probability of a terrorist attack occurring, it still must "assess likely modes of attack, weapons, and vulnerabilities of the facility, and the possible impact of each of these on the physical environment, including the assessment of various release scenarios." Id. at 1031.

Failure To Discuss Impacts Associated With Irradiating Food For Human Consumption

The DEA's failure to consider potential adverse affects on human health associated with irradiating food for human consumption also violates NEPA. As discussed in the enclosed declaration of Dr. William Au, a recently-discovered unique class of radiolytic products that are generated from the irradiation of fat-containing food is 2-alkylcyclobutanone ("2-ACB") with saturated and mono-unsaturated alkyl side chain: 2-decyl-, 2-dodecyl-, 2-dodecenyl-, 2-tetradecyl- and 2-tetradecenyl-cyclobutanone. Studies have confirmed the presence of 2-ACB in irradiated mango and papaya, two types of fruit proposed for processing at the Pa'ina's irradiator, should it be approved.

Since 1998, concern regarding health hazards from the consumption of irradiated food has focused on the toxicity of 2-ACB. Recent studies have demonstrated that 2-ACB compounds, which are found exclusively in irradiated dietary fats, may promote colon carcinogenesis in animals, identifying a new area of toxicity that neither the U.S. Food and Drug Administration nor the World Health Organization has yet examined. These studies indicate that consumption of irradiated food containing 2-ACB, such as the fruit Pa'ina proposes to process, may increase the risk of humans developing colon cancer, which currently causes approximately 60,000 deaths per year in the United States.

There can be no serious dispute that Pa'ina's irradiator "would not be built but for the contemplated" sale of irradiated food for human consumption. Thomas v. Peterson, 753 F.2d 754, 758 (9th Cir. 1985); see also 71 Fed. Reg. at 78,231 ("The irradiator would primarily be used for phytosanitary treatment of fresh fruit and vegetables bound for the mainland from the Hawaiian Islands and similar products being imported to the Hawaiian Islands"). Since the irradiator and the contemplated sale of irradiated food "are inextricably intertwined," they "are 'connected actions' within the meaning of the CEQ regulations," requiring the DEA to analyze potential health impacts. Id. at 759. In addition, the fact the Pa'ina irradiator is intended to increase the supply of irradiated food establishes the requisite "close causal relationship" to trigger the Staff's obligations to analyze potential health impacts in the DEA. See DEA at 6, 8; see also Ocean Advocates, 402 F.3d at 868. The DEA also must assess the potential for cumulatively significant impacts from increasing the supply of irradiated food for human consumption. Ocean Advocates, 402 F.3d at 868-70; see also 40 C.F.R. §§ 1508.25(a)(2), 1508.27(b)(7).

Inadequate Discussion of Alternatives

In enacting NEPA, Congress intended that all federal agencies, including the NRC, would consider in their review of project proposals "choices or alternatives that might be pursued with less environmental harm." Lands Council v. Powell, 395 F.3d 1019, 1027 (9th Cir. 2005). "[C]onsideration of alternatives is critical to the goals of NEPA even where a proposed action does not trigger the [environmental impact statement ("EIS")] process. Bob Marshall Alliance v. Hodel, 852 F.2d 1223, 1228-29 (9th Cir. 1988); see also 40 C.F.R. § 1508.9(b). Agencies must consider "all possible approaches to a particular project ... which would alter the environmental impact and the cost-benefit balance." Id. at 1228 (quoting Calvert Cliffs' Coordinating Comm., Inc. v. United States Atomic Energy Comm'n, 449 F.2d 1109, 1114 (D.C. Cir. 1971)).

"[T]he evaluation of 'alternatives' mandated by NEPA is to be an evaluation of alternative means to accomplish the general goal of an action; it is not an evaluation of the alternative means by which a particular applicant can reach his goals." Van Abbema v. Fornell, 807 F.2d 633, 638 (7th Cir. 1986). Thus, while Pa'ina may prefer to operate a nuclear irradiator and locate it at the airport, the DEA's analysis of alternatives must focus on the general goal of the undertaking: to treat "fresh fruit and vegetables bound for the mainland from the Hawaiian Islands and similar products being imported to the Hawaiian Islands." 71 Fed. Reg. at 78,231. The DEA violates this core requirement, failing to consider reasonable alternatives that would avoid impacts inherently associated with Pa'ina's preferred technology (a Co-60 irradiator) and location (a site subject to aviation accidents and natural disasters).

Initially, the DEA fails adequately to analyze all reasonable alternative quarantine control technologies. While it briefly mentions two alternate methods for controlling fruit flies, methyl bromide gas and heat treatment, its cursory discussion does not "[r]igorously explore and objectively evaluate" the relative environmental costs and benefits of using these technologies in lieu of building and operating a Co-60 irradiator. Morongo Band of Mission Indians v. Federal Aviation Admin., 161 F.3d 569, 575 (9th Cir. 1998) (quoting 40 C.F.R. § 1502.14). The DEA neither "fosters informed decision-making" nor "informed public participation," violating NEPA's basic purpose. Id. (quoting City of Angoon v. Hodel, 803 F.2d 1016, 1020 (9th Cir. 1986); see also 40 C.F.R. § 1500.1(b) ("Accurate scientific analysis, expert agency comments, and public scrutiny are essential to implementing NEPA").

Even more glaring is the DEA's failure to consider the alternative control technology most similar to the one Pa'ina proposes: a facility using electron-beam irradiation instead of Co-60. As the DEA acknowledges, such a facility is currently in operation on Hawai'i Island, performing the identical tasks Pa'ina plans to carry out. DEA at 6. Using a non-nuclear technology would eliminate potential impacts associated with releases of radioactive material and exposure to unshielded sources, and, thus, consideration of such an alternative "would alter the environmental impact and the cost-benefit balance," as NEPA requires. Bob Marshall Alliance, 852 F.2d at 1228. The NRC's failure to consider this reasonable alternative renders its DEA "inadequate." Morongo Band of Mission Indians, 161 F.3d at 575.

The DEA's failure to consider alternate locations for the proposed irradiator further violates NEPA. The DEA's statement of purpose and need emphasizes the importance of "[c]entrally located treatment of products" for export from, and import to, Hawai'i and claims that locating a treatment facility on O'ahu is preferred, since it is "the central hub for air and sea transportation." DEA at 6. Even if limiting alternatives to O'ahu would be reasonable, nothing in the DEA suggests the parcel Pa'ina has selected at the airport is the sole possible location on the island for a treatment facility.[2] To allow the NRC and the public to consider "alternatives that might be pursued with less environmental harm," the DEA was obliged to consider alternate sites. Lands Council, 395 F.3d at 1027.

Had the DEA done so, it would have highlighted the environmental inferiority of Pa'ina's chosen site, as the enclosed expert reports make clear. Sites located inland and away from Ke'ehi Lagoon would eliminate all threat from tsunami runup and hurricane storm surges. Sites on solid ground, rather than unconsolidated fill, would lay to rest concerns about liquefaction during earthquakes. Sites a mere ten miles from Honolulu International Airport's runways would reduce the threat of an airplane accident by a factor of 1,000, placing the yearly crash probably within the limits the NRC generally deems acceptable for nuclear facilities. Moving out of urban Honolulu, away from strategic military bases, and far from Hawai'i's transportation and financial hubs would reduce the risks of terrorist attack. The DEA improperly fails to consider these reasonable alternatives, which would "avoid or minimize adverse effects of [Pa'ina's] actions upon the quality of the human environment." 40 C.F.R. § 1500.2(e).

NEPA's Significance Criteria Trigger The NRC's Obligation To Prepare An EIS

To determine whether Pa'ina's proposed irradiator would have "a significant effect on the environment," the NRC must consider a number of factors, any one of which can trigger the obligation to prepare an EIS. National Parks & Conservation Association v. Babbitt, 241 F.3d 722, 730 (9th Cir. 2001); see also id. at 731; 40 C.F.R. § 1508.27. Among the factors that must be considered are "[t]he degree to which the effects on the quality of the human environment are likely to be highly controversial" or "are highly uncertain or involve unique or unknown risks." 40 C.F.R. § 1508.27(b)(4)-(5).

NEPA requires preparation of an EIS "where uncertainty may be resolved by further collection of data, or where the collection of such data may prevent 'speculation on potential ... effects.'" National Parks & Conservation Association, 241 F.3d at 732 (internal citations omitted). In addition, "[a]gencies must prepare [EISs] whenever a federal action is 'controversial,' that is, when 'substantial questions are raised as to whether a project ... may

[2] At the February 1, 2007 hearing on the DEA, virtually every fruit producer who testified and indicated a desire to use the irradiator came from Hawai'i Island. Since there are many daily flights from airports on Hawai'i Island to the continental United States, reasonable alternatives clearly include locating a second treatment facility on that island, which would save the transportation costs of flying fruit to O'ahu for treatment prior to export.

cause significant degradation of some human environmental factor' or there this 'a substantial dispute [about] the size, nature, or effect of the major Federal action.'" Id. at 736 (internal citations omitted).

The enclosed expert reports make clear that both of these significance factors are present here. An EIS is necessary to gather the data required to resolve existing uncertainties about potential impacts associated with natural disasters, aviation accidents, transportation of Co-60 sources, and terrorist attacks. Moreover, the expert reports reveal substantial disputes with the NRC's consultants over the reasonableness of the agency's preliminary conclusion there would be no significant impacts. Each of these factors independently "necessitates preparation of an EIS." Id. at 731.

We appreciate the opportunity to provide these comments which hopefully will prompt the NRC to satisfy its obligations under NEPA by preparing the required EIS. Please feel free to contact me should you wish to discuss our concerns.

Sincerely,

David Lane Henkin
Staff Attorney

DLH/tt
Enclosures

ANALYSIS OF THE EFFECT OF IMPACT BY AN AIRCRAFT ON A STEEL STRUCTURE SIMILAR TO THE PROPOSED PA'INA IRRADIATOR

Mete A. Sozen and Christoph M. Hoffmann[1]

February 1, 2007

Summary

The numerical analysis generated by LS-DYNA (LSTC2005) indicates that a disastrous accident could occur in the event of an airplane crashing into a steel structure built adjacent to the Honolulu International Airport, similar to the proposed Pa'ina Hawaii nuclear food irradiator. Such an accident would create conditions that could lead to introduction of radioactive Cobalt-60 into the human environment. None of these eventualities was considered by the NRC's EA or Safety Report.

Introduction

This report describes a detailed numerical analysis conducted to investigate the potential for damage from an aircraft striking a steel structure adjacent to active runways at the Honolulu International Airport, similar to the proposed Pa'ina irradiator. The analysis involves modeling in finite elements a realistic aircraft and typical industrial building using LS-DYNA computer code. The use of the finite elements results in spatial discretization, allowing powerful computers to solve engineering problems through the application of complex algorithms, with the result in the form of a 3-dimensional simulation that is faithful to the physics of the collision. LS-DYNA antecedents and derivatives are commonly used in the private sector and government laboratories, including the Nuclear Regulatory Commission (NRC), for analyzing impact effects.

The numerical analysis assumes a typical industrial structure and one of the possible combinations of aircraft type and speeds – a Boeing 767, traveling at 100 mph – that could strike such a structure built near active runways at the Honolulu airport. An overall view of the aircraft and the building is shown below in Figure 1.

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[1] Dr. Mete A. Sozen has been the Purdue University Kettelhut Distinguished Professor of Structural Engineering since 1993. He has assisted in the development of structural criteria for earthquake and fire resistant building design and helped develop the first set of regulations for earthquake-resistant design. Dr. Sozen's current research focuses on vulnerability assessment of building and transportation structures and effects of explosions and high-velocity impact on building structures. He has been retained by numerous private organizations and state and federal agencies, including the NRC, on special projects concerned with structural safety.

Dr. Christoph M. Hoffmann has been a Professor of Computer Science at Purdue since 1989 and is currently the Director of Purdue's Rosen Center for Advanced Computing. Dr. Hoffmann recently spearheaded the effort to simulate and visualize the September 11, 2001 attacks on the Pentagon and the World Trade Center applying the same finite element crash analysis used in the present analysis.

Resumes for Drs. Sozen and Hoffmann are attached. Please note that Drs. Sozen and Hoffman have performed this analysis independently; it is not a Purdue University undertaking.

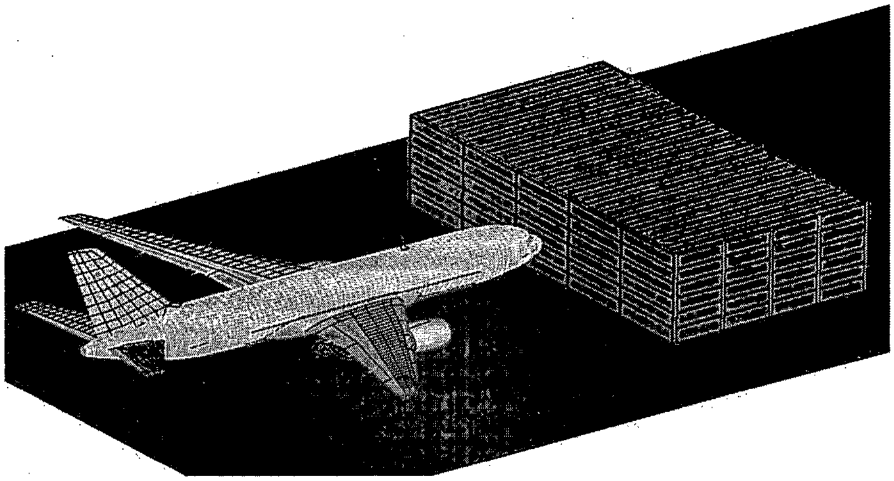

Figure 1. B767 and typical steel industrial structure.

The analysis of the impacts to the structure are considered in reference to the NRC's Draft Environmental Assessment Related to the Proposed Pa'ina Hawaii, LLC Underwater Irradiator in Honolulu, Hawaii (DEA) and the Draft Topical Report on the Effects of Potential Natural Phenomena and Aviation Accidents at the Proposed Pa'ina Hawaii, LLC, Irradiator Facility (Safety Report).

Aircraft Model

The structure of the Boeing 767-200ER aircraft, including dimensions, mass, material, and yield strengths, was modeled in detail based on known aircraft material property information that was obtained from public sources. Figure 2 shows the overall dimensions of the aircraft.

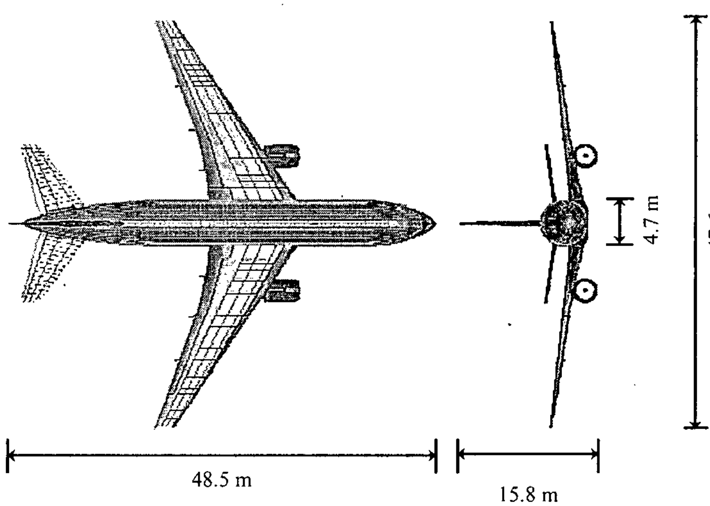

Figure 2. Dimensions of a Boeing 767-200ER.

Approximately 110,000 elements were used to numerically model the solid parts of the aircraft, with a total dry mass of 98 tonnes. The fuel mass totals 30 tonnes and was modeled using approximately 90,000 smoothed particle hydrodynamics (SPH) elements. SPH elements account for the difference in impact effects of solids and fuel. The distribution of the mass along the length of the aircraft is shown in Figure 3.

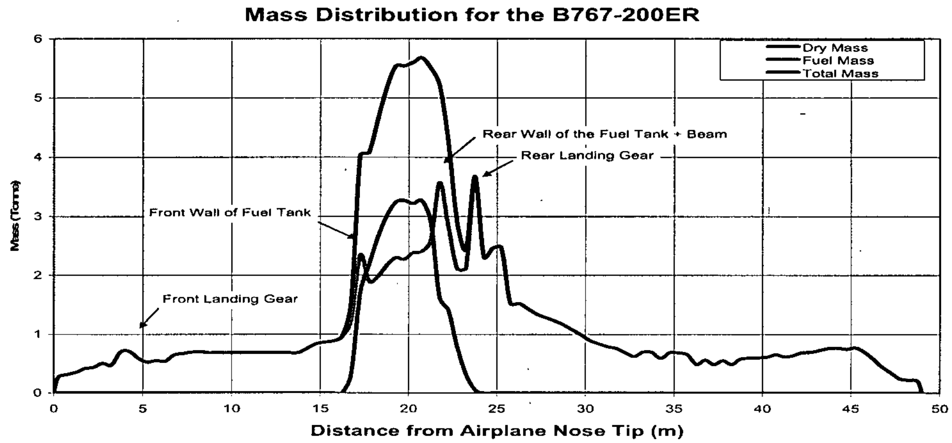

Figure 3. Mass Distribution for a Boeing 767-200ER.

An aluminum material model with yield strength of 380 MPa (55,000 psi) and limiting unit strain of 12% was used for the aluminum parts. For titanium elements, a titanium material model with yield strength of 860 MPa (125,000 psi) and limiting unit strain of 12% was used. Metal sheeting on the surfaces are 3 mm thick and have the same material properties as the main elements.

Structure Model

The structure of the building was modeled as a ductile moment-resisting frame with perfect continuity at the joints and at the bases of the column. Because the actual properties of the building are unknown (due to Pa‘ina's failure to provide construction plans), these conservative assumptions were employed to create a model structure that is stronger than what is likely to be achieved in practice. In other words, the proposed irradiator, if built, would suffer greater damage in the modeled aircraft collision than the structure used in this analysis.

Normal specifications were also assumed. The columns (14WF48) and the girders (12WF40) were modeled as structural steel with a normal yield strength of 345 MPa (~50,000 psi) and a limiting unit strain of 40%. Columns were spaced at 24 feet in the long and 16 feet in the short direction of the structure. Height to the roof was set at 30 feet, and the roof girders were spaced at 6 feet. A total of ~210,000 elements were used in the modeling of the building. The framing is shown in Figure 4.

The irradiator pool is modeled as made of a 1/4-inch stainless steel inner tank connected by welded I-beams to a 1/4-inch carbon steel outer tank, with a 42-inch lip extending above the facility floor. The space between the pool's inner and outer steel tanks is modeled as filled with concrete with a yield strength of 4,000 psi.

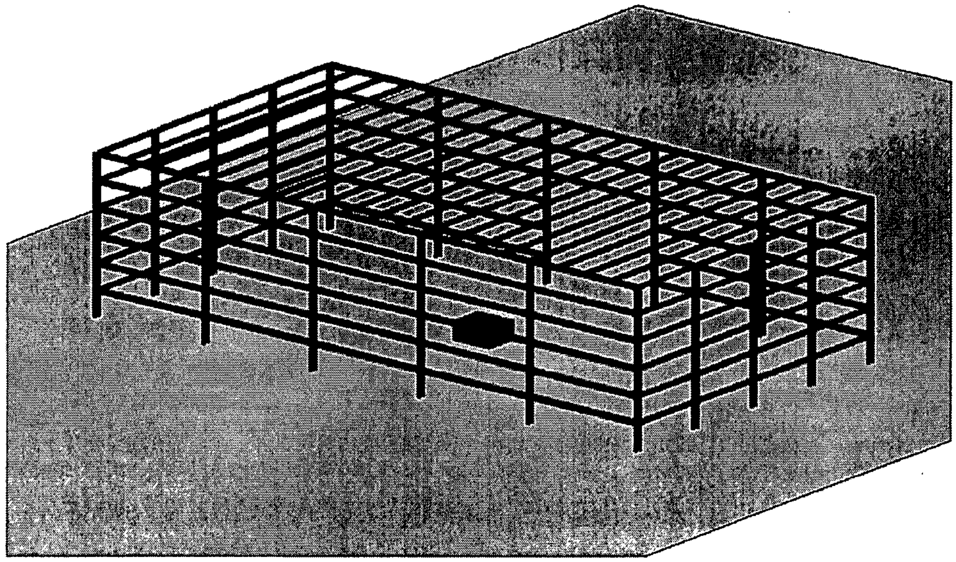

Figure 4. Model framing of steel structure and pool lip.

Impact Simulation Results

Impact simulations were performed using the nonlinear finite-element-based dynamic analysis software LS-DYNA [version 970 r5434a SMP] (LSTC2005) on a multi-processor nano-regatta computer system.

The aircraft was assumed to impact the structure head-on while traveling on the ground at a speed of 100 mph.[2] The "flight path" was assumed to be parallel to the ground and perpendicular to the rear façade of the structure. As depicted in Figure 5, the calculations indicated that the aircraft will crash through the columns and girders of the building. Impact of the structure at any angle would produce similar results.

[2] 100 mph is a conservative assumption for the aircraft speed, because most aviation crashes occur at landing or take-off, and aircraft generally land and take off at speeds exceeding 100 mph.

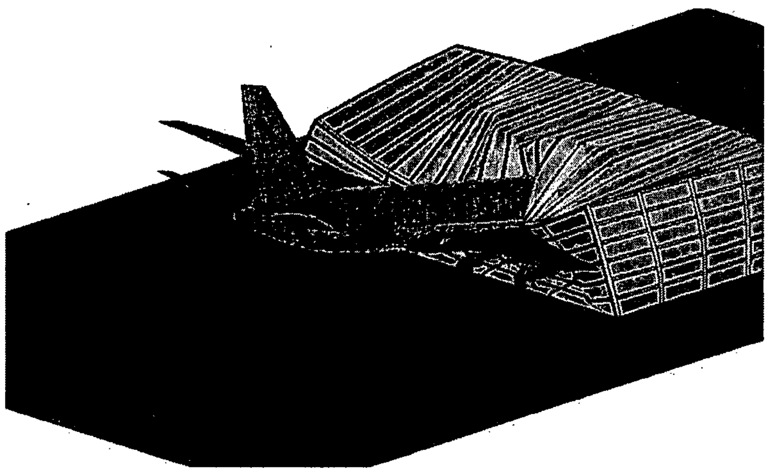

Figure 5. Impact of B767 with steel structure at 100 mph.

Because the building was modeled with a toughness that could not be achieved in practice, this simulation results in acute bending of the columns and the girders, visible in Figure 5. Under actual conditions, many of the columns and girders would fracture or be torn off the connections. Debris and fuel would fill the structure, and the fuel would be expected to ignite explosively, causing a massive conflagration. The total damage within the structure would depend on the existing fire load, including the fuel load and the flammable materials within the building. However, the fire is likely to soften all metals, burn all non-metals, and deteriorate the concrete. This could result in a breach of both the source assemblies and the pool, allowing shielding water to escape. The Co-60 sources could also be exposed if extreme temperatures evaporate the pool water or if the force of the impact disperses the source. In addition, all personnel in the building would likely be killed or incapacitated in the event of a crash and conflagration, and Pa'ina Hawaii's proffered emergency procedures would be rendered useless, because no personnel would be there to implement them.

Chunks of debris, such as engine and landing-gear components, traveling through the building at great speed would likely destroy all equipment, controls, and instrumentation in the building. It is possible that debris could enter the pool and breach the radioactive sources. Debris may directly impact the sources or cause heavy equipment held in place above the pool to snap, fall into the pool, and strike the source assemblies, resulting in dispersal of radioactive material.

The "very strong forces" that the source assemblies will have been tested against, according to the Safety Report, will not stand up to the forces of an airplane crash. For example, the mass and velocity of falling debris will deliver much more destructive energy than the NRC impact standard for source assemblies, which is a 2-kg steel weight falling from a height of 1 meter.

The lip of the irradiator pool, which extends 3 ½ feet above the floor, will likely buckle under the impact of an aviation crash, despite a 6-inch layer of reinforced concrete between two ¼ inch metal shells. Further, because the pool's inner and outer steel layers are likely connected with welded I-beams, which do not perform well under extreme impact, the shock of the impact could affect the welds and cause the pool to breach, allowing the water to drain out.

Conclusion

The preceding analysis leads to the conclusion that the effects of a plane crash on an industrial building housing a nuclear irradiator would be devastating. Because the modeled steel structure is more robust and more tenacious than what Pa'ina Hawaii is likely to build, the effects in reality are likely to be greater than the modeled effects. Such an impact could directly destroy the building housing the irradiator and the 3 ½ foot lip of the irradiator pool. Destruction of the pool lip could undermine the integrity of the pool, causing the water shielding the Co-60 sources to drain out. A high-temperature conflagration caused by the impact could destroy the pool by melting the steel. Flying debris could breach the source assembly or pool. In all of these instances, a plane crash would create conditions that could lead to introduction of radioactive Cobalt-60 into the human environment. None of these eventualities was considered by the NRC's EA or Safety Report.

The Probability of Aircraft Impact into the Proposed Pa'ina Hawaii Irradiator

NRC Docket No. 030-36974

By
M. Resnikoff, Ph.D.

For
Earthjustice

February 7, 2007

This report evaluates the expected accident frequency, the number of accidents per year, of an aircraft impacting the proposed Pa'ina Hawaii food irradiator. No quantitative assessment is made of the consequences of an aircraft impact into the irradiator, though some of the criteria used by the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC), as they are applicable, are discussed.

The methodology follows the DOE standard, DOE-STD-3014-96, "Accident Analysis for Aircraft Crash into Hazardous Facilities."[1] The DOE standard is similar to the NRC methodology employed by the author in the NRC proceedings regarding the proposed PFS spent fuel storage facility at Skull Valley, Utah, and the Atomic Safety and Licensing Board accepted that testimony.[2] Numerous other analysts have employed this standard to analyze aviation risks at DOE nuclear facilities.[3]

Generally, the NRC methodology[4] in NUREG-0800 is used for potential facilities located at some distance from an airport, not for facilities like the Pa'ina irradiator, which would be in close proximity to airport runways. Accordingly, we question the Center for

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[1] Department of Energy, "Accident Analysis for Aircraft Crash into Hazardous Facilities," DOE-STD-3014-96, October 1996, available at http://hss.energy.gov/NuclearSafety/techstds/standard/std3014/std3014.pdf.

[2] State Of Utah's Prefiled Testimony Of Dr. Marvin Resnikoff For Contention Utah K/Confederated Tribes B, Docket No. 72-22-ISFSI, ASLBP No. 97-732-02-ISFSI, February 19, 2002.

[3] DOE-STD-3014-96, p. B-24.

[4] NUREG-0800, NRC Standard Review Plan, Section 3.5.1.6, Aircraft Hazards.

Nuclear Waste Regulatory Analyses' (CNRWA's) decision to rely solely on NUREG-0800 for its analysis.[5]

We contrast our methodology with that of CNWRA in a section of this report, but many aspects are identical. Similar to the CNWRA analysis, we consider four types of aircraft: commercial air carriers, air taxis, general aviation and military aircraft. The specific aircraft types for commercial air carriers are generic, that is, no distinction is made for major aircraft carriers between a Boeing 727, 737, 747 or 767 aircraft. For military aircraft, as in the CNWRA analysis, we consider only light fighter jets, like the F-16, and ignore large military aircraft. Our calculation of the fly-in and skid-in area of the proposed facility is identical.

If the impact frequency exceeds 1 in a million per year, the NRC has customarily proceeded to the next step, evaluating the consequences of an airplane crash (i.e., the likelihood that, in the event of an airplane crash, radiation releases would occur). CNWRA devotes only a single paragraph to this important analysis and, without presenting any calculations or other meaningful analysis, simply asserts there are no consequences - end of story. This section of the CNWRA, and of the Environmental Assessment that relies on it, will clearly have to be supplemented to provide a meaningful discussion of the consequences of an aviation accident involving Pa'ina's proposed irradiator.

In the next section we discuss the methodology and the selected data. We also contrast our methodology and data with those of CNWRA. In the following section, we discuss the results of our analysis and recommendations.

Methodology

Aircraft crash frequencies are estimated with a formula that takes into account (1) the number of operations, (2) the probability that an aircraft will crash, (3) given a crash, the probability that the aircraft will crash into a 1-square mile area where the facility is located (the conditional probability), and (4) the size of the facility.[6] In the PFS proceeding[7], we evaluated non-airport activities, that is, the number of crashes per square mile per year expected to occur for Air Force fighter jets during the flight phase. In

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[5] Durham, J, *et al*, "Draft Topical Report on the Effects of Potential Natural Phenomena and Aviation Accidents at the Proposed Pa'ina Hawaii, LLC, Irradiator Facility," Center for Nuclear Waste Regulatory Analyses, December 2006.

[6] DOE-STD-3014-96, p. 38.

[7] Ref. 2 above

contrast, for Pa'ina's proposed facility, we take into account only takeoffs and landings, using a combination of Honolulu International Airport (HNL) specific information and generic information. A second calculation we perform employs the default assumptions of DOE's standard, DOE-STD-3014-96.

Mathematically the formula that is employed is the following:

$$F = \sum_{i,j,k} N_{ijk} P_{ijk} f_{ijk}(x,y) A_{ij} \qquad (1)$$

where:

F =	estimated annual aircraft crash impact frequency into the proposed irradiator (no./y),
N_{ijk} =	estimated annual number of takeoffs and landings for each aircraft category and each runway,
P_{ijk} =	aircraft crash rate per take-off and landing for HNL or generically for the U.S.
$f_{ijk}(x,y)$ =	crash location conditional probability – given a crash, the likelihood it will be into the facility,
A_{ij} =	the effective area of the facility that includes skid-in and fly-in effective areas for each aircraft, for takeoffs and landings,
i =	index for flight phase, i = 1,2,3 for take-off, in-flight and landing (for purposes of this analysis, we ignore in-flight crashes),
j =	index for aircraft category (Air Carrier Operations, Air Taxi Operations, General Aviation Operations, and Military Operations),
k =	flight source (4 runways).

We next evaluate each of the parameters in Equation (1).

Number of Operations

We first estimate the number of aircraft operations N_{ijk}, that is, the total takeoffs and landings at the Honolulu International Airport, by averaging the historical data. The data for each type of aircraft operation at HNL appear in Table 1; the data are provided by the Federal Aviation Administration (FAA). Over a 30-year period of time, the average number of aircraft operations at HNL, according to the FAA, is 356,772 per year.[8] For

[8] http://www.apo.data.faa.gov, "APO Terminal Area Forecast Summary Report, HNL"

2005, the number of air craft operations, according to the FAA, was 334,660.[9] Hawaii DOT says the number of aircraft operations in 2005 was 330,506.[10] The number of aircraft operations at HNL declined following September 11th, but increased in 2005. As noted in the CNWRA analysis, the FAA expects the number of persons visiting Hawaii and the number of aircraft operations at HNL to continue to increase, with an increase to 510,000 operations by fiscal year 2012. However, this potential increase is not factored into CNWRA's probability calculations, nor ours.

The accident rates at HNL for each aircraft category, except for military aircraft (for which HNL-specific accident rates were not available) appear in Tables 2 through 4.[11] The average number of accidents per year at HNL, averaged over all non-military aircraft, is 2.633; the average number of fatal accidents per year, averaged over all non-military aircraft, is 0.5. Expressed in terms of the average number of accidents per 100,000 takeoff and landings (excluding military aircraft), the number is 0.80; the average number of fatal accidents per 100,000 takeoff and landings of non-military aircraft at HNL is 0.153.

The NTSB defines a crash as "any aircraft accident that results in destruction or substantial damage to the aircraft."[12] A crash is therefore not necessarily an accident involving fatalities, but for this analysis, we equate a fatal accident with a crash. Further, we sum up all fatal accidents for all aircraft types to get an HNL-specific fatal accident rate. Also we carry out a separate analysis employing the crash rates for individual aircraft, as developed by the DOE.[13] The contrasting crash rates are presented in Table 6.

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[9] *Ibid.* In contrast, CNWRA claims the FAA has recorded 323,726 aircraft operations for the year 2005. Since both CNWRA and RWMA state they are using data from the FAA, the discrepancy between the two figures will have to be resolved.
[10] Schlapak, B, email to M Blevins, NRC, 10/31/2006.
[11] Table 5 sets forth the annual number of departures and landings of military aircraft.
[12] DOE-STD-3014-96
[13] *Ibid.*

Table 1. Departures and Landings for Honolulu International Airport, 1975-2005[a]

Year	Aircraft Operations	All Accidents	Fatal Accidents	Incidents	Acc/100,000 Dep + Land	Facc/100,000 Dep+Land
2005	318853	1	0	0	0.314	0.000
2004	290737	2	0	0	0.688	0.000
2003	294631	0	0	1	0.000	0.000
2002	300111	1	0	0	0.333	0.000
2001	323522	1	0	2	0.309	0.000
2000	326698	1	0	1	0.306	0.000
1999	323922	2	0	0	0.617	0.000
1998	312596	0	0	2	0.000	0.000
1997	340742	3	0	0	0.880	0.000
1996	351065	3	0	0	0.855	0.000
1995	352814	4	1	0	1.134	0.283
1994	335532	2	1	1	0.596	0.298
1993	341316	2	2	0	0.586	0.586
1992	381879	3	2	0	0.786	0.524
1991	369856	3	0	0	0.811	0.000
1990	368827	0	0	0	0.000	0.000
1989	362644	4	1	0	1.103	0.276
1988	331229	2	0	1	0.604	0.000
1987	365111	6	1	0	1.643	0.274
1986	334884	2	0	0	0.597	0.000
1985	323598	2	0	0	0.618	0.000
1984	312492	3	0	0	0.960	0.000
1983	297071	2	0	0	0.673	0.000
1982	278589	2	0	1	0.718	0.000
1981	320079	2	1	2	0.625	0.312
1980	352856	5	1	0	1.417	0.283
1979	379488	4	0	0	1.054	0.000
1978	329969	3	0	2	0.909	0.000
1977	296869	9	3	1	3.032	1.011
1976	274714	5	2	0	1.820	0.728
1975		5				
	329756.5	**2.633**	**0.500**	**average =**	**0.800**	**0.153**

a In this table, military operations at HNL are excluded in determining total operations and accident and fatal accident rates.

Table 2. Departures and Landings (HNL) Air Carrier

Year	Air Carrier Operations	All Accidents	Acc/100,000 Dep + Lnd
2005	184937		0
2004	166121		0.000
2003	167562	1	0.597
2002	174544		0.000
2001	196351	2	1.019
2000	206786	1	0.484
1999	192137	1	0.520
1998	183856	2	1.088
1997	186648	2	1.072
1996	205600	2	0.973
1995	199801	1	0.500
1994	191176	1	0.523
1993	187950		0.000
1992	201999		0.000
1991	194293		0.000
1990	194000		0.000
1989	195981	1	0.510
1988	187445	1	0.533
1987	214028	1	0.467
1986	184523	1	0.542
1985	163562		0.000
1984	150273	1	0.665
1983	137420	1	0.728
1982	126981	1	0.788
1981	123148	2	1.624
1980	125185		0.000
1979	132696	1	0.754
1978	117663	2	1.700
1977	112111	3	2.676
1976	106447	2	1.879

Table 3. Departures and Landings (HNL) Air Taxis

Year	Air Taxi Operations	All Accidents	Acc/100,000 Dep + Lnd
2005	65843		0.000
2004	51030		0.000
2003	46433		0.000
2002	44742	1	2.235
2001	35037		0.000
2000	30402		0.000
1999	38675		0.000
1998	42195		0.000
1997	68423	1	1.461
1996	60536		0.000
1995	70245		0.000
1994	55425		0.000
1993	55216		0.000
1992	59984		0.000
1991	63608	1	1.572
1990	56909		0.000
1989	67022		0.000
1988	57366	1	1.743
1987	65993		0.000
1986	71823		0.000
1985	78638		0.000
1984	75101	1	1.332
1983	74530		0.000
1982	69106	1	1.447
1981	75354		0.000
1980	77632	2	2.576
1979	87131	1	1.148
1978	81108		0.000
1977	66783	1	1.497
1976	53896		0.000

Table 4. Departures and Landings (HNL) General Aviation

Year	General Aviation Operations	All Accidents	Acc/100,000 Dep + Lnd
2005	68073	1	1.469
2004	73586	2	2.718
2003	80636		0.000
2002	80825		0.000
2001	92134	1	1.085
2000	89510	1	1.117
1999	93110	1	1.074
1998	86545		0.000
1997	85671		0.000
1996	84929	2	2.355
1995	82768	3	3.625
1994	88931	2	2.249
1993	98150	2	2.038
1992	119896	3	2.502
1991	111955	2	1.786
1990	117918		0.000
1989	99641	3	3.011
1988	86418	1	1.157
1987	85090	4	4.701
1986	78538	1	1.273
1985	81398	2	2.457
1984	87118	1	1.148
1983	85121	1	1.175
1982	82502	1	1.212
1981	121577	2	1.645
1980	150039	3	1.999
1979	159661	2	1.253
1978	131198	3	2.287
1977	117975	6	5.086
1976	114371	3	2.623

Table 5. Departures and Landings (HNL) Military[a]

Year	Military Operations	All Accidents	Acc/100,000 Dep + Lnd
2005	15807		
2004	16847		
2003	15884		
2002	15978		
2001	16465		
2000	16598		
1999	21080		
1998	21685		
1997	23991		
1996	23900		
1995	23410		
1994	21584		
1993	23879		
1992	31846		
1991	23853		
1990	37998		
1989	43466		
1988	35912		
1987	23924		
1986	29011		
1985	30293		
1984	30938		
1983	29669		
1982	27403		
1981	31813		
1980	32607		
1979	31888		
1978	35564		
1977	33704		
1976	43473		

[a] In our calculations for crash rates we use the data from DOE-STD-3014-96.

From Tables 2,3 and 4, we see that the average number of accidents for air carriers, air taxis and general aviation is, respectively, 0.655, 0.5 and 1.768 per 100,000 takeoffs and landings. The accident rate for military aircraft was not provided by the Hawai'i Department of Transportation, so we employed the average crash rate for small military aircraft for the entire U.S., 0.18 and 0.33 crashes per 100,000 takeoffs and landings, respectively.[14] For all of the above aircraft categories, for the RWMA calculations, we averaged the accidents due to takeoffs and due to landings at HNL, assuming the number of takeoffs equal the number of landings. Table 6 compares our results to those of DOE.

Table 6. Aircraft Accident Rates

	DOE Crash Rate		RWMA
Aircraft	Takeoff per 100,000	Landing per 100,000	HNL Takeoff, Landing per 100,000
General Aviation[1]	0.35	0.83	0.153
Air Carrier	0.019	0.028	0.153
Air Taxi	0.1	0.23	0.153
Military[2]	0.18	0.33	0.18/0.33

Notes:
[1] Fixed wing turboprop
[2] Small military aircraft includes fighter jets, attack aircraft and trainers

The data for the DOE crash rates are taken from an NTSB data base, for the country as a whole.[15] As expected, the crash rate for landings is greater than the crash rate for takeoffs. The RWMA crash rate combines takeoffs and landings (except for military aircraft), but is specific to HNL. Except for air carriers, DOE's accident rate for all aircraft is generally greater than RWMA's, but this is somewhat misleading, since air carriers comprise over half the takeoffs and landings at HNL. Weighted by the number of aircraft operations for each aircraft, DOE's average crash rate is actually smaller than RWMA's, reflecting a higher than average crash rate at HNL.

The crash rate used in the CNWRA analysis is not directly comparable to the rates listed in Table 6, since CNWRA combines the overall crash rate with a type of conditional probability, as discussed further below. But it is important to note that the CNWRA

[14] FAA data, footnote 8.
[15] DOE-STD-3014-96

crash rate does not distinguish between takeoffs and landings, and this is clearly incorrect. Further, conditional probability analysis takes into account the spatial distribution of accidents, which will differ depending on whether a takeoff or landing is involved. In contrast, RWMA's analysis considers takeoffs and landings, as well as the specific aircraft involved, in calculating the conditional probabilities.

Conditional Probabilities

Given an air crash, we next have to determine the likelihood that the proposed irradiator would be hit within a square mile area; this is called the conditional probability, $f_{ijk}(x,y)$. These conditional probabilities come from NTSB national averages and appear in the DOE report,[16] updated to 1996. Essentially, from a large database listing locations of crashes near airports, NTSB has determined, for each type of aircraft, the probability of an air crash with distance from the center of a runway. To utilize the database, one must determine the location of the proposed facility with respect to the center of each runway. A Cartesian coordinate system must be set up. See Figure1 below. The origin is the center of each runway.

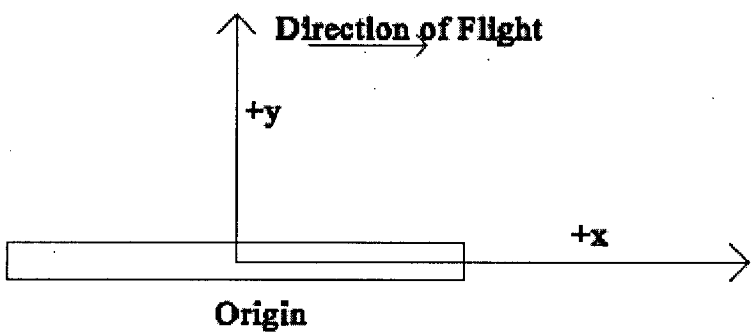

Figure 1. Coordinate convention for use with crash location probability tables for commercial and general aviation

The conditional probabilities for military aircraft are more complicated, but since the basic information is presently not available to us, we have had to simplify the data. Military aircraft land by first approaching parallel to the runway, turning 180 degrees and then landing. See Figure 2. For this reason, the side of the runway the military aircraft approaches before its base leg turn (called the pattern side), has a higher probability distribution. However, since we do not have information regarding military aircraft

[16] DOE-STD-3014-96, Appendix B.

landings at HNL, we have assumed that the pattern side is over the ocean. For military aircraft, there is no pattern side for takeoffs.

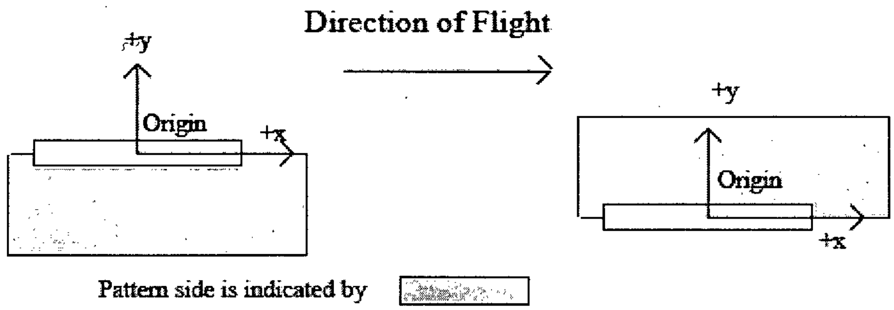

Figure 2. Coordinate convention and pattern side, for use with crash location probability tables for military aviation.

The conditional probabilities specify, given an air crash, the likelihood the accident will take place at a specific location. We therefore have to place the proposed irradiator facility in its relation to each of the four runways at Honolulu International Airport. The locations of the runways at HNL and of the proposed Pa'ina Hawaii irradiator are shown in Figure 3.

As seen in Fig. 3, the proposed facility is located extremely close to and lies between the runways (4R,22L) and (8R,26L), the reef runway. It is approximately ¼ mile from each runway and a little more than ½ mile from the major runway (8L,26R). Table 7 lists the distances of the proposed facility from the center of each of the four runways. The conditional probability distributions are probability estimates in one square mile blocks. That is, given a crash, the conditional probabilities provide the probability that the crash takes place in an area of one square mile. As seen in Table 7, the centers of all runways are within one mile of the proposed facility.

Effective Area Calculations

Employing the conditional probabilities developed by DOE from the NTSB database, we now have three parts of the probability calculation – the number of flights of each type aircraft, the probability of a crash per 100,000 takeoff and landings, and the conditional probability, if a crash takes place, that it will occur within a specific 1-square mile area. The final piece is to calculate the effective area of the facility such that if an unobstructed aircraft were to crash within the area, it would impact the facility, either by direct fly-in or by skidding into the facility. The effective area depends on the dimensions of the

Table 7. (X,Y) Coordinates of Facility with Respect to Center of Each HNL Runway[a]

	8R	**26L**
Landing coordinates	(-1.13,0)	(-1.13,0)
Facility coordinates	(0.47,0.43)	(-0.47,-0.43)
Distance from Runway Center	0.62 mi	0.62mi
	8L	**26R**
Landing coordinates	(-1.17,0)	(-1.17,0)
Facility coordinates	(0.3,-0.81)	(-0.3,0.81)
Distance from Runway Center	0.86 mi	0.86 mi
	4R	**22L**
Landing coordinates	(-0.84,0)	(-0.84,0)
Facility coordinates	(-0.28,0.55)	(0.28,-0.55)
Distance from Runway Center	0.60 mi	0.60
	4L	**22R**
Landing coordinates	(-0.65,0)	(-0.65,0)
Facility coordinates	(-0.36,0.73)	(0.36,-0.73)
Distance from Runway Center	0.81 mi	0.81 mi

Notes:

a. The center of each runway is located at (0,0).

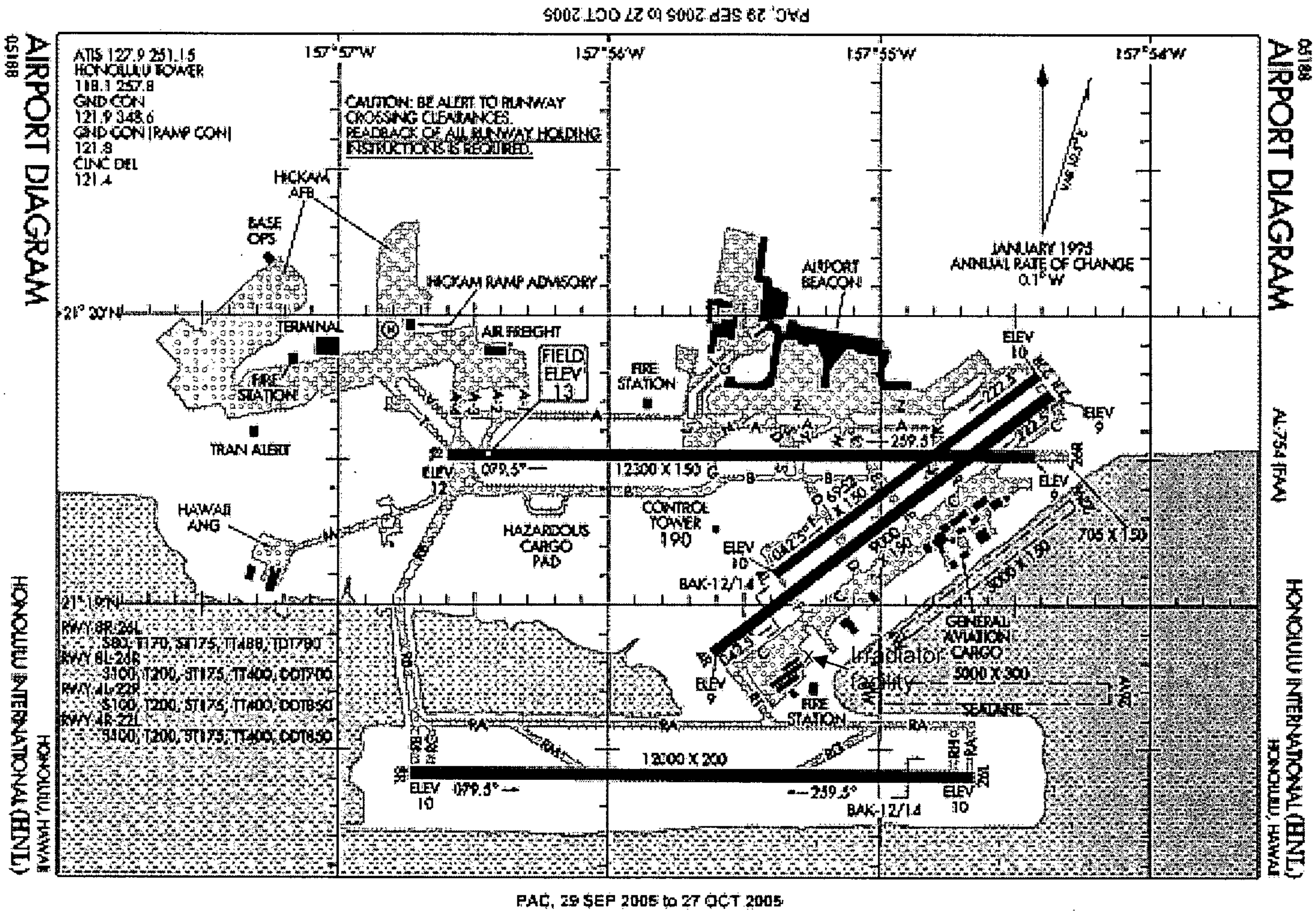

Figure 3. Airport Diagram Honolulu International Airport

proposed facility, the aircraft's wingspan and heading, and the length of the skid. The fly-in area is not just the two dimensional footprint of the building, but the shadow area that takes into account the height of the proposed facility. For this calculation, we will provide two effective area estimates, one for the entire building and another for the irradiator itself, which is a smaller area. We believe it is important to examine not only the probability of impacting the irradiator directly, but impacting the building as well. This is because, as the 9/11 attack has shown, air carriers, particularly on takeoff, carry a tremendous amount of fuel and this must be taken into account in any consequence analysis. Further, as the consequence analysis by M. Sozen and C. Hoffmann has shown, an air crash into the proposed facility will likely bring down part of the building.[17]

A general diagram that shows the parameters used in the equations to calculate the effective area is shown below in Figure 5.

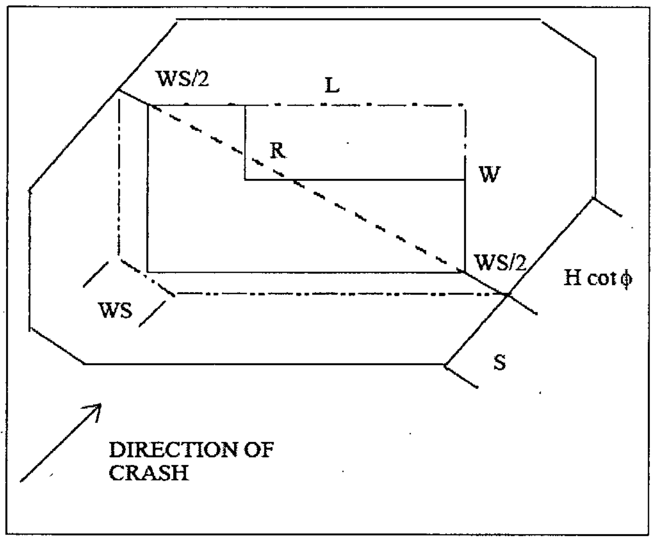

Figure 5. Rectangular facility effective target elements

The effective area of the facility is composed of two elements, the fly-in area A_f and the skid-in area A_s.

$$A_{eff} = A_f + A_s \qquad (2)$$

[17] Sozen, M. and Hoffmann, C., "Analysis of the Effect of Impact by an Aircraft on a Steel Structure Similar to the Proposed Pa'ina Irradiator," January 2007.

As shown in Equation (3), the effective skid-in area is the length of the diagonal of the facility R plus the wingspan of the aircraft WS times the skid distance of the aircraft S. The effective skid-in area is aircraft dependent.

$$A_s = (WS + R)*S \qquad (3)$$

where R is the length of the diagonal of the building or the irradiator, $R = (L^2 + W^2)^{0.5}$. The length L = 64 ft and width W = 116 ft of the proposed irradiator facility[18] and the L = 7.92 ft and width W = 6.75 ft of the irradiator itself[19] are taken from information provided by the applicant. The facility height is 29.6 feet.

Average skid-in areas and wing spans for individual aircraft types are shown in Table 8 below.

Table 8. Skid-In Area (sq mi)

Aircraft	Skid-In Distance (ft)[a]	Wing Span (ft)[a]	Skid-In Area (sq mi) Irradiator Facility	Irradiator
Air Carrier	1440	98	0.01667	0.005599
Air Taxi	1440	59	0.000611	0.000149
General Aviation	73	60	0.000641	0.00018
Military[b]	347	78	0.003763	0.004566

a. From DOE-STD-3014-96, App B
b. Small aircraft – jet fighters, average of take-offs and landings

Note that the skid-in distance and skid-in area for the major air carriers are much greater than for the other aircraft since it is difficult to stop a large, heavy aircraft. For small military aircraft we have averaged the takeoff and landing skid-in areas. Since there are far fewer small military aircraft movements at HNL than air carrier movements, this simplification has a small effect on the overall crash likelihood. The CNWRA and RWMA skid-in areas are the same.

[18] Pa'ina email communication (Oct. 23, 2006) (ML063060603).

[19] Paina Hawaii, Application for Material License, June 23, 2005, Fig. 9-F.

The fly-in area is a sum of three elements - the footprint of the building, an additional element due to the wing span, and a shadow area, taking into account the height of the building. The effective fly-in area can be expressed as follows:

$$A_f = (WS + R)*H\cot\Phi + 2*L*W*WS/R + L*W \quad (4)$$

where $\cot\Phi$ is the mean of the cotangent of the aircraft impact angle, based on accidents investigated by the NTSB and the FAA. Based on the information provided by the applicant, the height of the irradiator facility is 29.6 feet. The same height is used to calculate the fly-in areas for the irradiator itself.

The results from Eq. (4) for the fly-in area appear in Table 9 below. As seen, the fly-in area for major carriers is much smaller than the skid-in area. Note: the fly-in and skid-in areas calculated by CNWRA are the same as employed by RWMA.

Table 9. Fly-In Area (sq mi)

Aircraft	Fly-In-In Area (sq mi) Irradiator Facility	Irradiator
Air Carrier	0.003156	0.001212
Air Taxi	0.002171	0.000628
Genl Aviation	0.002349	0.000628
Military	0.003419	0.000925

Finally, we combine the fly-in and skid-in areas, with the number of crashes for each aircraft, the number of operations for each aircraft, and the conditional probabilities that estimate locational probabilities given a crash, to obtain the yearly probability of a crash into the irradiator facility, using HNL-specific crash rate (RWMA) and DOE crash rate averages, by aircraft, for the entire U.S. These results are presented in Table 10 below. As seen, the air carriers dominate the probability. The crash probability for RWMA crash rate, number/year, is 5.69E-04. Using DOE (i.e., NTSB) national statistics, the crash probability, number per year, is somewhat lower, 3.59E-04, but both rates are significantly higher than that calculated by CNWRA, 2.0E-04.

Table 10. Probability of Aircraft Accident at Irradiator Facility (#/yr)

Aircraft	DOE	RWMA
General Aviation Takeoff	5.87E-05	2.56E-05
General Aviation Landing	1.25E-04	2.30E-05
Air Carrier Takeoff	3.21E-05	2.59E-04
Air Carrier Landing	2.50E-05	1.36E-04
Air Taxi Takeoff	4.99E-05	7.63E-05
Air Taxi Landing	6.04E-05	4.02E-05
Military Aviation Small Aircraft Takeoff	2.90E-06	2.90E-06
Military Aviation Small Aircraft Landing	5.32E-06	5.32E-06
sum =	**3.59E-04**	**5.69E-04**

Critique of the CNWRA Analysis

1) The crash data in NUREG-0800 employed by CNWRA is apparently based on a 1973 paper by Eisenhut.[20] CNWRA thus relies on airplane crash data that are more than thirty years old and not applicable to all aircraft. In contrast, the DOE data we use are applicable to all aircraft, including air taxis, and are updated to 1996. In addition, the CNWRA analysis fails to account for the fact the air crash rates for HNL are higher than the national average.
2) The NRC and CNWRA methodology, in NUREG-0800, is not specific to take-offs and landings. The crash rates shown in Table 2-6, which are taken from NUREG-0800, are functions of the distance from the end of the runway. However, as the NTSB data shows, landings have a higher crash rate than takeoffs, and this is not taken into account in the CNWRA report.

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[20] Eisenhut, D.G., "Reactor Siting in the Vicinity of Airfields," Paper presented at the American Nuclear Society Annual Meeting, June 1973.

3) Further, the NRC and CNWRA methodology employs an equal probability of an air crash to all locations in the vicinity of an airport, and this is not correct. To take one example, for military aircraft, planes fly parallel to the runway, then make a U-turn and land. The side where military planes first fly is called the "pattern" side. In the RWMA analysis, we assume that the pattern side is over the ocean. This type of fine detail is missing from NUREG-0800 and the CNWRA analysis.

4) The number of aircraft operations at HNL used in the CNWRA analysis understates the actual number of current operations, and also fails to account for anticipated future growth during the time period for which Pa'ina seeks a materials license. Although unstated in the CNWRA analysis, it appears it used the average number of aircraft operations at HNL over the past five years, which would factor in the substantial decrease in the number of operations at HNL following September 11, 2001. Since the number of operations at HNL did not begin to increase again until 2005 and, as the CNWRA analysis concedes, is expected to increase by another 20% during the 10-year period of Pa'ina's license application, the number of operations CNWRA uses in its calculations is unrealistically low. A more realistic, but still conservative, assumption is to use current operational levels. The RWMA analysis took this approach, using the most recent numbers available, which are from airport operations in 2005.

5) Because of its methodological flaws, CNWRA underestimates the probability an airplane will crash into the proposed Pa'ina irradiator. Instead of the 2E-4 per year probability CNWRA calculated, the probability should be 3.59E-4, if DOE/NTSB data are used. If HNL-specific data are used, the crash probability should be increased to 5.69E-4.

6) The consequence analysis by the NRC and CNWRA fails to provide any data or calculations to support its conclusions and does not take into account realistic accident scenarios. The CNWRA report asserts that sources that can satisfy the tests set forth in 10 C.F.R. § 36.21 would be robust enough to survive an aviation accident, but never performs any calculations to back up that claim. For example, CNWRA never quantifies the impact of flying airplane debris to compare it with the impact associated with a 2.5 cm-diameter, 2-kg steel weight dropped from a height of 1 meter, the standard set forth in 10 C.F.R. § 36.21(d). Nor does CNWRA assess the extreme temperatures that would be associated with burning thousands of pounds of jet fuel, which could far exceed the 600 °C for 1 hour standard in 10 C.F.R. § 36.21(b). The CNWRA's analysis must be quantified to provide meaningful information about the

possible consequences of an aviation accident involving the Pa'ina irradiator.

7) Damage to the irradiator pool due to an air crash (such as from the shaft of a jet plane striking the pool) may damage the pool structure under the floor level, such as tears of the welds and consequent loss of irradiator pool shielding water. Since the floor level is also the minimum water level necessary to shield the Co-60 sources, such a breach of the pool structure would eliminate the irradiator's passive shielding, on which the NRC and CNWRA rely to justify their "no significant impact" conclusion. Since the CNWRA analysis assumes the depth of the water table is 2 meters (6.6 feet) below the facility floor, its assumption that sea water infiltrating through a breach would adequately shield the Co-60 sources is unsupported. It also ignores the potential for contamination of the water in the pool in the event that an airplane crash breaches the sources. If the aviation accident also ruptured the pool lining, water contaminated with radioactive cobalt could escape the facility, contaminating groundwater and nearby Ke'ehi Lagoon. All of these risks need to be, but were not, analyzed by the NRC and CNWRA.

8) The force of the impact from an air crash into the facility and/or the ensuing fire and explosion of aviation fuel will likely lead to loss of all monitoring equipment, loss of the structure itself, loss of irradiator shielding, and the loss of all personnel (and consequent inability to implement necessary emergency procedures). The NRC and CNWRA fail to analyze any of these potential consequences, any of which would pose significant threats to public health and safety.

Conclusions and Recommendations

As seen, using NTSB data and the DOE methodology, which is standard for these calculations, the expected frequency of an aircraft impacting the proposed Pa'ina Hawaii irradiator is quite high (3.59E-4), over 300 times greater than the NRC's guideline, 1 in a million/year crash probability. The applicant and the NRC must therefore take the next step, conducting a detailed, quantitative investigation of the consequences of an impact. Using HNL specific crash rate, the expected frequency is 5.69E-4.

In this report, we have focused on the likelihood of an aircraft impact. The reason for the high probability we identified is the proximity of the proposed facility to active runways at HNL. If the proposed facility were located over ten miles from the center of the runways, the conditional probability would decline by a factor of 1,000, placing the yearly probability within the limits the NRC generally deems acceptable for nuclear facilities. The NRC should consider in its environmental review alternate locations, which would substantially reduce risks to the public associated with aviation accidents.

The skid-in distance for air carrier operations appears to be the dominant factor behind the high risk to the Pa'ina irradiator. If the facility remains in its present location, the NRC must consider requiring Pa'ina to surround the facility with major obstructions, such as earthen berms, or substantially hardening the facility, to mitigate and minimize the threats to the public.

Potential aviation accidents include impacts into the proposed facility and into the irradiator itself. Based on experience with the 9/11 attack, it is crucial, in evaluating the consequences of an impact, to analyze the potential for a major fuel fire and explosion. The NRC and CNWRA improperly fail to consider such consequences, which could cause the loss of the Radiation Safety Officer and facility personnel, as well as the loss of electricity and monitoring instruments, all of which would prevent implementation of emergency procedures vital to protecting the general public. The fire and explosion from an airplane crash could also evaporate or displace the irradiator's shielding water or damage the irradiator pool, allowing the shielding water to escape. Sea water infiltrating through a breach in the pool structure could cause contamination of the pool water. Moreover, contaminated water could escape the facility through a breach in the pool structure, contaminating groundwater. Any of these eventualities could expose surviving facility personnel, emergency responders, the public and/or the environment to very high radiation doses.

A direct fly-in into the irradiator itself, particularly if the engine shaft of a military aircraft or major carrier were to strike the irradiator, could puncture the irradiator pool, leading to a loss of shielding water, and shatter the Co-60 pencils.[21] The forces exerted by such a crash would far exceed the impact standards set forth in 10 C.F.R. § 35.21 on which CNWRA bases its claim the public would be safe. The NRC and CNWRA need to provide data and calculations to back up their currently unsupported claims of "no significant impact."

[21] This type of accident could also cause the loss of the RSO and facility personnel and the loss of electricity and monitoring instruments, with the serious consequences described above.

ASSESSMENT OF NATURAL DISASTER RISKS FOR THE PROPOSED SITE OF PA'INA HAWAII, LLC'S COBALT-60 IRRADIATOR FACILITY AT 192 PALEKONA STREET, HONOLULU, HAWAI'I

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February 2007

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SUMMARY

This report assesses the risks posed by Pa'ina Hawaii, LLC's proposed Cobalt-60 food irradiator (Irradiator) in the event of a natural disaster and analyzes the Draft Topical Report on the Effects of Potential Natural Phenomena and Aviation Accidents at the Proposed Pa'ina Hawaii, LLC, Irradiator Facility, prepared by the Center for Nuclear Waste Regulatory Analyses (CNWRA Report), which supports the Nuclear Regulatory Commission's (NRC's) Draft Environmental Assessment Related to the Proposed Pa'ina Hawaii, LLC Underwater Irradiator in Honolulu, Hawai'i (DEA).[1]

The proposed Irradiator site, which is adjacent to Ke'ehi Lagoon and the Honolulu International Airport, is relatively flat, at a low elevation, and within the tsunami evacuation zone, making it susceptible to flooding by tsunamis and hurricanes and wind damage by hurricanes. It is also proposed to be built on unconsolidated sediments, posing a risk of damage from earthquakes due to liquefaction. Therefore, this site presents risks to operation of a nuclear irradiator that could easily be avoided by siting the facility at a location away from the water's edge and on solid ground. To protect the public and the environment from unnecessary risk, the NRC ought to consider alternate siting locations.

Hurricanes: Weakness in the semi-permanent subtropical high-pressure ridge north of the Hawaiian Islands can allow a hurricane to hit on or near O'ahu and the proposed Irradiator site. There is an 80% estimated probability that a hurricane or tropical storm will pass within 360 nautical miles of the Honolulu Airport. In the event of the maximum probable hurricane landing on O'ahu, maximum sustained winds could reach up to 140 mph and gust up to 175 mph, with severe flooding due to intense storm surges. Smaller hurricanes could also cause flooding from the Ke'ehi Lagoon. The CNWRA Report and the DEA incorrectly assess the risks and effects of hurricane-force winds and storm surges.

Tsunamis: There is a 100% statistical probability that a future major Pacific-wide tsunami will impact the Hawaiian Islands, and the proposed Irradiator site is within a State Civil Defense tsunami evacuation zone. Because damaging tsunami effects, such as runup and strong currents, are exacerbated by the unique features of harbors and basins such as the Ke'ehi Lagoon, a pile-up effect could occur at the head of Ke'ehi Lagoon near the proposed Irradiator site. Enhanced tsunami waves could overtop Palekona Street and flood the site.

The CNWRA Report and DEA's reliance on the stylized fluid dynamic calculation to determine that a tsunami will not have a significant impact ignores other potential effects of tsunamis, such as flooding, which can be exacerbated in semi-enclosed bodies of water. Also, several factual inaccuracies were identified, including the assertion that the airport is not in a tsunami evacuation zone, and the statement that runup on south O'ahu has not exceeded 3 feet since 1837.

Seismic Hazards: Earthquakes have damaged Honolulu buildings in the past. The CNWRA Report and the EA trivialize the possible effects of liquefaction on the Irradiator, proposed to be

[1] This document attempts to use correct Hawaiian spelling, however, the author will use the spelling of the official business name "Pa'ina Hawaii, LLC".

built on unconsolidated alluvial sediments (i.e., gravel and sand). They also ignore the potential focusing effects of seismic energy on O'ahu, which can intensify ground motion, even for earthquakes with small magnitudes. Further, there is no proper analysis of the sufficiency of the load-bearing soil.

INTRODUCTION

Purpose and Scope

This report analyzes the potential impact of natural disasters on the proposed Pa'ina Hawaii Irradiator site and structure adjacent to the Honolulu International Airport reef runway and Ke'ehi Lagoon. The natural disasters with the greatest potential to affect the site – hurricanes, tsunamis, and earthquakes – are discussed in detail. A historical description and geographical delineation and distribution of each is provided, along with a discussion of the risks and consequences of a natural disaster event at the proposed Irradiator site.

This risk assessment is based on thorough research and analysis of all potential natural disasters specific to the proposed facility site and review of all available government databases, institutional reports, and public records, including the background materials provided by Pa'ina Hawaii's application to the NRC. The conclusions also analyze the DEA and CNWRA Report.

Physical Location and Description of the Proposed Cobalt-60 Irradiator Site

The proposed Irradiator site is about 375 feet from the Ke'ehi Lagoon shoreline and adjacent to the Honolulu International Airport reef runway at 192 Palekona Street. The site elevation is about 5-6 feet from mean sea level, but less than 3 feet during the highest spring tide. Seawalls and rock revetments surround the airport runways on the shores of both the ocean and Lagoon to prevent shoreline erosion, including at the end of Palekona Street, however, there are no berms or other physical barriers between the site and Ke'ehi Lagoon.

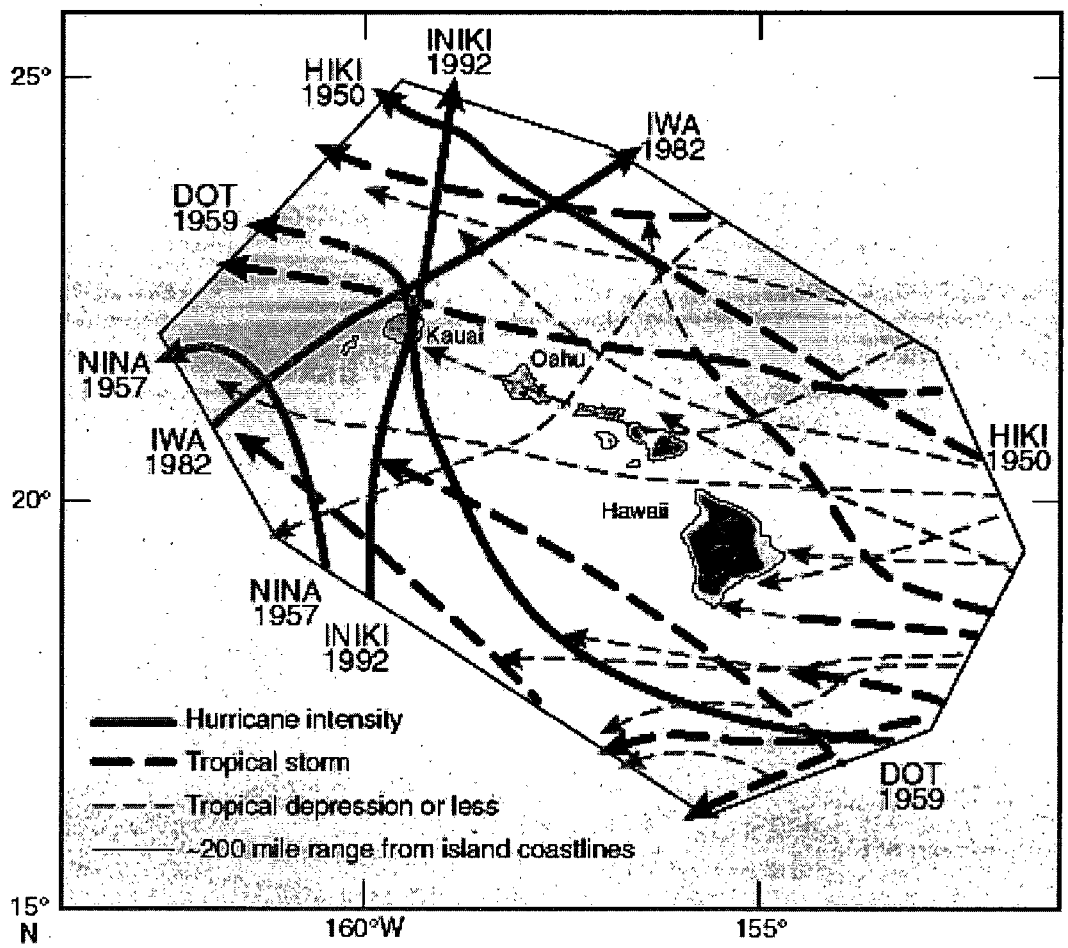
According to the Geoanalytical Report filed with Pa'ina Hawaii's NRC application, the entire area, including the shoreline, airport, and proposed site is comprised of "an eight-foot-thick zone of fill consisting of silty sand and gravel," and "the upper three feet of this fill is generally compact to dense, but the remainder is soft or very loose." This fill was removed from Ke'ehi Lagoon to reclaim land for sections of the airport, including the reef runway, and the surrounding industrial tracts. The extensive land reclamation has transformed the Ke'ehi Lagoon coastline. According to the Geoanalytical Report, "the fill overlies typically very loose to semi compact gravel and sand lagoon sediments to a depth of about 24.5 feet, below which are storm surge deposits composed of a dense, salty, gravelly sand to the maximum depth explored, about 36.5 feet. Ground water was intercepted at an average depth of about eight feet, near the contact between the fill and the marine soils."

HURRICANE HAZARDS

Storm surges associated with hurricanes present the greatest hazard risk for the proposed Irradiator site. High winds are also a concern. This section provides a detailed description of recent historical hurricanes in Hawai'i, as well as an extensive analysis of the risk of the proposed Irradiator site from potential future events. The description and the risk analysis are based on tables, charts, historical hurricane storm tracks, and data (water levels/barometric pressure, winds, waves, and tides) obtained from numerous reliable sources.

Historical Hurricanes and Storm Systems in the Hawaiian Islands

As detailed below, at least three major hurricanes have passed near or over the islands in the last 50 years, generating strong winds, heavy rains, and flooding – Iniki (1992), Iwa (1982), and Dot (1959). Although all three were centered over or near Kaua'i, O'ahu was considerably impacted, particularly along the southern and west coasts. Prior to these hurricanes, tropical depressions Hiki (1950) and Nina (1957) caused strong winds, heavy rains, and flooding on O'ahu. The diagram below illustrates the path of hurricanes, tropical storms and depressions near the Hawaiian Islands in recent years.



Tracks of recent hurricanes, tropical storms and depression in the Hawaiian Island Region.

Hurricane Dot – July 24 - August 8, 1959. Dot formed as a tropical storm in the eastern Pacific, west of Baja California. Dot tracked west northwest gaining strength until it passed within 90 miles of Hawai'i Island's South Point as a Category 4 hurricane. Dot turned northwest and made landfall on the island of Kaua'i as a Category 1 hurricane. Kaua'i was declared a disaster zone, with substantial damage to homes and utility lines. Damage to the agriculture industry was estimated at $5.5–$6 million in 1959 dollars. On O'ahu, flooding from heavy rainfall, wind damage, and high waves caused damage over $300,000 in 1959 dollars.

Hurricane Iwa - November 19- 25, 1982. Iwa formed as a tropical storm and reached Category 1 hurricane status near the Island of Kaua'i. The highest sustained winds reached 90 mph, with sudden gusts exceeding that velocity. When its energy finally dissipated, Iwa had taken one life and devastated the islands of Ni'ihau, Kaua'i and O'ahu with property damage amounting to over $250 million in 1982 dollars. On Wheeler Air Force Base on O'ahu, winds were measured at 45 knots from the North/Northwest, gusting to 68 knots. At Barber's Point the winds were from the Southwest at 37 knots and gusting to 61 knots.

Hurricane Iniki - September 5 - 13, 1992. Category 4 hurricane Iniki is the most destructive hurricane to hit the Hawaiian Islands in the 20th Century, and up until the 2005 hurricane Katrina, was the third most damaging hurricane in U.S. history.

Iniki's Formation: Iniki formed as a tropical depression southwest of Baja California. As it moved westward into the Central Pacific, it began to intensify and was upgraded to a tropical storm. It continued to strengthen while on a west-northwest course, and was upgraded to a hurricane, as it passed 300 miles south of Hawai'i. 385 miles SSW of Hilo, its maximum sustained winds reached 85 knots. Iniki continued west-northwest at a speed of translation ranging between 12 and 15 knots until it reached 425 miles south of Honolulu, where it began to slow its forward motion speed (speed of translation) and move in a westward direction at 10 knots. At the time, maximum sustained winds reached 100 knots with a central pressure of 951 millibars. Iniki slowed even more and started to turn northwest, and about 400 miles south of Kaua'i, it strengthened with maximum winds estimated at 110 knots and gusts up to 135 knots.

Iniki continued to strengthen and accelerated as it turned more northward. Hurricane warnings were extended eastward to include the island of O'ahu. Increased maximum sustained winds were estimated at 125 knots with gusts as high as 150 knots, and the central pressure was recorded at 938 millibars, the lowest ever recorded in a central Pacific hurricane up to that time.

Iniki's Landfall and Departure: In the afternoon of September 11, the eye of Iniki crossed Kaua'i's south coast, with maximum sustained winds estimated at 145 mph over land, and gusts up to 175 mph miles. After centering 50 miles north over Kaua'i's Nā Pali coast, the hurricane warning for O'ahu was downgraded to a tropical storm warning, then cancelled.

Iniki's Damage and Destruction: Iniki's most severe wind conditions on O'ahu were measured at Wheeler Air Force Base - winds of 29 knots from the Southeast, gusting to 47 knots. At Barber's Point the winds were from the Southeast at 34 knots gusting to 45 knots. Iniki produced tides of 1.7–3 feet (0.5–0.9 m) above normal on O'ahu. Prolonged periods of storm waves superimposed on the elevated sea level severely eroded and damaged O'ahu's southwestern coast, particularly Barbers Point through Ka'ena Point. The Wai'anae coastline experienced the most damage on O'ahu, with waves and storm surge flooding the second floors of beachside apartments. Hurricane Iniki ultimately caused 2 deaths on O'ahu and several million dollars in property damage.

On Kaua'i, storm tides ranged from 4.5 to 6.3 feet above normal, with 20 to 35 foot storm waves battering south Kaua'i. Maximum flooding began at the peak of the astronomical tide, and was augmented by reduced barometric pressure. Inundation was reported at between 22-29 feet above mean lower low water (MLLW). Property damage caused by Iniki reached close to $3 billion. 1,421 homes were completely destroyed, 5,152 suffered major damage, and another 7,178 received minor damage. Electric power and telephone service were lost throughout the island, and four weeks after the storm, only 20 percent of the island's power had been restored. Crop damage was extensive, with sugar cane stripped, banana and papaya crops destroyed, and fruit and nut trees broken or uprooted.

Hurricane and Storm Surge Risk Assessment for the Proposed Irradiator Site

Strong hurricane winds and storm surges can impact the proposed Irradiator site. Flooding due to potential storm surges present a high risk for damage in the event of a hurricane. The following is a brief overview of the basic concepts used to predict and quantify surge components that cumulatively contribute to the generation of hurricane surge flooding.

Hurricane Surge

Extreme coastal water fluctuations during hurricane events are caused by a number of factors. Cumulative hurricane surge height on an open-ocean coast depends on components such as atmospheric pressure variation, the phase of astronomical tide, storm intensity, size, path, duration over water, speed of translation, winds and rainfall, initial water level rise, and surface waves and associated wave setup and runup due to wind frictional effects. The bathystrophic component is another important parameter of the coastal hurricane surge. In the northern hemisphere, hurricane winds approaching a coast have a counterclockwise motion. Because of the Coriolis effect caused by the earth's rotation, the flow of water induced by the cyclonic winds deflect to the right, causing a rise in the water level. Therefore, the bathystrophic storm tide is important in producing maximum surge even when the winds blow parallel to the coast.

To what extent the bathystrophic component will add to the flooding at a specific site on the coast depends on the storm's direction of approach. Thus, the proposed Irradiator site could be flooded to a greater extent if the hurricane makes landfall westward of the site, rather than to the east. However, even if a hurricane does not make landfall on O'ahu but passes considerably south of the island and is moving in a west/northwest direction at a distance of 150 miles or less, flooding of the Irradiator site could occur.

In a semi-enclosed basin, such as Ke'ehi Lagoon, coastal morphology, direction of hurricane approach, radius of maximum winds, coastal configuration, and geometry of the basin also affect water level rise and the degree of surge flooding. An example is hurricane Katrina, which resulted in a higher surge approaching from Lake Pontchartain, rather than from the Gulf of Mexico, causing New Orleans levees to overtop and fail.

Prediction and Quantification of Hurricane Surge

Difficulties arise in the prediction of surge flooding because a hurricane is a three dimensional weather system, with ever-changing dynamic meteorological and oceanic conditions, such as wind speeds, directions, and atmospheric pressures. Predictions are primarily based on analytic and mathematical models, which estimate interactions between winds and the ocean. Numerical models develop the three dimensional wind field of a hurricane, the radius and changing direction of maximum winds, the landfall, and the resulting storm surge flooding.

The simplest quasi-one-dimensional model is a steady-state integration of stresses of the hurricane winds on the surface of the water from the edge of the Continental Shelf to the shore. Sophisticated mathematical models have been developed in recent years to provide more accurate three-dimensional estimates of energy flux and flooding that can be caused by a passing hurricane. All mathematical models, regardless of sophistication of methodology, must use the Bathystrophic Storm Tide Theory. The NRC has used numerical models in the past *(e.g. "Pararas-Carayannis 1975 - Verification Study of a Bathystrophic Storm Surge Model", Technical Memorandum No. 50, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Washington D.C., May 1975 - supported by the NRC for the licensing of the Crystal River nuclear plant in Florida).*

To model a hurricane and calculate maximum surge heights, certain meteorological parameters must be determined, including the hurricane's central pressure index, its peripheral pressure, the radius to maximum winds, the maximum gradient wind speed, the maximum wind speed, and the speed of hurricane translation (i.e., overall speed of the system). The models must also integrate the astronomical tide, existing ambient wave conditions, ocean surface and bottom friction, and coastal topography. Once these parameters are established, complex hydrodynamic equations of motion and continuity are applied, which are then solved to determine the time history of expected sea level change associated with the hurricane at any given point along a shore. Most hurricane surge numerical model predictions are fairly accurate and have been verified with historical data. Recently developed numerical models using a three dimensional approach, faster and more efficient computers, and more accurate weather data from satellites, have greater potential for more accurate predictions.

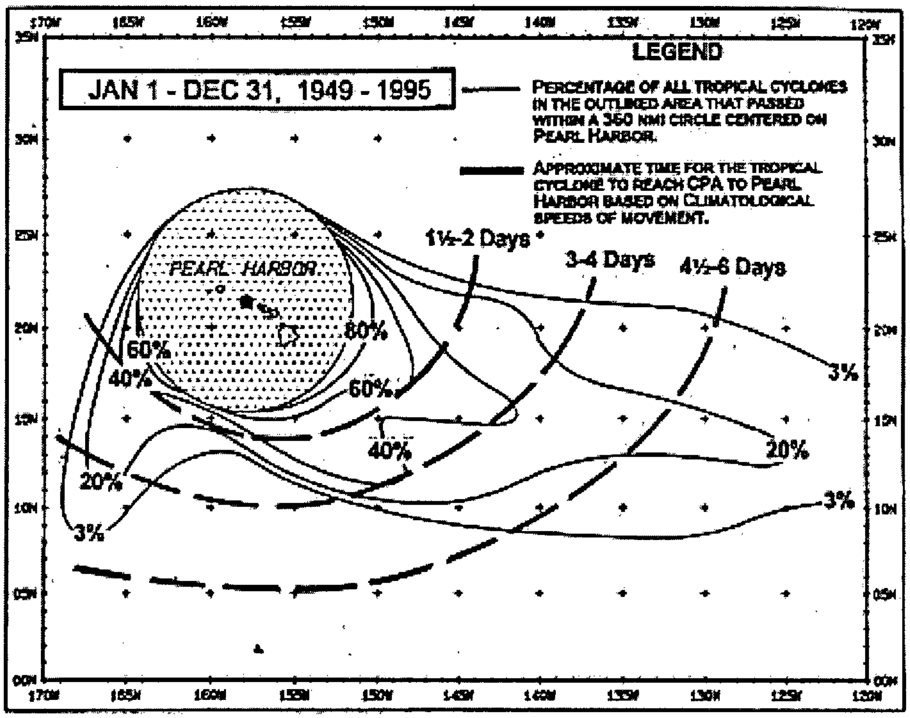
Statistical Probability of a Tropical Storm or Hurricane Striking O‘ahu

Hurricanes similar in intensity to Iniki or Iwa can be expected to occur again near the Hawaiian Islands, and could make landfall on O‘ahu or pass close to the island. For example, as Iniki's track shows, the hurricane was heading for an almost direct hit of O‘ahu 24 hours before changing direction, with the potential for much greater death and damage. Generally, a semi-permanent subtropical high-pressure ridge northwest of the Hawaiian Islands helps to keep hurricanes south of the islands. The western edge of this high-pressure ridge deflected Iniki's path from making landfall on O‘ahu or passing closer, in 1992.

Nonetheless, the high-pressure ridge can develop weaknesses, and there is no guaranty that it will always be strong enough to deflect hurricanes away from the islands. This situation occurred in September 1992, when a large low system or trough began to drift south along and just east of the International Dateline, causing the high-pressure system to weaken. The change in air mass flow caused Iniki to change its path northward, bringing it closer to the islands. If the large low system had been further east of the International Date Line, or if there were additional weakness of the Pacific High that had occurred a day earlier, Iniki could have made landfall on O'ahu. Hurricane Iwa is another example of how unexpected steering flow changes can occur. Even though Iwa appeared to be too far west of the islands and heading north, its path suddenly changed to the northeast, and the hurricane made landfall on Kaua'i.

Abrupt changes in atmospheric circulation have become more frequent in recent years, perhaps because of global warming and a more intense El Nino ocean circulation. For example, in 2006, anomalies in the flow of the jet stream caused atmospheric changes in the Central Pacific that caused four months of heavy rains and flooding in the Hawaiian Islands. Thus, it is possible that more frequent weakening of the Pacific High will occur in the future, allowing hurricanes to travel closer to the Hawaiian Islands.

The U.S. Navy has determined that there is a 80% probability of a tropical storm or hurricane passing within 360 nautical miles of Pearl Harbor (Department of Navy, Hawai'i Region, Civil Emergency Management Program Manual - Instructions for Hurricane Preparedness by Naval activities on Oahu in COMNAVBASEPEARLINST 3440.7, Pearl Harbor and Honolulu Harbor Hurricane Haven Study, Fig. 14. (see map below)). The Navy study, which was based on 27 tropical storms and hurricanes occurring from 1949-1995, indicates that there is a 20% probability that storm systems will approach O'ahu from the east-southeast direction, which would facilitate the maximum probable hurricane scenario discussed below.



Probability that a tropical storm or hurricane will pass within 360 nmi of Pearl Harbor, and approximate point of approach (CPA) (Pearl Harbor study).

Maximum Probable Hurricane Impact Scenario for the Proposed Irradiator Site

The maximum probable hurricane (MPH) at the Irradiator site would result from a Category 4 hurricane, similar in intensity to Iniki, approaching Honolulu from a southern or an east-southeast direction and making landfall west of the proposed Irradiator site at a distance corresponding to the radius of its maximum winds. The following analysis provides documentation in support of such hurricane occurrence and estimates of expected winds and surge inundation at the Irradiator site.

Sequence of Potential Winds and Surge Flooding at the Proposed Irradiator Site in Event of a Maximum Probable Hurricane on O'ahu

The following analysis provides a probable time history of wind and surge flooding effects that could be expected at the Irradiator site in the event of a MPH (category 4) with landfall near Barber's Point. Under this scenario, the proposed Irradiator site, Honolulu Airport, and the rest of O'ahu would be in the dangerous semicircle of the hurricane's impact. Sustained winds could reach up to 140 mph, with gusts up to 175 mph, and flooding would be severe.

Potential Winds: When the center of the MPH is about 180-200 miles south or southeast of Honolulu, there will be strong winds at the proposed Irradiator site, with gusts up to 35-40 mph. When the hurricane's center is about 130 miles south of Honolulu, the gusts could increase to about 55 mph. As the MPH moves closer, winds at the site will be from the east northeast with sustained speeds of 55 mph, gusting to about 60-65 mph. Wind damage will begin in the area and sea level will start rising, both in the Ke'ehi Lagoon and the open coast along the reef runway.

As the MPH gets even closer to Honolulu, the winds in the airport area will be from the east (090) with average sustained speeds of about 80 mph and gusts ranging from 115 mph to 140 mph. Because the wind design threshold of 80 to 100 mph that applies to most of the buildings within the Honolulu airport will be exceeded, gradual wind damage will begin.

As the center of the MPH nears the Honolulu coastline (perhaps 40 miles away or closer), winds will be down slope and at their strongest. Thus, maximum winds can be expected along the southern coast of O'ahu at the proposed Irradiator site before the hurricane's eye makes landfall. Maximum sustained winds will be from an east-southeast direction at speeds of about 140 miles per hour with peak gusts up to 175 miles per hour. At this time, major damage to the airport hangar buildings in the area will occur. Also, the frictional effects of the wind will be in a landward direction along Ke'ehi Lagoon.

Potential Hurricane Surge Flooding Effects: The flooding effects at the proposed Irradiator site, the reef runway, and the entire southern and eastern coast of O'ahu will vary depending on the hurricane speed of translation when it is near or over the island. A slow moving hurricane with very low central barometric pressure (950 mm) will cause more flooding than a fast moving one. Because the end of Palekona Street is at the apex of the Keehi Lagoon, flooding will begin near the Irradiator site.

Maximum flooding of 5 to 7 feet will occur if the hurricane makes landfall near the time of the highest astronomical tide (spring tide). After the center of the MHP crosses the southern coast of O'ahu near Barber's Point, the wind direction can be expected to change rapidly from the eastern direction to south-southeast and then to a southern direction. Maximum surge flooding will begin to occur along the ocean side of the reef runaway, and the protective wall will be breached completely.

At this time, wind friction, the bathystrophic component, and the wave setup will be at a maximum along the reef runway. Coupled with the maximum astronomical tide and the rise in sea level due to reduced atmospheric pressure (as the hurricane center passes), maximum flooding will result along O'ahu's south coast and east of the hurricane's trajectory path. Storm waves will be superimposed on the elevated sea level and intensified at the proposed Irradiator site when the landward component of wind friction aligns along the 3-4 mile fetch within Ke'ehi Lagoon, causing a pile-up of waves at the end of Palekona Street, and flooding the proposed Irradiator site from the Lagoon.

Conclusions: Both winds and flooding from a severe hurricane could adversely impact the Irradiator site, resulting in damage to the facility's superstructure. Additional collateral damage could result from hurricane winds and surges uprooting trees and damaging airport hangar facilities and grounded airplanes. The airplanes, trees, and other debris in the area could act as missiles flying through the air and structurally damage the facility. Because nearby aviation fuel storage tanks could ignite, fire is also a potential hazard.

Because of its low elevation, the proposed Irradiator site is also vulnerable to damage by small hurricanes and hurricanes that do not pass directly over or near O'ahu. As discussed above, for example, even with Iniki passing far from O'ahu, the Wai'anae coastline experienced flooding reaching the second floor of beachside apartments. Category 1 or 2 hurricanes can be expected to flood the proposed Irradiator site by about 1-3 feet of water. In the event of a Category 3 or 4 hurricane, inundation of up to 5-7 feet is possible, due to the combination of storm surges and storm waves. The entire reef runway and the proposed Irradiator site can be expected to flood.

The applicant's Geoanalytical Report confirms the existence of past storm surge deposits in the area (p. 192). In view of such considerations, the engineering design of the proposed Irradiator must take into consideration at least the wind and surge flooding effects for the MPH scenario described above, which is for a Category 4 event.

In addition, the Geoanalytical Report states that approximately 760 pounds per square foot would be exerted against the bottom surface of the Irradiator pool at foundation level. The buoyancy pressure at the foundation level can be expected, however, to increase significantly under hurricane surge flooding conditions. Therefore, an additional buoyancy assessment of the proposed irradiator pool for various flooding levels must be performed to ensure the pool (1) will maintain its integrity (i.e., not be breached) and (2) will not tilt, losing vital shielding water and possibly damaging the Cobalt-60 sources, under hurricane surge flood conditions.

Comments on CNWRA Report and EA's Hurricane Analysis

Incorrect Assessment of Potential Peak Winds at the Proposed Irradiator Site – The CNWRA evaluation of maximum possible wind speeds of 168 km/h [105 mph] (the American Society of Civil Engineers standard) at the proposed irradiator site is insufficient. The designation of the site as Exposure Category C contradicts the CNWRA Report's correct assertion that Hurricane Nina (in 1957) produced record winds with gusts of 131 km/h [82 mph] at the Honolulu International Airport.

Also, the CNWRA's analysis and conclusions are based on data that goes back only to 1950, and incorrectly assumes that all future hurricanes in the region always pass south and west of O'ahu and that none will ever pass closer or make landfall on the island. As discussed above, this is simply not correct. Hurricane Hiki in 1950 passed north of O'ahu. Other tropical storms passed directly over O'ahu. In 1957, Nina – only a category 1 hurricane - passed at a distance which was even further west of O'ahu than that of hurricanes Iniki (1992) and Dot (1959). Nina's record winds of up to 131 km/h [82 mph] at the Honolulu International Airport significantly exceeded the maximum wind speeds for designation of the irradiator site to Category C Exposure.

The American Society of Civil Engineers standard designating maximum possible wind speeds of 168 km/h (105 mph) represents an underestimate for the proposed site, even if a hurricane passes to the south and west of O'ahu. Even without landfall on O'ahu, a hurricane similar to the 1994 Iniki (category 4), with as small of a diameter, passing south of O'ahu and heading in a northwest direction at a distance which corresponds approximately to the radius of its maximum winds, can be expected to have sustained winds of up to 225 Km/hr (about 140 mph) and gusts of as much as 280 Km/hr (175 mph) at the Honolulu International Airport.

The conclusion that there is no danger to the proposed site because no hurricane on record had a direct landfall on O'ahu is misleading. The historic record on storms and hurricanes in the Hawaiian Islands covers only a short period of time. Contrary to the CNWRA analysis, as discussed above, a future hurricane could make landfall on O'ahu's southern shore or pass closer to the island.

Incorrect Assessment of Hurricane Surge Risk - The CNWRA and EA hurricane surge risk analysis for the proposed irradiator site is unrealistic. The CNWRA Report applies the "stylized fluid dynamic calculation" prepared for the tsunami risk analysis (discussed at page 18 below), and concludes that because tsunami waves cannot generate the "wave velocity and shear forces necessary to create a vortex inside the pool that would pull a radioactive Co-60 source assembly out of the irradiator pool," then it follows that hurricanes waves could not either. First, the conclusion is based on the erroneous presumption that hurricane surges and tsunami waves behave similarly, which they do not. For example, tsunami waves have shorter periods than hurricane surges, so hurricane surges can create flooding at the site that will last considerably longer than flooding from tsunami waves.

Second, the analysis incorrectly assumes that the only safety consideration for the proposed Irradiator site is wave velocity lifting the radioactive source from the pool. Forces other than drag force could affect the safety of the Irradiator if flooded by storm surges. For example, buoyancy forces from a rise in sea level due to hurricane surge may lift or tilt the Irradiator pool and radioactive effluent could drain into the surrounding environment. The CNWRA Report also ignores other effects of potential hurricane surges to the safety of the site, such as failure of electric power supply, the destruction of back up generators that are needed to run Irradiator pumps, possible fires from nearby fuel depots, aircraft or equipment crushing against the Irradiator facility, or concurrent wind effects on the facility, and the mixing of seawater into the Irradiator pool.

Incorrect Assessment of Potential Hurricane Surge Heights - The CNWRA Report incorrectly assesses the height of sea level flooding that can be expected on O'ahu from potential storm surges and downplays the impact on the safety of the Irradiator. It concludes erroneously that none of the hurricanes that have passed near O'ahu since the 1950's "have produced a storm surge that would pose a hazard to the facility." The Report incorrectly assumes that storm surges "appear to be bounded by the more significant wave heights that could be generated by tsunamis." In fact, potential hurricane surges could result in longer and more extensive flooding at the site than from tsunamis. The analysis completely overlooks the proximity of the proposed site to the shoreline of Ke'ehi Lagoon, and the long fetch of the Lagoon along which hurricane wind frictional effects could add to other surge height components. Because the applicant's Geoanalytical Report confirms the existence of past storm surge deposits in the area (p. 192), the CNWRA Report and the EA are deficient in their failure to take into consideration the wind and surge flooding effects for the MPH scenario (i.e., a Category 4 event).

The EA bases its conclusion of no significant impact on Table 3.3, which lists the historical tropical cyclones within 322 km (200 mi) of Honolulu International Airport and the associated maximum water levels above mean sea as recorded by the National Water Level Observation Network and referenced to Honolulu Station 1612340. Based on this limited database for the Honolulu station only, the CNWRA report concludes that since the maximum water-level produced by Iniki in 1992 was 0.78 m (2.6 ft) at this station, this represents the maximum possible water-level of hurricane surge that can be expected in the future, and therefore this assures the safety of the proposed site.

The CNWRA conclusion is erroneous. The value of 2.6 ft above mean sea level for Iniki, which was recorded by the Honolulu Station (owned and maintained by NOAA's National Ocean Survey), and the 2.6 ft height that is given, represents an instrumental recording by a tide gauge inside the harbor (at end of Pier 4). This station, which is also a tsunami tide gauge station, filters out the short-period storm waves that contribute to the total hurricane surge heights. The storm waves superimpose on other component parts of the hurricane surge and contribute significantly to greater maximum water level heights of the destructive hurricane effects (Pararas-Carayannis, 1975). Such tide gauge measurements do not, therefore, give accurate or realistic measurements of expected hurricane surge inundation on the island. In fact, along the Wai'anae coast, Iniki's hurricane surge reached the second story of apartment buildings and houses and was extremely damaging.

TSUNAMI HAZARDS

As detailed below, the proposed Irradiator site is within the O'ahu Civil Defense tsunami evacuation zone and is at risk of flooding from tsunamis. This section provides a detailed description of recent tsunami events in Hawai'i and analysis of the risk from potential future tsunami events on the proposed Irradiator site.

Tsunami Hazard Risk Assessment

The primary source of historical tsunami data is the "Catalog of Tsunamis in the Hawaiian Islands," (Pararas-Carayannis 1967, 1974, 1977) published by the Hawai'i Institute of Geophysics of the University of Hawai'i, updated in 1974 by the World Data Center A-Tsunami, and further updated in 1977 by the World Data Center -A for Solid Earth Geophysics (U.S. NOAA).

The runup data for major tsunamis impacting Hawai'i in 1946, 1952 1957, 1964 and 1975 is based on original measurements and observations initially plotted on the U.S. Geological Survey Topographic Quadrant Maps (Scale, 1:24,000) at the Hawai'i Institute of Geophysics (HIG) (Pararas-Carayannis, 1964, 1965, 1967). These maps were subsequently summarized and republished on charts supplied to the State Tsunami Observation Program and Civil Defense agencies (Walker 2002). The National Geophysical Data Center also compiled secondary data from the original HIG maps (Lander and Lockridge, 1989).

Historical Pacific-wide and locally generated tsunamis affecting O'ahu

The following overview discusses the six major tsunamis that have affected south O'ahu in the last 50 years – 1946 (Aleutians), 1952 (Kamchatka), 1957 (Aleutians), 1960 (Chile), 1964 (Alaska), and 1975 (Hawai'i).

April 1, 1946 Aleutian Tsunami - One of the most destructive Pacific-wide tsunamis was generated by a magnitude 7.8 earthquake near Unimak Island in Alaska's Aleutian Island chain. A 35-meter wave completely destroyed the U.S. Coast Guard's Scotch Cap lighthouse on Unimak, killing all five occupants. Five hours later, destructive tsunami waves reached the Hawaiian Islands and completely obliterated Hilo's waterfront on the Big Island, killing 159 people. At the Big Island's Laupahoehoe Point, waves reached up to 8 meters and destroyed a hospital and a school, both of which had not been evacuated. Altogether, 165 people were killed across the islands and property damage was estimated at $26 million in 1946 dollars.

November 4, 1952 Kamchatka Tsunami - A magnitude 8.2 earthquake off the Kamchatka Peninsula generated the 1952 tsunami which was felt throughout the Pacific Rim including the Kamchatka Peninsula, the Kuril Islands and other areas of Russia's Far East, Japan, Peru, Chile, New Zealand, Alaska and the Aleutian Islands, and California. The largest waves were recorded in the Hawaiian Islands, outside the generating area. Damage was estimated to reach up to $1 million in 1952 dollars. Boats and piers were destroyed, telephone lines downed, and extensive beach erosion observed.

O'ahu's north shore experienced waves up to 4.5 meters, while on the south shore, the tsunami was powerful enough to throw a cement barge in the Honolulu Harbor into a freighter. On the Island of Hawai'i, tsunami runup reached 6.1 meters, and the bridge connecting Coconut Island in Hilo Bay to the shore was destroyed by a tsunami wave lifting it off its foundation and smashing it down.

March 9, 1957 Aleutian Tsunami - An 8.3 magnitude earthquake off Alaska's Aleutian Islands of Alaska generated the 1957 Pacific-wide tsunami. Property damage in the Hawaiian Islands was estimated at $5 million in 1957 dollars. Waves on the north shore of Kaua'i reached 16 meters, flooding the highway and destroying houses and bridges. At Hilo, Hawai'i, the tsunami runup reached 3.9 meters, damaging buildings along the waterfront and covering Coconut Island with 1 m of water. The bridge connecting it to the shore was again destroyed.

May 22, 1960 Chilean Tsunami - The largest earthquake (magnitude 8.6) of the 20th century occurred off the coast of Chile and generated the 1960 Pacific-wide tsunami. 2,300 people were killed in Chile alone, and more lives were lost throughout the Pacific. 61 people were killed in Hilo, Hawai'i, and property damage there was estimated at more than $500 million in 1960 dollars.

March 28, 1964 Alaska Tsunami – In 1964, a magnitude 8.4 earthquake off Alaska produced a tsunami that affected southeastern Alaska, Vancouver Island (British Columbia), Washington, California and Hawai'i, killing more than 120 people and causing $106 million in damages.

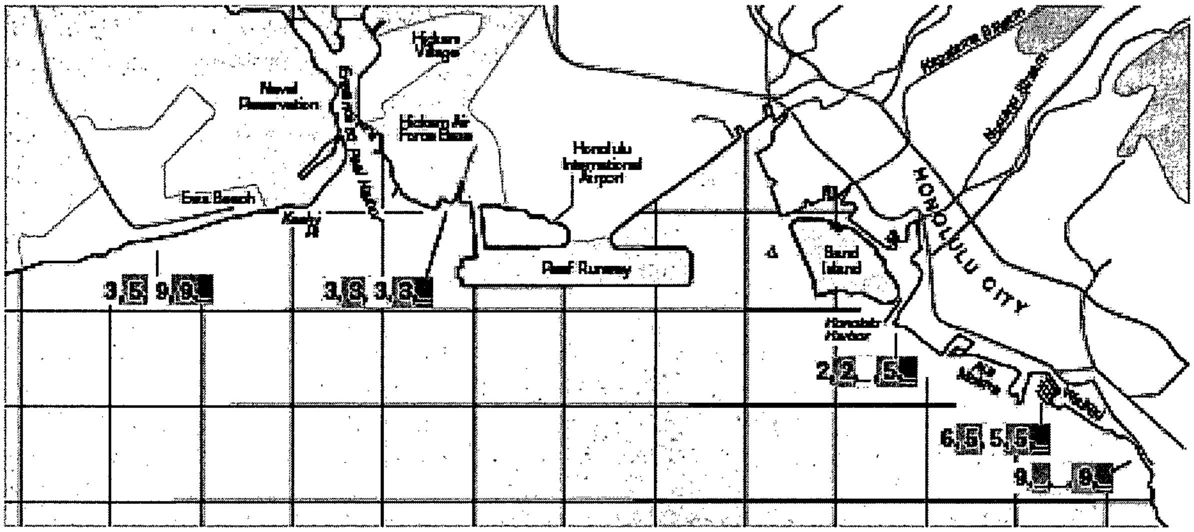
November 29, 1975 Local Hawai'i Tsunami: A 7.2 magnitude earthquake on Hawai'i Island's south coast caused the most recent local tsunami on November 29, 1975. The tsunami was destructive throughout Hawai'i Island.

Historical Tsunami Runup Heights Along the Southern Coast of O'ahu

Tsunami waves can be measured in terms of runup height and inundation. The tsunami inundation limit is the horizontal measure of the maximum inland penetration of the tsunami waves from a certain reference point, such as mean sea level. In other words, the farthest distance inland that tsunami waves traveled. Runup refers to the maximum inland elevation reached by tsunami waves, also generally measured in reference to the mean sea level. Thus, if the reference point is mean sea level, runup is the elevation of the inundation limit.

Interpolations of tsunami runup at the proposed Irradiator site can be made based on reliable runup measurements taken from the coastal areas to the east and west of the Honolulu Airport during the tsunamis of 1946 (Aleutian Islands), 1952 (Kamchatka Peninsula), 1957 (Aleutian Islands), 1960 (Chile), and 1964 (Alaska). As shown in the map below, tsunami runup on south O'ahu shores has reached up to 9 feet, contrary to the incorrect statement made in the CNWRA Report that maximum recorded runup since 1837 is 3 feet.[2]

[2] Prior to 1946, Chilean earthquakes generated tsunamis with considerable runups in Honolulu in 1837 (over 8-foot runup), 1868 (over 5-foot runup) and 1877 (almost 5-foot runup) (Pararas-Carayannis, G., and Calebaugh P.J., 1977. Catalog of Tsunamis in Hawaii, Revised and Updated, World Data Center A for Solid Earth Geophysics, NOAA, 78 p., March 1977).



Tsunami Runup in feet for the 1946 (pink), 1952 (red), 1957 (yellow), 1960 (green) and 1964 (blue) tsunamis near the proposed site for the Irradiator.

Because harbors and basins react differently with each tsunami, under the right set of conditions, a tsunami with minimal runup on the open coast results in greater runups and stronger currents within a harbor or semi-enclosed body of water. This can occur when resonance effects excite a basin's natural modes of oscillation, resulting in greater runups and stronger currents. Greater runups can also be generated when certain wave periods combined with certain drainage characteristics of a basin create a cumulative pile-up effect within the basin.

For example, in 1964, the pile-up effect caused extensive flooding and property damage in Port Alberni, Canada, at the head of a 35-mile long inlet on the west coast of Vancouver Island. The first tsunami wave to reach the head of the inlet caused major flooding, but the second wave, which arrived almost an hour later, caused the most destruction. Although the total tsunami energy that entered the inlet was relatively small, a pile-up effect likely caused the second wave to gain force, resulting in greater wave height and runup.

Notably, all the tsunami runup data on which the CNWRA report and DEA rely predate the massive alterations of Ke'ehi Lagoon caused by dredging the lagoon for construction of Honolulu Airport's reef runway, which began in 1973. Dredging deepened Ke'ehi Lagoon, which could increase resonance effects and cumulative pile-up of a tsunami at the apex of the basin, which, incidentally, is at the end of Palekona Street. Only numerical modeling, which neither the CNWRA Report nor the DEA have performed, can reveal the full effects of dredging the lagoon and altering the shoreline.

Tsunami Warnings

Tsunami warnings are issued throughout the state by the Hawai'i Civil Defense based on warnings of the international Pacific Tsunami Warning Center. For tsunamis of distant sources, warnings are issued in Hawai'i about three hours before the tsunami's estimated arrival, although earlier advisories may also be issued. Warnings often stay in effect for several hours before cancellation, because the danger of a tsunami often lies in multiple waves.

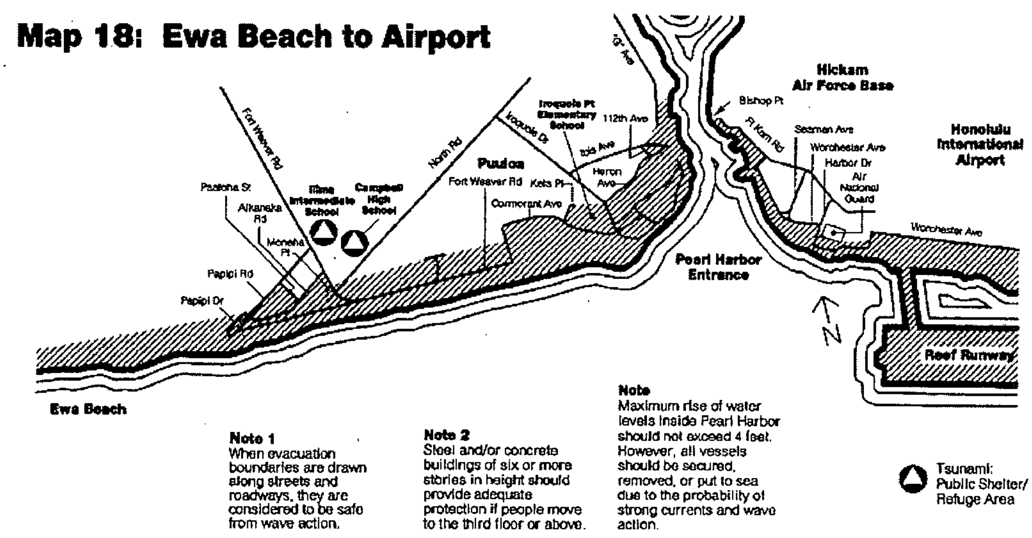
Tsunami Evacuation Areas in the Vicinity of the Proposed Irradiator Site

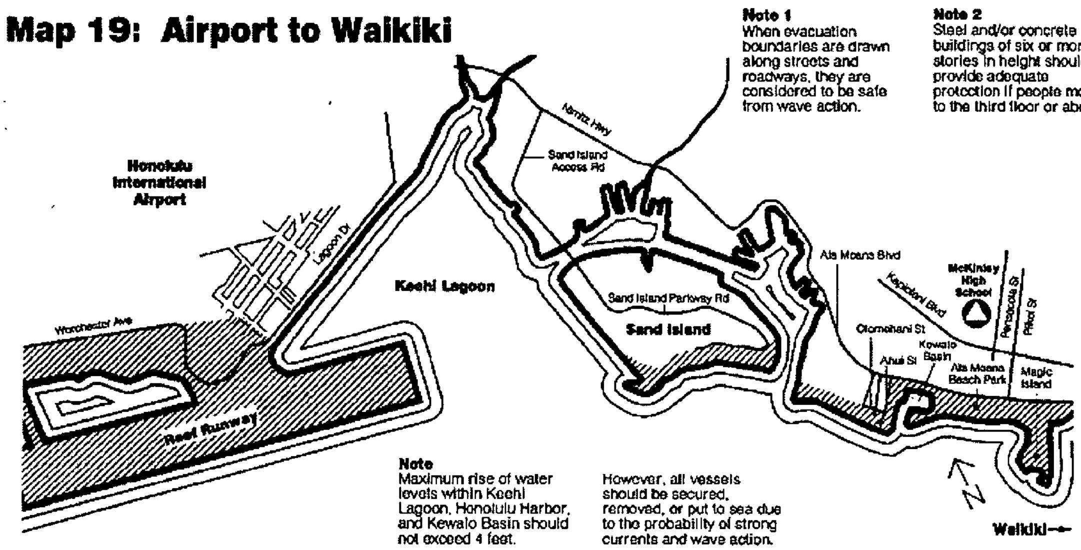
The Hawai'i State Civil Defense requires evacuation of all low lying coastal areas, marked as "tsunami zones" on Civil Defense maps, when tsunami warnings are issued for waves of over 3 feet. When a tsunami warning is issued, the present guidelines recommend evacuating, vertically or horizontally, to a location at least 50 ft above sea level.

Map 19, provided below, indicates that the tsunami evacuation zone currently extends to the 'ewa (west) side of the last street on Lagoon Drive. Because Palekona Street is the last street on Lagoon Drive, and the proposed Irradiator site is on the 'ewa side of Palekona Street, the proposed Irradiator site is within the tsunami zone. Map 18 and 19 also show that the entire reef runway is within the tsunami zone.

Current evacuation maps are based on original maps prepared by the late Prof. Doak Cox and the present reviewer, which relied primarily on historical tsunami data using empirical methods, rather than numerical modeling (Cox & Pararas-Carayannis, 1967). This method tends to underestimate the potential impact of a tsunami, including inundation limits and runups. For example, unusual underwater or shoreline barriers such as reefs, roads, trees, buildings, and other features could focus the tsunami energy so strongly that runups and inundations could far exceed current estimates.

The State Civil Defense, in accordance with the National Tsunami Hazards Mapping Program guidelines, is in the process of updating the current evacuation maps based on accurate numerical modeling of maximum expected tsunami runup values for a given shoreline. The present reviewer is a member of the scientific advisory committee preparing the updated maps.





Tsunami Evacuation Maps from Ewa Beach to Airport, and from Airport to Waikiki (shaded areas indicate potential inundation zones that need to be evacuated horizontally or vertically in solid structures)

<u>Tsunami Risk Assessment for the Proposed Irradiator Site</u>

Due to its low elevation (3-6 feet, depending on tide) and proximity to Ke‘ehi Lagoon (375 feet), the proposed Irradiator site is vulnerable to the impacts of a future tsunami, particularly to flooding from the Ke‘ehi Lagoon.

Probability of Tsunami Occurrence: Based on the historical record, there is a 100% statistical probability that a major Pacific-wide tsunami will occur again and greatly impact the Hawaiian Islands. The last Pacific-wide tsunami occurred in 1964, and a major tsunami is long overdue. Likely source areas for the generation of major tsunamigenic earthquakes that will affect Hawai‘i are the Aleutian Trench, the Gulf of Alaska, and the Chile-Peru Trench.

Potential Tsunami Impact at the Proposed Irradiator Site: The following assessment of the tsunami hazard for the proposed Irradiator site is based on a physical inspection of the site, during which geological conditions; elevation above sea level; distance to the Ke‘ehi Lagoon shoreline; background materials submitted with Pa‘ina Hawaii's NRC application pertaining to engineering design; photographs; and all available historical tsunami runup data were assessed.

The proposed Irradiator site is relatively flat, with a normal elevation of about 6 feet above mean sea level. During the highest spring tide, elevation is less than 3 feet. The site is 373 feet from the Ke‘ehi Lagoon shoreline, and there is no berm or physical barrier between the site and Ke‘ehi Lagoon. The Irradiator site is in a tsunami evacuation zone and is near a coastal region that has been inundated by tsunamis in the past.

Due to its low elevation, it is possible that tsunami waves will flood the Irradiator site from the Ke‘ehi Lagoon. As previously discussed, a tsunami that generates small runup on the adjacent open coast can still be damaging within Ke'ehi Lagoon. Resonance caused by the tsunami may excite Ke'ehi Lagoon's natural modes of oscillation, and/or cumulative wave pile-up effects may occur near the head of the Ke'ehi Lagoon basin, either of which would cause greater runup within Ke'ehi Lagoon than the open coast.

Recent numerical studies for the Hawai'i Kai Basin involving tsunami waves of different periods show overtopping of the highway and cumulative effects of runup at the head of the basin.[3] Like the Hawai'i Kai basin, Ke'ehi Lagoon is a semi-enclosed body of water, and under the right conditions, a similar cumulative pile-up effect could occur at the apex of the basin, which is near the proposed Irradiator site. Combined with a high astronomical tide, tsunami waves could overtop the retaining wall at the end of Palekona street and flood the site.

Even without flooding, because of the site's proximity to Ke'ehi Lagoon, a lesser tsunami run-up, superimposed on the ambient water table, could create buoyancy uplift forces on the concrete slab floor and Irradiator platform housing.

Comments on CNWRA Report and EA's Tsunami Analysis

Tsunami Evacuation Limits – The EA and the CNWRA Report both fail to assess or even mention the fact that the proposed Irradiator site is in a tsunami evacuation zone, based on the Civil Defense maps. Also, the CNWRA Report incorrectly states that the O'ahu Civil Defense Agency tsunami flood maps (2006) show the Honolulu International Airport above the tsunami evacuation zone. The Civil Defense maps in fact show that the reef runway and some peripheral airport facilities are within the zone of potential tsunami inundation.

Incorrect Assertion of Tsunami Runup – The CNWRA Report quotes a May 2005 letter from the State of Hawai'i's Department of Transportation, which incorrectly states that "the south shore of O'ahu has never sustained more than a 3 [foot] wave from any tsunami since 1837." Contrary to this assertion, the historic runup record shows that a 1946 tsunami reached a maximum runup on O'ahu's southern coast of 31 feet (Pararas-Carayannis, G., and Calebaugh P.J., 1977, Catalog of Tsunamis in Hawaii, Revised and Updated, World Data Center A for Solid Earth Geophysics, NOAA, p. 78, March 1977). The O'ahu Tsunami Runup Maps show that the 1957 and 1960 tsunamis had maximum runups of 9 feet in east Pearl Harbor. Three Chilean earthquakes generated tsunamis with runup in Honolulu of over 8 feet in 1837, over 5 feet in 1868, and nearly 5 feet in 1877.

Inadequacy of Tsunami Inundation Assessment – The CNWRA Report does not properly consider flooding due to a tsunami. First, the analysis inaccurately relies on tide gauge recordings as evidence of low tsunami runup. Tide gauges filter out short period waves, giving smaller runup heights. Second, the report fails to distinguish between tsunami runup heights (a vertical measurement) with tsunami inundation limits (horizontal measures of inland penetration of a tsunami's waves). In low-lying areas, tsunami inundation can extend inland for several

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[3] Personal communication with Dr. Charles Mader, Los Alamos National Laboratory (LANL). Author provides LANL scientists with tsunami source parameters for tsunami modeling studies. Hawai'i Kai Basin models were prepared to illustrate to the Hawai'i Civil defense the potential vulnerability of the coastline from tsunamis with certain characteristic periods and wavelengths.

hundred yards, even with relatively low runup, depending on the stage of the astronomical tide and the ambient storm wave conditions at the time the tsunami arrives. Third, as explained above, small tsunami run-up height on an open coast does not necessarily mean that the tsunami will not be damaging inside a harbor or within a semi enclosed body of water. The CNWRA Report failed to take into account resonance effects or cumulative pile-up that could occur within Ke'ehi Lagoon and cause higher runup at the proposed Irradiator site than on the open coast. Fourth, runup potential cannot be adequately quantified without a proper numerical modeling study, which CNWRA failed to do. Fifth, the report fails to take into account potential damage from strong currents generated by certain periods of tsunami waves within Ke'ehi Lagoon, which can increase runup.

Irrelevant Assertion of Site Safety Based on the Stylized Fluid Dynamic Calculation - The CNWRA Report's "stylized fluid dynamic calculation" is devoid of any realistic practical value in assessing the potential tsunami hazard or risk to the proposed irradiator site. The calculation does not demonstrate the safety of the site from the potential impacts because it assumes that lifting the source assembly out of the pool is the only danger to the public. It ignores other potential direct impacts and collateral damage, such as failure of peripheral equipment, power and back up generators needed to circulate and cool water in the irradiator pool, leaking of pool water, and dispersal to the surrounding area by potential tsunami flooding, fires from nearby fuel depots, or aircraft or equipment carried and crushing against the irradiator facility, which could affect the integrity of the pool, causing shielding pool water to leak. Reliance on the stylized fluid dynamic calculation further indicates a lack of understanding of a tsunami's terminal characteristics when it moves over land; there is no structured wave form but a chaotic turbulent water mass that cannot be very well correlated to "wave velocity and shear forces necessary to create a vortex inside the pool that would pull a radioactive Co-60 source assembly out of the irradiator pool."

SEISMIC HAZARDS

Historical earthquakes in the Hawaiian Islands are well-documented in the modern (1959–1997) and historic (1868–1959) catalog of the Hawaiian Volcano Observatory. Earthquakes generated within the Moloka'i Fracture Zone and/or the postulated Diamond Head Fault resulted in the upgrade of O'ahu's seismic code from seismic zone 1 to zone 2A.

Historic O'ahu Earthquakes

Earthquakes felt on Oahu generally occur on the Moloka'i Fracture Zone, a seafloor zone of lithospheric weakness south of O'ahu. Two of the largest historical earthquakes, the Lāna'i earthquake of 1871 and the Maui earthquake of 1938 (both about magnitude 7) occurred within the Moloka'i Fracture Zone's complex of ridges and escarpments, which cross the islands south of O'ahu. The 1871 earthquake near Lāna'i caused damage to every building on the Punahou School campus in Honolulu due to an apparent directional focusing of energy. As recently as 27 July 2006 a magnitude 4.5 earthquake occurred 37 km (23 miles) SSW of Mākena, Maui – shaking buildings in Honolulu. In 1948, a magnitude 4.8 earthquake occurred offshore from Honolulu, and caused cracks and other damage in many Honolulu buildings. The 1948 earthquake could have been generated within the Moloka'i Fracture Zone or the postulated

Diamond Head Fault.

<u>Comments on CNWRA Report and EA's Seismic Activities Analysis</u>

Seismic Ground Motions and Potential of Liquefaction - The CNWRA Report improperly trivializes the potential intensity of ground motions and liquefaction potential at the proposed Irradiator site. The Report relies on the assumption that the Modified Mercalli Intensity V estimated for the island of O'ahu for the October 2006 earthquake, which is based on damage reports and observations, also represents the maximum earthquake ground forces that can be expected at the proposed Irradiator site at Honolulu Airport. Unlike magnitude, which represents a single quantity of an earthquake's energy release, intensity does not have one single value for a given earthquake, but can vary significantly from place to place depending on substrata soil conditions. Because the Modified Mercalli Intensity estimate may not have taken into account the properties of unconsolidated sediments, the assumption that maximum ground forces at Honolulu Airport of Intensity V may be incorrect for the proposed Irradiator site. Similarly, the potential horizontal seismic ground motions given in Table 3-1 of the report represent statistical estimates for the southern coast of O'ahu which may not necessarily be valid for the proposed facility site, which is on land reclaimed with unconsolidated sediments.

The Report also fails to consider the potential focusing effects of seismic energy on O'ahu, which can intensify earthquakes with small magnitudes. For example, the 15 October 2006 Hualālai earthquake on O'ahu resulted in relatively high intensity, even though the magnitude was only 6.7 (considerably less than that of 1868 and 1975 earthquakes) and the focal depth was quite deep at 29 km. Unfortunately, it is not known whether any accelerometer readings were taken for this event near Honolulu Airport or elsewhere on the island. Other examples are the 1948 4.6 magnitude earthquake that caused cracks and other minor damage in many Honolulu buildings, and the 1871 earthquake near Lāna'i, which damaged every building on the Punahou School campus in Honolulu. Like the 2006 event, these two historical earthquakes indicate that there is an apparent directional focusing of seismic energy on O'ahu from certain seismic sources which could affect the proposed Irradiator site.

Following an earthquake, ground liquefaction of unconsolidated sediments results primarily from vertical rather than from horizontal ground motions. For example, considerable liquefaction and damage to new buildings occurred in Mexico City during the Great Earthquake of 19 September 1985. Although the epicenter was more than 300 Km away, the valley of Mexico experienced acceleration up to 17% g. with peaks concentrated at 2 sec. period. The extreme damage in Mexico City was attributed to the monochromatic type of seismic wave with this predominant period causing 11 harmonic resonant oscillations of buildings in downtown Mexico City (Pararas-Carayannis, 1985). The ground accelerations were enhanced within a layer of 30 ft. of unconsolidated sediments underneath downtown Mexico City, which had been the site of a lake in the 15th Century, causing many buildings to collapse.

Similarly, the 17 January 1994 Northridge Earthquake had unusually high ground accelerations, even though it had a moment magnitude (Mw) of only 6.7. Extremely strong ground motions - among the strongest ever recorded - occurred in areas in the valley that had thick accumulations of unconsolidated sediments, amplifying the seismic energy and causing extensive damage to the well-developed metropolitan areas of the San Fernando Valley. Accelerations in the range of 1.0 g and up to 1.78 g were recorded over a large area, and the Modified Mercalli Intensities ranged from VIII to XI (Pararas-Carayannis, 2000). The earthquake was felt over an area of more than 200,000 square kilometers and as far away as 400 kilometers from the epicenter, and landslides and ground failures occurred as far away as 90 kilometers from the epicenter. Extensive ground liquefaction and landslides damaged many structures in San Fernando Valley.

Insufficiency of Load-Bearing Soil Evaluation - The CNWRA Report states that the proposed irradiator pool will be fabricated and installed in accordance with applicable industry codes - but without indicating whether a similar construction of an irradiator has been made elsewhere on reclaimed land that has similar soil conditions. The Report further states that most of the irradiator pool will be below sea level and the load-bearing capability of the soil at the site cannot be evaluated until the pool excavation phase is conducted. Regardless of the soil bearing capacity, there may be a propensity for liquefaction if earthquake ground motions are enhanced due to focusing of seismic waves, particularly if peak ground accelerations exceed 0.20 g.

<u>Conclusions Regarding Safety of Proposed Irradiator at Honolulu International Airport</u>

The DEA and CNWRA Report conclusions that the potential effect of hurricanes, tsunamis, and earthquakes are insignificant are misleading. The site proposed for the construction and operation of the Honolulu Irradiator is clearly marginal and potentially unsafe given its low elevation above sea level, proximity to Ke‘ehi Lagoon, and location in the tsunami evacuation zone. The site is particularly vulnerable to potential flooding by future hurricane surges and tsunamis, which could pose environmental risks to public health and safety. Locating the site inland and away from the shores of Keehi Lagoon would eliminate the risk of impacts from tsunami runup and hurricane storm surges.

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)	
Pa'ina Hawaii, LLC	)	Docket No. 030-36974
	)	
Materials License Application	)	
	)	

**DECLARATION OF DR. WILLIAM W. AU
IN SUPPORT OF PETITIONER'S AREAS OF CONCERNS**

I, William W. Au, declare that if called as a witness in this action I could testify of my own personal knowledge as follows:

1. Since 1991, I have been employed as a Professor in the Department of Preventive Medicine and Community Health, University of Texas Medical Branch, in Galveston, Texas. My office address is: Division of Environmental Toxicology, Department of Preventive Medicine and Community Health, Ewing Hall, 700 Harborside Drive, University of Texas Medical Branch, Galveston, Texas 77555-1110.

2. My curriculum vitae indicating my professional qualifications as a toxicologist is attached hereto as Exhibit "A." My primary research interest is in conducting molecular and cellular studies to elucidate toxicological mechanisms for the induction of human disease. Since obtaining my Ph.D. from the University of Cincinnati, I have more than 20 years of experience teaching, conducting and publishing peer-reviewed research, consulting and speaking internationally, editing professional publications, and serving on numerous expert committees. I am a member of the major scientific societies related to toxicology and have received approximately one dozen awards recognizing my professional contributions. I have delivered

more than 35 invited lectures internationally and published or co-published more than 200 articles in the toxicology field.

3. I have been retained by Concerned Citizens of Honolulu as an expert witness in a proceeding before the U.S. Nuclear Regulatory Commission (NRC), regarding an application by Pa'ina Hawaii, LLC for a license to build and operate a commercial pool type industrial irradiator in Honolulu, Hawai'i, to treat tropical fruit and other produce grown in Hawai'i for fruit flies, so that the produce may be exported to the continental United States.

4. The purpose of this declaration is to provide an evidentiary basis for Concerned Citizens' contention that, due to the significant scientific controversy surrounding the health impacts of consuming the irradiated food that the Pa'ina Hawaii irradiator would produce, "special circumstances" exist that distinguish this project from more common medical instrument sterilization and other non-food irradiators, precluding the NRC's use of a categorical exclusion from the National Environmental Policy Act's mandate to prepare either an environmental assessment or environmental impact statement for the proposed license. 10 C.F.R. § 51.22(b); see also id. § 2.335(b); 40 C.F.R. § 1508.4.

5. In formulating my opinions, I have reviewed relevant documents and studies and conducted independent research. I have also published a paper in an international, peer-reviewed journal on health hazards from the consumption of irradiated food (Ashley et al., 2004).[1]

6. My opinions, based on a reasonable degree of scientific certainty, are as follows:

a. The use of radiation to treat produce destined for human consumption for fruit flies and other agricultural pests should be evaluated for health concerns very carefully. Radiolytic products are formed during the irradiation of food (Schubert, 1969). Some radiolytic

[1] Full citations to the studies cited herein are attached to this declaration as Exhibit "B" and incorporated herein by reference.

products are unique to the food irradiation process, and there are scientific data indicating their potential health hazards. More research is needed on the products that are unique to the irradiation process.

b. A recently-discovered unique class of radiolytic products that are generated from the irradiation of fat-containing food is 2-alkylcyclobutanone (2-ACB) with saturated and mono-unsaturated alkyl side chain: 2-decyl-, 2-dodecyl-, 2-dodecenyl-, 2-tetradecyl- and 2-tetradecenyl-cyclobutanone (Miesch et al., 2002). Studies have confirmed the presence of 2-ACBs in irradiated mango and papaya, two types of fruit proposed for processing at the Pa'ina Hawaii facility, should it be approved (Ndiaye et al. 1999; Stewart et al., 2000).

c. Since 1998, concern regarding health hazards from the consumption of irradiated food has been focused on the toxicity of 2-ACB. Using in vitro assays, 2-ACB has been shown to be genotoxic and mutagenic (Delincee and Pool-Zobel, 1998; Delincee et al., 1998; Delincee et al., 2002; Burnouf et al., 2002). 2-ACB has also been tested in experimental animals. In one report (Horvatovich et al., 2002), laboratory rats were fed a very low concentration of 2-ACB in drinking water, and the absorption and excretion of the chemical were monitored. The study showed that less than 1% of the administered chemical was excreted in feces. A portion of the chemical crossed the intestinal barrier, entered the blood stream and accumulated in the adipose tissues of the animal. It follows that consumption of irradiated food for a long time can cause accumulation of toxic 2-ACB in the adipose tissues of human consumers.

d. The recent findings by Raul et al. (2002) raise a high level of concern. In the study, Wistar rats received a daily solution of 2-tetradecylcyclobutanone or 2-(tetradec-5'-enyl)-cyclobutanone and a known colon carcinogen (azoxymethane [AOM)]. Observations were made at two distinct intervals. At three months after initiation of the exposure, no significant changes in the number of pre-neoplastic colonic lesions were observed among the rats (all were exposed to AOM). At six months, however, the total number and the overall size of tumors were markedly increased in the 2-ACB-AOM treated rats as compared to the ethanol-AOM control rats. This demonstrates that compounds found exclusively in irradiated dietary fats may promote colon carcinogenesis in animals treated with a known carcinogen and identifies a new area of toxicity that neither the U.S. Food and Drug Administration nor the World Health Organization has yet examined.

e. A promoting agent does not usually cause cancer by itself but alters cellular functions (Zheng et al., 2002; Yamagata et al., 2002). The unique concern with promoters is that they can significantly enhance the carcinogenic effects of known carcinogens (Hecker et al., 1980; Slaga, 1983; Langenbach et al., 1986). Experimental animals that are treated with both promoters and carcinogens develop tumors much earlier and have more tumor nodules than animals treated with the carcinogens alone. Animals treated with the promoters alone would not develop tumors more often than the untreated animals.

f. Colon cancer (as was discovered in the rat study on 2-ACBs) is a serious health problem in humans, causing approximately 60,000 deaths per year in the United States. Consumption of improper diet is a major cause for colon cancer: foods that are high in fat especially from animal sources, meat cooked with high heat, charred meat, and food with high content of aromatic/heterocyclic amines (Colon cancer folder in the American Cancer Society website – www.cancer.org; Lang et al., 1986; Vineis and McMichael, 1996). Consumption of the improper diet together with food that contains 2-ACB, which acts as a tumor promoter, can increase the risk for the development of colon cancer. Under this scenario, individuals who would normally outlive the risk for colon cancer might develop the cancer.

g. Numerous other peer-reviewed published reports have long indicated the mutagenic activities of irradiated foods fed to mammals (Anderson et al., 1980; Bhaskaram and Sadasivan, 1975; Bugyaki et al, 1968; Maier et al., 1993; Moutschen-Dahmen, et al., 1970; Vijayalaxmi, 1975, 1976, 1978; Vijayalaxmi and Rao, 1976; Vijayalaxmi and Sadasivan, 1975). While the health concerns from consumption of irradiated food simply cannot be considered to have been resolved conclusively (Louria, 2001), the data indicate that consumption of irradiated food can cause genotoxic effects and therefore health hazards in the population. Moreover, there may be subpopulations, such as children, who are most susceptible to toxic effects of irradiated food. Strong reasons exist for considering children generally to be especially susceptible to toxic materials (Au 2002).

h. In the final analysis, the only thing certain about the impacts on human health associated with the consumption of irradiated food, including the papayas, mangos, and other produce proposed to be processed at the Pa'ina Hawaii facility, is that it is the subject of considerable scientific debate. A recent article I co-authored summarizing the controversy over this issue (Ashley et al., 2004) is attached hereto as Exhibit "C" and incorporated herein by reference.

I declare under penalty of perjury that I have read the foregoing declaration and know the contents thereof to be true of my own knowledge.

Dated at Galveston, Texas, September 29, 2005.

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WILLIAM W. AU

EXHIBIT B

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ELSEVIER

Int. J. Hyg. Environ. Health 207 (2004); 1–12
http://www.elsevier.de/intjhyg

International Journal of Hygiene and Environmental Health

Health concerns regarding consumption of irradiated food

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Received March 8, 2004 · Revision received August 5, 2004 · Accepted August 10, 2004

Abstract

Food irradiation is being promoted as a simple process that can be used to effectively and significantly reduce food-borne illnesses around the world. However, a thorough review of the literature reveals a paucity of adequate research conducted to specifically address health concerns that may directly result from the consumption of irradiated food. Consequently, there is considerable debate on the issue of health concerns from irradiated food among international agencies and between different nations. This report presents a critical review of scientific data and recommendations from different agencies and consumer groups. The objective of this review is to provide the scientific community and the general public with a balanced discussion on irradiated food from the viewpoint of an environmental or public health professional. As a result of this review, the authors conclude that current evidence does not exist to substantiate the support or unconditional endorsement of irradiation of food for consumption. In addition, consumers are entitled to their right of choice in the consumption of irradiated versus un-irradiated food. Different countries should further evaluate their local and global risks and benefits prior to developing and recommending national and international food irradiation policies.

Key words: Food irradiation – environmental health – public health – mutagenesis – tumor promotion – food safety – food borne illness

Introduction

Food safety is a global issue with paramount environmental and public health consequences if inadequately maintained. With the increased globalization of food supply, ensuring the safety of this supply to consumers has become an international collaborative endeavor. The concern for ensuring food safety can be illustrated by the extent of food-borne illnesses around the world. Even with a well-established food inspection and supply system in the US, food-related health problems are estimated to cause 76 million illnesses, 323,000 hospitalizations and 5,000 deaths annually (Mead et al., 1999). A large portion of the health problems is caused by the contamination of food by infectious agents such as *Salmonella*, *E. coli* and *Listeria*. The potential for contamination is inherent at each step along the food supply and preparation processes. Therefore, a variety of procedures have been developed and

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1438-4639/04/207/03-1 $ 30.00/0

used to reduce food-borne contamination Since the late 1980's, the World Health Organization and the US Food and Drug Administration have approved the irradiation of food by ionizing radiation at the beginning of the food supply chain as an inexpensive and effective procedure (http://www.cdc.gov/ncidod/dbmd/diseaseinfo/foodirradiation.htm; http://www.who.int/archives/inf-pr-1997/en/pr97-68.html). In a recent conference (First World Conference, 2003), it was estimated that there were approximately 7,000 stores representing more than 50 retail chains that sold irradiated food. Additionally, more than 2,000 restaurants (including major fast food chains) served meals containing irradiated food. Although the application of the food irradiation procedure has been heavily promoted and recommended, unresolved health concerns related to the consumption of irradiated food remain. In this review, background information and concerns with the use of irradiation for food preservation are presented followed by recommendations for academic, industry and consumer consideration.

Food irradiation technology typically uses electron beam and ionizing radiation (e.g. X-rays). The energy from the irradiation breaks chemical bonds and produces toxic ions and free radicals that react with cellular constituents in food to form altered products (often classified as radiolytic products). With respect to dose, the amount of radiolytic products increases in proportion to the radiation dose (Federal Register, 1997). It is by breaking the bonds in a microorganism's DNA structure and prohibiting its replication that food irradiation prevents spoiling and food-born illness. However, irradiated food is not radioactive.

The radiation dose and exposure time can affect the taste and consistence of foods in addition to its effect on microorganisms. Odd odors and discoloration have been noted in some irradiated foods in the past, and radiolytic compounds have been implicated. Specifically, radiolytic compounds have been shown to cause oxidation of myoglobin and fat in meat, which in turn is thought to produce foul odors and discoloration. Ozone can be produced from oxygen during irradiation which can also cause discoloration. Irradiating food at appropriate doses and under appropriate conditions such as a reduced oxygen environment and/or a frozen state can minimize these effects (Federal Register, 1997). Perhaps the most important radiolytic products are 2-alkylcyclobutanones (2-ACBs) which are produced from the irradiation of fat in food. This family of cyclobutanones includes 2-dodecylcyclobutanone (2-DCB) from irradiation of palmitic acid, 2-tetradecylcyclobutanone (2-TCB) from stearic acid, and 2-tetradecenylcyclobutanone (2-TDCB) from oleic acid (Delincee et al., 2002). To date there is no evidence that 2-ACBs are found in any non-irradiated foods and concern for cytotoxic and genotoxic effects from these by-products has been raised (Delincee et al., 2002).

Results

In vitro toxicological evaluation

The generation of altered cellular substances, e.g. radiolytic products, by radiation has caused concern regarding the mutagenicity of irradiated food. Several in vitro studies have therefore been conducted using bacterial mutagenic assays to address this concern. A summary of these published studies is shown in Table 1. In order to test irradiated foodstuffs, which are complex macromolecules, early in vitro tests were conducted utilizing natural juices, extracts or digests from irradiated food. Inherent limitations with these approaches are apparent. For example, it is difficult to extract all compounds from all food types. Chemically altered macromolecules that are different from those found under human study conditions may be formed during the preparation process. Cellular uptake of the mixtures by the bacteria, especially the toxic component, is unknown. Food juices, extracts, and digests may contain compounds that interfere with the essential component of the test, e.g., the presence of histidine will render the Ames assay ineffective (Ames, 1975). In addition, many of the in vitro assays were not conducted in a systematic and comprehensive manner. As shown in Table 1, the majority of the studies using food juice, extracts and digests produce negative results in mutagenic assays.

During the last few years, attention has been focused on evaluating the mutagenic effects of unique radiolytic products from irradiated food, e.g., 2-ACBs. Testing of these products becomes possible because they can be synthesized instead of extracted from irradiated food. As shown in Table 1, one of the 2-ACBs, 2-DCB, was tested in bacterial and mammalian cells for toxic activities (Delincee and Pool-Zobel, 1998; Delincee, 2002; Titeca et al., 2003; Sommers, 2003). These studies did not depict 2-DCB as mutagenic. However, cytotoxic and other biological effects were observed. As shown in the next section, some radiolytic products have been shown to be probable tumor promoters. Since tumor promoters are not mutagenic agents, 2-ACBs are not expected to cause gene mutations. However, testing

Table 1. In vitro mutagenicity studies

Study	Food	Cell type	Dose (Kgy)	High dose irradiation mutagenic effect	Author
1	Glucose, peptone	*E. coli*	50	Negative	Bugyaki et al., 1963
2	Sucrose	Human lymphocytes	20	**Possible*** Chromosomal breaks in human lymphocytes	Shaw and Hayes, 1966
3	Sucrose	Vicia faba	20	**Possible*** Chromosome changes	Bradley et al., 1968
4	Strawberry	*Salmonella*, Human	15	Negative	Schubert et al., 1973
5	Paprika	*Salmonella*	50	Negative	Central Food Research Institute, 1977
6	Sucrose, ribose	*Salmonella*	20	**Possible***	Aiyar and Rao, 1977
7	Cod	*Salmonella*	12	Negative	Joner et al., 1978
8	Growth medium	Human lymphocytes	10, 20	Negative	Vijayalaxmi, 1980
9	Herring	*Salmonella*	12	Negative, possible effect of nutrition or diet	Joner and Underdal, 1980
10	Dates, fish, chicken	*Salmonella*, CHO cells	10	Negative	Phillips et al., 1980a
11	Dates, fish, chicken	CHO cells	10	Negative	Phillips et al., 1980b
12	Onion powder	*Salmonella*	13.6	Negative	Münzer and Renner, 1981
13	Spice mix	*Salmonella*	14, 45	Negative	Farkas et al., 1981
14	Beef, pork, veal	*Salmonella*	50	Negative	Münzer, 1983
15	Sucrose, fructose, glucose, maltose, mango	*Salmonella*	50	**Possible*** Simple sugar mutagenic in one of five strains. Negative in Mango	Niemand et al., 1983
16	2-DCBs	Rat and human colon cells	N/A	**Possible** DNA strand breaks and oxidative damage, cytotoxic, genotoxic	Delincée and Pool-Zobel, 1998
17	2-DCBs	Human colon cells	N/A	**Possible** Cytotoxic, genotoxic	Delincée et al., 2002
18	2-DCBs	*Salmonella*	N/A	**Possible** Cytotoxic	Titeca et al., 2003
19	2-DCBs	*E. coli*	N/A	Negative	Sommers, 2003

May have this mutagenic effect as a result of radiation-induced chemistry of simple carbohydrate solutions
Table adapted from FAO/IAEA/WHO 1999.

should still be conducted on 2-ACBs to determine the degree of tumor promotion activity.

In vivo toxicological evaluation

Experimental animal studies with whole food

In 1999, the Food and Agriculture Organization (FAO), International Atomic Energy Agency (IAEA) and World Health Organization (WHO) reviewed the scientific literature on in vivo toxicological evaluation of irradiated food and produced the Technical Report #890 that is entitled "High-Dose Irradiation: Wholesomeness of Foods Irradiated Above 10Kgy" (FAO/IAEA/WHO, 1999). A summary from the technical report is shown in Table 2. The Table includes 27 peer-reviewed publications that mostly report negative results but ignores 5 peer-reviewed publications that illustrate toxicologic effects (Vijayalaxmi, 1975; 1976; 1978; Vijayalaxmi and Sadasivan, 1975; Vijayalaxmi and Rao, 1976). The latter publications were disregarded based on the decision that the observed toxicity could have been caused by confounding factors such as nutritional and dietary deficiencies. However, the exclusion of these studies has been criticized (Vijayalaxmi, 1999; Kimbrell and Hauter, 2002; http://www.centerforfoodsafey.org/li.html).

Based on the review by the WHO and FDA (FAO/IAEA/WHO, 1999; Food and Drug Administration, 1986), the wholesomeness of irradiated food is generally considered to be safe to consumers. There are, however, major limitations with regard to published animal studies that were used in support of this position. There is no documentation to indicate that the experimental animals had in fact consumed the putative hazardous (e.g. radiolytic) products in the food mixture. In addition, the animal bioassays are not designed to show adverse effects

Table 2. In vivo mammalian mutagenicity studies

Study no	Food type (% in diet)	Species type	Irradiation dose (kGy)	Notations	Reference
1	Black beans	Mouse Swiss-55	15, 20	NHDIR. Dominant lethal test. No difference in pregnancy rates, total implants, live and dead implants, sex distribution, or abnormalities.	Bernardes et al. (1981)
2	Chicken (35%)	Mouse	59	NHDIR. Dominant lethal test. Feeding of radiation-sterilized chicken meat did not induce dominant lethal events. Positive control produced negative results, unsuiTable for supporting safety.	Raltech Scientific Services (1978)
3	Glucose powder	Mouse Swiss	20, 50	NHDIR. Dominant lethal test. No mutagenic effects.	Varma et al. (1982)
4	Glucose powder	Mouse Swiss	20, 50	NHDIR. Micronucleus test in bone marrow cells and chromosomal aberration assay. No evidence of mutagenic effects in somatic or germ cells.	Varma et al. (1986)
5	**Laboratory diet: solid cakes**	**Mouse C57BL**	**50**	NHDIR/PEND. Dominant lethal test. Increased pre-implementation embryonic deaths; not confirmed by cytological analysis.	**Moutschen-Dahmen et al., (1970)**
6	Laboratory diet: pellets, enriched with amino acids and vitamins	Rat SPF Wistar	50	NHDIR. Dominant lethal test. No evidence of mutation.	Eriksen and Emborg (1972)
7	**Laboratory diet: food pellets**	**Mouse Swiss SPF**	**0, 7.5, 15, 30**	NHDIR/PEND. Host-mediated assay. Significant increase in the mutation frequency induced by the high-dose irradiated food.	**Johnston-Arthur et al. (1979)**
8	Laboratory diet: pellets	Mouse	0, 7.5, 15, 30	NHDIR/PEND. Host-mediated assay for 3 commercial food pellets. Irradiation increased mutation frequency between 10 and 60 fold for the 3 products compared to controls. Subsequent extraction study found mutagenic agent extracted by alcohol. Water extract had a lower effect and ether extract had no effect.	Johnston-Arthur et al. (1975)
9	Laboratory diet, 10% moisture	Rat Wistar	25	NHDIR. Dominant lethal test. No evidence of mutagenic effects.	Chauhan et al. (1975a)
10	Laboratory diet, 10% moisture	Mouse Swiss	25	NHDIR. Dominant lethal test. No evidence of mutagenic effects.	Chauhan et al. (1975b)
11	Laboratory diet: pellets	Mouse	45	NHDIR. Host-mediated assay. No mutagenic effects.	Münzer and Renner (1975)
12	Laboratory diet	Mouse BALB/c	28.5	NHDIR. Bone marrow and male germ cells examined for chromosome aberrations. No mutagenic effects.	Leonard et al. (1977)
13	Laboratory diet: pellets	Chinese hamster	45	NHDIR/PEND. No increase in chromosomal aberrations;	Renner (1977)

Tab. 2 (cont.)

Study no	Food type (% in diet)	Species type	Irradiation dose (kGy)	Notations	Reference
				slightly increased incidence of polyploidy.	
14	**Laboratory diet**	**Mouse CD1**	**10, 25, 50**	NHDIR/PEND. Dominant lethal test. Used 4 diets on 2 strains. Some evidence of weakly mutagenic effect with one diet.	**Anderson et al. (1981)**
15	Laboratory feed	Mouse, SPF Ha/ICR (Swiss)	30	NHDIR. Host-mediated assay. No mutagenic effects.	Münzer and Renner (1976)
16	Milk powder (35%)	Mouse: NMRI/Han, Rat, Sprague-Dawley	45	NHDIR. Dominant lethal test, reproduction. High content of radicals in the irradiated food. No harmful effects.	Renner et al. (1973)
17	Onion powder (10%)	Chinese hamster, Mouse	13.6	NHDIR. Sister chromatid exchange tests negative in hamsters and 3 strains of mice.	Münzer and Renner (1981)
18	Paprika	Mouse	50	NHDIR. Host-mediated assay. No increase in number of revertants.	Central Food Research Institute (1977)
19	Paprika (20%) 8.6% moisture	Mouse Swiss	30	NHDIR. Micronucleus test. No differences in the incidence of erythrocytes with micronuclei, and polychromatic:normal ratio comparable among all groups.	Chaubey et al. (1979)
20	Spice mix pepper	Rat CFY	15	NHDIR. *E. coli* inductest on blood of rats. No induction of lysogenic bacteria.	Farkas and Andrassy (1981)
21	Spice mix	Rat CFY	15, 45	NHDIR. Negative Ames test on irradiated spice extracts and on urine of rats fed irradiated spices.	Farkas et al. (1981)
22	Spice mix (25%)	Rat Sprague-Dawley	15	NHDIR. Dominant lethal test. No significant difference between irradiated spice groups and controls.	Barna (1986)
23	Strawberry	Mouse	15	NHDIR. No clastogenic effects.	Schubert et al. (1973)
24	Sucrose, ribose solutions	Mouse	50	NHDIR. Host-mediated assay. No increase in number of revertants.	Aiyar and Rao (1977)
25	**Wheat (50%)**	**Mouse**	**0, 50**	NHDIR/PEND. Chromosomal abnormalities in germ cells presumed due to formation of peroxides and radicals with subsequent loss of lipids and carotenoid fractions in irradiated diet.	**Bugyaki et al. (1968)**
26	Wheat (freshly irradiated)	Chinese hamster	0, 15, 30	NHDIR. No difference in polyploids in bone marrow cells or micronuclei in reticulocytes 72h after diets irradiated in N2 or air. Analyses of micronuclei in peripheral blood of rat fed wheat flour irradiated at 0.75kGy done at 6 and 12 weeks.	Tanaka et al. (1992)

NHDIR = negative for high-dose irradiation effect (> 10 kGy); PEND = possible effect of nutrition or diet; % in diet based on dry weight unless otherwise specified indicated. Information presented in bold font indicates positive findings.
Table modified from FAO/IAEA/WHO, 1999.

from the consumption of a small amount of toxic substances, e.g., 2-ACBs in food. Traditionally, pure compounds, not mixtures, are tested in animal bioassays to generate dose-response observations and possibly to document the lowest no adverse effect dose. With the data that is obtained, it is then practical to evaluate the toxicity or safety of the compound and to extrapolate experimental findings to how it may pertain to human consumers. With these major limitations, the current data from animal studies are inadequate for making valid health risk assessment and such assessment has not enjoyed wide-spread acceptance.

Human studies with whole food

Only two human studies have been reported. In one study, ten children (2 to 5 years old) suffering from severe protein-calorie malnutrition were fed freshly irradiated wheat (N = 5) or stored irradiated wheat (N = 5) for six weeks (Bhaskaram and Sadasivan, 1975). These ten children were compared to a matched control group of five children who were fed unirradiated food during the same time period. The first group of five children developed significantly more polyploid cells and other cellular abnormalities in their lymphocytes than the five who were fed the stored irradiated food. In addition, the abnormality persisted for up to two months after the feeding period ended. None of the children fed the un-irradiated diet developed any abnormal cells.

In another study, healthy adults were fed irradiated food for three months (Institute of Radiation Medicine, 1987). They did not display any increase of chromosomal aberrations when compared to a control group. Upon reanalysis of the data (Louria, 1990), an increase in chromosomal aberrations was demonstrated. Although these results were from small scale investigations, the information is based on human responses and does raise some safety concerns about the health risk of irradiated food.

Potentially harmful radiolytic products

In the modern era, a new concern has arisen in regard to some of the radiolytic products formed uniquely in irradiated food. Of particular interest is 2-ACB, a radiolytic derivative of triglycerides. In one report (Horvatovich et al., 2002), laboratory rats were fed a low concentration of 2-ACBs in drinking water, and the absorption and excretion of the chemicals were monitored. The study showed that a substantial portion of the chemical crossed the intestinal barrier, entered the blood stream, and accumulated in adipose tissue. Therefore, consumption of irradiated food can possibly result in a significant accumulation of 2-ACBs in the adipose tissues of consumers. The long-term health consequences of this observation are unclear at this time.

In another study (Raul et al., 2002), Wistar rats received a daily solution of 2-tDCB or 2-tDeCB (while controls received ethanol) in combination with an intraperitoneal injection of a known carcinogen (azoxymethane [AOM]). Observations were made at two distinct intervals. At three months after initiation of the exposure, no significant changes in the number of pre-neoplastic colonic lesions were observed among the rats (all were exposed to AOM). At six months, however, the total number and the overall size of tumors were markedly increased in the 2-ACB-AOM treated rats as compared to the ethanol-AOM control rats. This demonstrates that compounds found exclusively in irradiated dietary fats may promote colon carcinogenesis in animals treated with a known carcinogen and identifies a new area of toxicity that the FDA and WHO have yet to examine. The 2-ACB tumor promotion activities should be further investigated, and their effects evaluated systematically.

Recommendations from regulating agencies

Various agencies from around the world have made recommendations regarding the safety of irradiated food consumption. The recommendations from major agencies that will be discussed in this review are the World Health Organization, the European Parliament, the US Food and Drug Administration, and the US Department of Agriculture.

World Health Organization (WHO)

The WHO has been an advocate of food irradiation since their appraisal of the technology. Based on a review of scientific evidence, their expert panel concluded that food irradiated at an appropriate dose was safe to consume and nutritionally adequate. The panel also concluded that an upper dose limit did not need to be imposed; stating "irradiated foods are deemed wholesome throughout the technologically useful dose range from below 10 kGy to envisioned doses above 10 kGy" (FAO/IAEA/WHO, 1999). In addition, they also stated that the limit could be set as based on the deterioration on the quality of the irradiated food. However, such decision that is based on vigorous scientific evaluation of public health impact should be more reliable.

Recently the Joint FAO/IAEA/WHO Food Standards Program (2003) under the United Nations promoted irradiation doses beyond the 10 kGy limit. During the deliberations, Germany objected to the absence of a 10 kGy limit and the United States argued for a 30 kGy limit to kill micro-

Table 3. Radiation conditions recommended by the FDA

Approval date	Food/product dose (kGy)*	Purposey
1964, 1965	Potatoes, 0.05 – 0.15	Inhibit sprouting (and extend shelf life)
1983	Spices and dry seasonings, < 30	Disinfestation and decontamination
1985	Pork, 0.3 – 1.0	Control of *Trichinella spiralis*
1985, 1986	Dry or dehydrated enzymes, < 10	Control of insects and microorganisms
1986	Fruit, < 1	Delay maturation and disinfestation
1986	Fresh vegetables, < 1	Disinfestation
1986	Herbs, spices and seasoning, < 30	Control of microorganisms
1990	Poultry, fresh or frozen, < 3	Control of microorganisms
1995	Meat, frozen and packaged (solely for use in NASA), > 44	Sterilization
1995	Animal feed and pet food, 2 – 25	Control of *Salmonella*
1997, 1999	Red meat, meat products (uncooked) Kv chilled (refrigerated), < 4.5 Kv frozen, < 7.0	Control of microorganisms

organisms on spices. In the end the Commission adopted a revised standard over the objections of Austria, Denmark, Germany, Greece, Hungary, Italy, Mexico, Poland, Spain and Sudan. The Commission argued that the higher levels of irradiation (30 kGy) were justified to eliminate bacterial spores. The Codex Alimentarius (Food Code) is a compilation of standards, codes of practice, guidelines and recommendations of the 169 countries represented in the Codex Alimentarius Commission, a subsidiary body of FAO and WHO. This commission previously recommended a minimum of 1 kGy and a limit of 10 kGy.

The European Parliament

The European community has provided funding for some of the recent studies on the safety of irradiated food (e.g. Horvatovich et al., 2002; Raul et al., 2002). Based on the observed adverse effects resulting from these investigations, the European Parliament has retained the 10 kGy limit and has issued a moratorium on the addition of food items for irradiation:

"In adopting this resolution, a majority of MEPs took the view that the current list of food ingredients authorized for irradiation treatment should not be extended at this stage. An amendment was adopted in favor of the third Commission option, the most restrictive one. The current list should be regarded as complete, which would mean that only dried aromatic herbs, spices and vegeTable seasonings are permitted for irradiation in the European Union as and when scientific knowledge suggested that it was safe and efficacious to do so." (Breyer, 2002)

The Food and Drug Administration (FDA)

The regulations from the FDA are codified in CFR 21 Part 179 (1986) and the recommended irradiation conditions are listed in Table 3. Since the regulation does not supercede the authority of the U.S. Department of Agriculture (USDA), anyone irradiating food needs to comply with regulations set forth by the Food Safety and Inspection Service.

Under general labeling requirements, the FDA requires that the label bear the radura symbol and a prominent phrase "treated with radiation" or "treated by irradiation." However, if irradiated ingredients are additives to foods that are not irradiated they do not require any special labeling. Labeling is also not needed for irradiated food items that are prepared and served in restaurants. To ensure foods are not irradiated multiple times, pre-retail labeling is required for any food that may need further processing. The FDA encourages other truthful statements about food irradiation on labels to educate consumers.

U.S. Department of Agriculture (USDA)

In May of 1993, the USDA released specifications to guide the National School Lunch Program in purchasing irradiated ground beef. Under the 2002 Farm Bill, the USDA may not prohibit approved food safety technologies on foods purchased for the National School Lunch Program. In California, the legislature has recommended that the local school boards provide consumer educational materials on irradiated food and decide on how to serve irradiated food (Legislative Session in Sacramento, California, June – July, 2004).

Meat and poultry establishments that use irradiation must meet sanitation and Hazard Analysis and Critical Control Point (HACCP) regulations. Additionally, the USDA conducts microbial testing to ensure processing plants are producing wholesome products.

Concerned citizen groups positions on irradiated food

Citizen groups, like citizens themselves, have widely varying opinions on the safety of irradiated food. For the context of this review, the consumer groups will be classified broadly into those who oppose food irradiation, those that are neutral, and those who support it. In addition, only positions from representative citizen groups that are not observably funded by industry or whose opinions are not obviously based on financial or political interest are presented.

Groups that are against food irradiation, e.g. Public Citizen and The Center for Food Safety, base their concerns on peer-reviewed journal articles that state that the safety of consuming these foods has not been established (Is Irradiated Food Safe, 2003; Kimbrell and Hauter, 2002; http://www.centerforfoodsafety.org/li.html). They believe there are unique by-products of irradiated fat that can potentially cause cancer. They also believe that these products, 2-ACBs, have not been tested properly in the traditional toxicological manner. Another argument of the anti-irradiation food groups is the concept of sterilized filth. These groups contend that the food industry will use irradiation as a substitute for normal precautions when handling food, thus leaving the entrails, feces, blood, pus, tumors and other contaminates on the meat (Kimbrell and Hauter, 2002). Providing credence to this statement, the European Parliament has cited examples of illegal use of irradiation at European facilities to clean up contaminated seafood (Breyer, 2002). The consumer groups also contend that food irradiation would lead to a false sense of security in consumers. Consequently, consumers of irradiated foods may believe these foods cannot ever become contaminated, and would thus minimize traditional precautions instituted to ensure sanitary and safe food preparation, ultimately leading to more food-borne illness.

Another category of consumer groups is comprised of organizations that maintain a neutral position (e.g. Consumer Reports, Safe Tables Our Priority (STOP), The American Council on Science and Health, and the Center for Science in the Public Interest). These groups are well aware of the dangers of food-borne pathogens and see a need to improve the process of food handling overall. Some of them, such as STOP are groups of concerned citizens which have themselves, or have a relative, that has been a victim of food-borne illness. In general, these groups have no official policy stance on food irradiation, but they can see its potential benefit in protecting the general public from food-borne pathogens such as *Eschericia coli, Salmonella* and *Campylobacter*. These groups do emphasize the need to maintain normal safety precautions when handling food, and recommend that food be irradiated in its final packaging to reduce the chances of recontamination (Donley, 1999; Consumer Union, 2003). They feel that the irradiated products should be clearly labeled and the words "treated by irradiation" be used, as opposed to "cold pasteurized or electric pasteurized" (Donley, 1999; Mitchell, 1999). As long as the proper labeling (which includes the radura symbol) is present, and the public is educated about the possibility of recontamination, these groups contend that consumers can vote with their pocketbooks, thus choosing for themselves whether or not they want irradiated food products. These groups believe that the benefits of a safer food supply protected from bacterial and viral pathogens may outweigh any risks.

The last category of citizen groups, including the Hudson Institute's Center for Global Food Issues and the Competitive Enterprise Institute, endorse food irradiation. They contend irradiation defeats well-known and potentially deadly food-borne pathogens, and will save lives. These groups cite the fact that food irradiation has been used for decades by the military and NASA to prepare long shelf-life food products for soldiers and astronauts (CEI Staff, 1999; Avery, 2003). They also referenced estimates from the USDA that the American consumer would receive approximately $ 2 in benefits from reduced spoilage and less illness for each $ 1 spent on food irradiation (Loaharanu, 2003).

Whether citizen groups are for or against food irradiation, nearly all groups agree the consumers should be informed of any food that has been irradiated. However, the groups that are most in favor of irradiation do not usually mention the issue of labeling.

Other methods for food preservation and sanitation.

In addition to destroying, inhibiting, or removing microorganisms from food products, other goals of food processing are to retard or prevent deleterious biochemical, chemical and physiochemical changes, to maintain and generate accepTable organoleptic (taste, texture, color, and aroma) properties, and to preserve and enhance the nutritive value. Examples of bacteriostatic food processing methods include drying, freezing, pickling, salting, smoking, and fermenting. Bacteriocidal procedures include thermal processing, electric energy, high pressure processing, and electromagnetic microwave technology.

Emerging electromagnetic microwave technology has some highly desirable features (http://www.pubit.it/sunti/euc0301q.html; http://www.techmonitor.net/techmon/03sep_oct/fpr/fpr_preserve.htm). The process has the potential to extend shelf life of food for a minimum of nine months, eliminate the need for refrigeration and offer the convenience of ready-to-eat food while maintaining organoleptic qualities and more than 90% of the nutritional value. In addition, the process uses a patented electromagnetic microwave (non-ionizing radiation) that has not been shown to generate unique radiolytic products. Nevertheless, the overall quality and safety of the application needs to be determined scientifically and systematically.

Regardless of the ultimate technology applied, emphasis on sanitary processing of food prior to the radiation phase and also at the time of food preparation by the consumer, should not be undermined. To prevent food-borne illnesses, it would be prudent to practice the four Cs of food safety: Clean well, Cook thoroughly, Combat cross contamination (separate), and Chill (refrigerate).

Discussion

Improvement of food safety and prevention of food-borne illness are fundamental and crucial public health objectives. The use of radiation on food has been heavily promoted as the approach to achieve these stated objectives. However, less emphasis has been placed on determining the potential health consequences that can result from this process. The justification used for approving food irradiation is based mainly on early studies which demonstrate that (1) the process did not generate substances that are not also generated by other food preservation procedures and (2) the wholesomeness of irradiated food is safe based on animal bioassays. However, recent studies have propagated uncertainty with regard to the safety of irradiated food that is to be provided to the consumer.

The in vitro and in vivo research outlined in this review clearly depict the formation of radiolytic products, e.g. 2-ACBs, in irradiated food that are not found in food items prepared by using other food processing technologies. Preliminary studies demonstrate that 2-ACBs accumulate in fatty tissues in experimental animals, exhibit toxicity, and possess tumor promoting activities. Testing for toxicity using wholesome irradiated food in animal bioassays is not entirely appropriate because these assays are not designed to show the adverse effects of exposure to small concentrations of toxic substances such as 2-ACBs in food. These assays are traditionally used to test pure compounds, not mixtures, in order to demonstrate a dose-response effect for toxicity evaluation. Up to this point in time, there have been no comprehensive and systematic studies to assess human toxic effects resulting from irradiated food. Given the history of use of this technology thus far, one could argue that if it were unsafe then we should have seen some specific adverse health effects. However, if the toxic by-products are acting as promoters we may only recognize a small increase in cancer in the population (in terms of percentages but not in terms of number of affected individuals) and it would be very difficult to prove that irradiated food was in fact the direct cause of increased cancer morbidity and mortality. Any argument would have to be made inferentially based on the data presented.

The greatest concern expressed by mainstream consumer advocacy groups is the use of the technology without first informing the consumer. Even the names used are confusing. The proposed labeling statements "cold pasteurization" and "electronic pasteurization" instead of radiation are misleading to consumers.

There are many differing opinions on the use of radiation in food processing. However, there appears to be universal support for sanitary processing as being one of the most important considerations. Irradiation of poorly processed food only sterilizes something that should not be consumed in the first place. In addition, other useful procedures that do not generate health concerns should not be precipitately discarded without due consideration. The other major consideration is that evolving technology may replace the need to use radiation as a means to process food.

Recommendations

In summary, it is quite clear that additional research is needed in order to fully address the issue and concerns of irradiated food. The toxicity of unique radiolytic products should be tested vigorously, especially in regards to the tumor promoting activities. Animal bioassays should be conducted systematically and comprehensively with whole food and with unique radiolytic products to generate a dose-response understanding of the toxicity and safety of irradiated food. It would prove beneficial to establish a dose that does not cause any observable toxic effects in an experimental animal model. The data obtained would better substantiate extrapolation and application in human health risk evaluation. In addition, as of now, there are no extensive human trials available to assess irradiated food safety in human populations. Regulatory agencies in the US and around the world need to be proactive in resolving these health concerns prior to the ubiquitous consumption of irradiated food. It is noTable that the European Parliament has halted the addition of new food products for irradiation and has chosen to maintain the 10kGy limit on irradiation.

In a global perspective, prevention of food-borne illness is a critically important practice. Third world countries with malnutrition, widespread famine and limited hygiene resources may view the concept of irradiated food differently from developed countries. Nevertheless, considerations for the approval of irradiated food for consumption need to be based on realistic and informed evaluation of the risk and benefits to the populations.

This illustrates the core issue in processing food with radiation. One can argue their respective position based on sound reasoning and with a convincing tone. Therefore, the decision to consume irradiated food should be made through knowledgeable risk assessment, using all available scientific evidence-based data, and involving all stakeholders prior to achieving an informed decision.

Acknowledgement. This review is the product of a class project resulting from an Environmental Health and Toxicology course in the Master of Public Health program at the University of Texas Medical Branch (UTMB) in Galveston, Texas. B. C. Ashley, M.D., B. Chamberlain, M.D. and S. Moynahan, M.D. are in the UTMB Aerospace Medicine Residency Program; P. T. Birchfield, D.O., R. S. Kotwal, M.D., S. F. McClellan, M.D., and S. A. Salmon, M.D. are in the Army Aerospace Medicine Residency Program; S. B. Patni, M.D. is in the UTMB Occupational Medicine Residency Program.

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of Pa'ina Hawaii, LLC Materials License Application	)))))	Docket No. 030-36974

DECLARATION OF DR. GORDON R. THOMPSON IN SUPPORT OF PETITIONER'S AREAS OF CONCERN

I, Gordon R. Thompson, declare that if called as a witness in this action I could testify of my own personal knowledge 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, Massachusetts 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. In addition to holding my position at IRSS, I am also a research professor at the George Perkins Marsh Institute, Clark University, Worcester, Massachusetts. My professional qualifications are discussed in Section II of this declaration.

I-2. I have been retained by Concerned Citizens of Honolulu as an expert witness in a proceeding before the US Nuclear Regulatory Commission (NRC), regarding an application by

Pa'ina Hawaii, LLC, for a license to build and operate a commercial pool-type industrial irradiator in Honolulu, Hawai'i, at the Honolulu International Airport.

I-3. The purpose of this declaration is to support Concerned Citizens' contention that "special circumstances" exist, precluding the NRC's use of a categorical exclusion from the National Environmental Policy Act's mandate to prepare either an environmental assessment (EA) or environmental impact statement (EIS) in the context of the proposed license.[1] In this declaration, I focus on the potential for acts of malice or insanity, related to the proposed Pa'ina Hawaii irradiator, to cause harm to people and/or the environment. As part of that focus, I address the potential to reduce the risk of harm by adopting alternatives to the proposed mode of construction and operation of the irradiator. Also, I address the processes whereby acts of malice or insanity could be considered in a licensing proceeding or during the preparation of an EA or EIS. My focus on the implications of potential acts of malice or insanity does not indicate that I regard other issues, relevant to licensing of the proposed irradiator, as having a lesser significance.

I-4. The remainder of this declaration has seven sections. Section II discusses my professional qualifications. Section III discusses some of the characteristics of the proposed Pa'ina Hawaii irradiator. The potential for commercial nuclear facilities, including irradiators, to be affected by acts of malice or insanity is addressed in Section IV. That discussion is continued in Section V, with a focus on irradiators. Section VI discusses the potential to reduce the risk of harm, arising from acts of malice or insanity, by adopting alternatives to the proposed design and mode of operation of the Pa'ina Hawaii irradiator. Section VII addresses the processes whereby acts of malice or insanity could be considered in a licensing proceeding, or during the

[1] 10 C.F.R. § 51.22(b); see also id. § 2.335(b); 40 C.F.R. § 1508.4.

preparation of an EA or EIS, for the Pa'ina Hawaii irradiator. Major conclusions are set forth in Section VIII. Documents cited in this declaration are listed in a bibliography that is appended to the declaration.

II. MY PROFESSIONAL QUALIFICATIONS

II-1. I received an undergraduate education in science and mechanical engineering at the University of New South Wales, in Australia. Subsequently, I pursued graduate studies at Oxford University and received from that institution a Doctorate of Philosophy in mathematics in 1973, for analyses of plasmas 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-2. Since 1977, a significant part of my work has consisted of technical analyses of safety, security and environmental issues related to nuclear facilities. These analyses have been sponsored by a variety of nongovernmental organizations and local, state and national governments, predominantly in North America and Western Europe. Drawing upon these analyses, I have provided expert testimony in legal and regulatory proceedings, and have served on committees advising US government agencies. In a number of instances, my technical findings have been accepted or adopted by relevant governmental agencies. To illustrate my expertise, I provide in the following paragraphs some details of my experience.

II-3. During the period 1978-1979, I served on an international review group commissioned by the government of Lower Saxony (a state in Germany) to evaluate a proposal for a nuclear fuel cycle center at Gorleben. I led the subgroup that examined safety and security risks, and identified alternative options with lower risk. One of the risk issues that I identified and analyzed was the potential for self-sustaining, exothermic oxidation reactions of fuel cladding in a high-density spent-fuel pool if water is lost from the pool. Hereafter, for simplicity, this event is referred to as a "pool fire". In examining the potential for a pool fire, I identified partial loss of water as a more severe condition than total loss of water. I identified a variety of events that could cause a loss of water from a pool, including aircraft crash, sabotage, terrorism and acts of war. Also, I identified and described alternative spent-fuel-storage options with lower risk; these lower-risk options included design features such as spatial separation, natural cooling and underground vaults. The Lower Saxony government accepted my findings about the risk of a pool fire, and ruled in May 1979 that high-density pool storage of spent fuel was not an acceptable option at Gorleben. As a direct result, policy throughout Germany has been to use dry storage in casks, rather than high-density pool storage, for away-from-reactor storage of spent fuel.

II-4. My work has influenced decision making by safety officials in the US Department of Energy (DOE). During the period 1986-1991, I was commissioned by environmental groups to assess the safety of the military production reactors at the Savannah River Site, and to identify and assess alternative options for the production of tritium for the US nuclear arsenal. Initially, much of the relevant information was classified or otherwise inaccessible to the public. Nevertheless, I addressed safety issues through analyses that were recognized as accurate by nuclear safety officials at DOE. I eventually concluded that the Savannah River reactors could not meet the safety objectives set for them by DOE. The Department subsequently reached the same conclusion, and scrapped the reactors. Current national policy for tritium production is to employ commercial reactors, an option that I had concluded was technically attractive but problematic from the perspective of nuclear weapons proliferation.

II-5. In 1977, and again during the period 1996-2000, I examined the safety and security of nuclear fuel reprocessing and liquid high-level radioactive waste management facilities at the Sellafield site in the UK. My investigation in the latter period was supported by consortia of local governments in Ireland and the UK, and I presented findings at briefings in the UK and Irish parliaments in 1998. I identified safety issues that were not addressed in any publicly available literature about the Sellafield site. As a direct result of my investigation, the UK Nuclear Installations Inspectorate (NII) required the operator of the Sellafield site -- British Nuclear Fuels -- to conduct extensive safety analyses. These analyses confirmed the significance of the safety issues that I had identified, and in January 2001 the NII established a legally binding schedule for reduction of the inventory of liquid high-level radioactive waste at Sellafield. The NII took this action in recognition of the grave offsite consequences of a release to the environment from the tanks in which liquid high-level waste is stored. I had identified a variety of events that could cause such a release, including acts of malice or insanity.

II-6. In January 2002, I authored a submission to the UK House of Commons Defence Committee, addressing the potential for civilian nuclear facilities to be used by an enemy as radiological weapons. The submission drew upon my own work, and the findings of other analysts, dating back as far as the mid-1970s. My primary recommendation was that the Defence Committee should call upon the Parliamentary Office of Science and Technology (POST) to conduct a thorough, independent analysis of this threat. I argued that the UK government and nuclear industry could not be trusted to provide a credible analysis. The Defence Committee subsequently adopted my recommendation, and a study was conducted by POST.

II-7. I was the author or a co-author of two documents, published in 2003, that addressed the safety and security risks arising from the storage of spent fuel in high-density pools at US nuclear power plants.[2] This work expanded on analysis that I had first conducted in the context of the proposed nuclear fuel cycle center at Gorleben, as discussed in paragraph II-3, above. The two documents became controversial, and their findings and recommendations were challenged by the NRC. The US Congress recognized that our findings, if correct, would be significant for national security. Accordingly, Congress requested the National Academy of Sciences (NAS) to conduct an independent investigation of these issues. The Academy's report vindicated the work done by my co-authors and me.[3]

III. CHARACTERISTICS OF THE PROPOSED IRRADIATOR

III-1. According to the NRC, Pa'ina Hawaii has stated that the proposed irradiator would be used primarily for the irradiation of fresh fruit and vegetables bound for the US mainland. Other items to be irradiated would include cosmetics and pharmaceutical products.[4] A story in the technical press has stated that the irradiator would be the Genesis model manufactured by Gray-Star, using a 1 million-Curie Cobalt-60 source located in a water-filled pool 22 feet deep.[5] Cobalt-60 is a radioactive isotope with a half-life of 5.3 years. According to an April 2004 NRC fact sheet, all US commercial irradiators regulated by the NRC currently use Cobalt-60; the amount used at each irradiator typically exceeds 1 million Curies and can range up to 10 million

[2] Thompson, 2003; Alvarez et al, 2003.
[3] NAS, 2005.
[4] NRC, 2005.
[5] Nuclear News, 2005.

Curies.[6] The Cobalt-60 is present in the form of sealed sources typically consisting of metallic "pencils" said to be about one inch in diameter and one foot long.[7]

III-2. The version of Pa'ina Hawaii's license application that has been posted at the NRC website has major redactions. That document does not allow the reaching of any conclusion about the safety and security of the proposed irradiator.

IV. THE POTENTIAL FOR NUCLEAR FACILITIES TO BE AFFECTED BY ACTS OF MALICE OR INSANITY

IV-1. No commercial nuclear facility in the United States was designed to resist attack. Facilities have some capability in this respect by virtue of design for other objectives (e.g., resisting tornado-driven missiles). Beginning in 1994, with the NRC's promulgation of a vehicle-bomb rule, each US nuclear power plant has implemented site-security measures (e.g., barriers, guards) that have some capability to prevent attackers from damaging vulnerable parts of the plant. The scope of this defense was increased in response to the attacks of 11 September 2001. Nevertheless, it continues to reflect the NRC's judgment that a "light defense" of nuclear power plants, to use military terminology, is sufficient.[8] This judgment is not supported by any published strategic analysis. The NRC takes the same approach in regulating nuclear facilities other than power plants, including commercial irradiators.

IV-2. A strategic analysis of needs and opportunities for security of a nuclear facility should have three parts. It should begin with an assessment of the scale of damage that could arise from an attack. A major determinant of this scale is the amount of radioactive material that is available for release to the atmosphere or a water body; other determinants are the

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[6] NRC, 2004b.
[7] Kelly, 2002.
[8] NRC, 2004a.

vulnerability of the facility to attack, and the consequences of attack.[9] The second step in the strategic analysis should be to assess the future threat environment. The third step should be to assess the adequacy of present measures to defend the facility, and to identify options for providing an enhanced defense.

IV-3. The analyst should seek to understand the interests and perspectives of potential attackers. To illustrate, a sub-national group that is a committed enemy of the United States might perceive two major incentives for attacking a US commercial nuclear facility. First, release of a large amount of radioactive material could cause major, lasting damage to the United States. Second, commercial nuclear technology could symbolize US military dominance through nuclear weapons and associated technologies such as guided missiles; a successful attack on a commercial nuclear facility could challenge that symbolism. Conversely, the group might perceive three major disincentives for attack. First, nuclear facilities could be less vulnerable than other potential targets. Second, radiological damage from the attack would be indiscriminate, and could occur hundreds of km downwind in non-enemy locations (e.g., Mexico). Third, the United States could react with extreme violence.

IV-4. The threat environment must be assessed over the entire period during which a nuclear facility is expected to operate. For spent-fuel storage facilities, that period could exceed a century. The risk of attack will accumulate over the period of operation. Forecasting international conditions over several decades is a notoriously difficult and uncertain enterprise. Nevertheless, an implicit or explicit forecast must underlie any decision about the level of security that is provided at a nuclear facility. Prudence dictates that a forecast in this context

[9] Direct release of radioactive material is not the only potential consequence of an attack on a nuclear facility. There is also concern that radioactive or fissile material could be removed from the facility and incorporated into a radiological or nuclear weapon.

should err on the side of pessimism. Decision makers should, therefore, be aware of a literature indicating that the coming decades could be turbulent, with a potential for higher levels of violence.[10] One factor that might promote violence is a perception of resource scarcity. It is noteworthy that many analysts are predicting a peak in world oil production within the next few decades.[11] Also, a recent international survey shows significant degradation in the Earth's ability to provide ecosystem services.[12]

IV-5. The potential for attacks on nuclear facilities has been studied for decades.[13] Nevertheless, the NRC remains convinced that these facilities require only a light defense. The NRC's position fails to account for the growing strategic significance of sub-national groups as potential enemies. Various groups of this kind could possess the motive and ability to mount an attack on a US nuclear facility with a substantial probability of success. The unparalleled military capability of the United States cannot deter such a threat if the attacking group has no territory that could be counter-attacked. Moreover, use of US military capability could be counter-productive, creating enemies faster than they are killed or captured. Many analysts believe that the invasion of Iraq has produced that outcome.

IV-6. The discussion in the preceding paragraphs shows that it would be prudent to consider options for providing an enhanced defense of nuclear facilities. Design studies have identified a large potential for increasing the robustness of new facilities.[14] This finding argues for careful consideration of alternative options during the licensing of a new facility. At existing facilities, there is usually less opportunity for increasing robustness. Nevertheless, there are

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[10] Kugler, 1995; Raskin et al, 2002.
[11] Hirsch et al, 2005.
[12] Stokstad, 2005.
[13] Ramberg, 1984.
[14] Hannerz, 1983.

many opportunities to enhance the defenses of an existing facility. I have identified such opportunities in a number of instances. For example, I have identified a set of measures that could provide an enhanced defense of the San Onofre nuclear power plant.[15]

V. POTENTIAL ACTS OF MALICE OR INSANITY IN THE CONTEXT OF IRRADIATORS

V-1. Section IV, above, shows that it would be prudent, in the licensing and regulation of a range of nuclear facilities, to consider the implications of potential acts of malice or insanity. Commercial irradiators, such as that proposed by Pa'ina Hawaii, are among the facilities for which this consideration would be prudent. The reason is that these irradiators contain large amounts of Cobalt-60. If that material were removed from its containment and brought into proximity to humans and other life forms or their habitats, significant harm could occur. The nature of that harm is illustrated by a case study that is discussed in paragraph V-3, below.

V-2. An act of malice or insanity could remove Cobalt-60 from its containment, and bring this material into potential proximity to life forms, in two ways. First, a violent event involving mechanisms such as blast, impact and fire could release Cobalt-60 to the atmosphere from the irradiator facility or during transport of Cobalt-60 sealed sources to or from the facility.[16] This violent event could be a deliberate attack or, conceivably, a collateral event deriving from an attack directed elsewhere. Second, Cobalt-60 sealed sources could be removed intact from the irradiator facility or during transport to or from the facility, and these sources could be used to deliberately irradiate life forms or their habitats. This irradiation could be accomplished by atmospheric dispersal of Cobalt-60 from a sealed source, with or without

[15] Thompson, 2004.

[16] After release to the atmosphere, the Cobalt-60 would be present in fragments or particles of various sizes, which would eventually be deposited on the ground around or downwind of the point of release.

chemical and physical manipulation of the source prior to dispersal.[17] An explosive charge could be used to achieve dispersal, a process that is commonly described as the use of a "dirty bomb". Atmospheric dispersal might also be achieved, after chemical and physical manipulation of the source, through mechanisms such as spraying and combustion. As an alternative to atmospheric dispersal, hostile irradiation could be accomplished by clandestinely placing sealed sources, or fragments thereof, in locations (e.g., bus or train stations) where targeted populations are likely to be present.[18]

V-3. Findings of a theoretical case study on atmospheric dispersal of Cobalt-60 were summarized in Congressional testimony by the Federation of American Scientists in 2002.[19] The case study assumed that one Cobalt-60 "pencil" from a commercial irradiator would be explosively dispersed at the lower tip of Manhattan. The results were compared with those from an assumed dispersal of radioactive cesium, in the following statement:[20]

> "Again, no immediate evacuation would be necessary, but in this case [the Cobalt-60 dispersal], an area of approximately one thousand square kilometers, extending over three states, would be contaminated. Over an area of about three hundred typical city blocks, there would be a one-in-ten risk of death from cancer for residents living in the contaminated area for forty years. The entire borough of Manhattan would be so contaminated that anyone living there would have a one-in-a-hundred chance of dying from cancer caused by the residual radiation. It would be decades before the city was inhabitable again, and demolition might be necessary."

V-4. Following an atmospheric dispersal of radioactive material such as Cobalt-60, the area of land that would be regarded as contaminated, and the overall economic consequences of the event, would depend on the contamination standard that would apply.[21] At present, there are

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[17] Zimmerman and Loeb, 2004.
[18] NRC, 2003.
[19] Kelly, 2002.
[20] Kelly, 2002.
[21] Reichmuth et al, 2005.

competing standards, and no clarity about which one would apply.[22] Resolving this issue could be politically difficult, either before or after a dispersal event. A further complicating factor is the exclusion of radiation risk from virtually all insurance policies written in the United States.[23]

V-5. A malicious actor who seeks to expose a population to radioactive material, such as Cobalt-60, could have a range of goals including: (i) causing prompt casualties; (ii) spreading panic; (iii) recruitment to the actor's cause; (iv) asset denial; (v) economic disruption; and (vi) causing long-term casualties.[24]

V-6. Many public officials in the United States and elsewhere are aware of the threat of malicious exposure to radioactive material. At times, substantial resources have been allocated to addressing this threat. For example, a major US government effort was mounted in December 2003 to detect "dirty bombs" in various US cities.[25] Recently, the Australian government has located large, unsecured radioactive sources in two countries in Southeast Asia. At least one of these sources was Cobalt-60.[26] Acting in a manner that invites comparison with licensing of the proposed Pa'ina Hawaii irradiator, the National Nuclear Security Administration (NNSA) removed Cobalt-60 from an irradiator at the University of Hawai'i in March 2005.[27] This removal occurred during the same week in which the NRC issued a Notice of Violation that responded to an NRC-observed security breach at the irradiator in March 2003.[28] It is said that

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[22] Medalia, 2004; Zimmerman and Loeb, 2004.
[23] Zimmerman and Loeb, 2004.
[24] Medalia, 2004.
[25] Mintz and Schmidt, 2004.
[26] Eccleston and Walters, 2005.
[27] NNSA, 2005.
[28] Environment Hawai'i, 2005b.

the irradiator contained about 1,000 Curies of Cobalt-60.[29] An NNSA official described the removal of this Cobalt-60 as follows:[30]

> "The removal of these radiological sources has greatly reduced the chance that radiological materials could get into the wrong hands. The university of Hawaii, its surrounding neighbors and the international community are safer today as [a] result of this effort."

V-7. There is a comparatively small technical literature on the safety and security of commercial irradiators, although it is known that safety and security incidents have occurred at these facilities.[31] Irradiators represent one application of sealed radioactive sources. Overall, the use of those sources has created grounds for concern from the perspective of security. According to NRC data, there were more than 1,300 instances of lost, stolen and abandoned sealed sources in the United States between 1998 and 2002.[32]

V-8. In June 2003, the NRC issued its first security order requiring enhanced security at large commercial irradiators.[33] The nature and scope of the required security measures have not been publicly disclosed. It is noteworthy that NRC officials have said that the NRC lacks sufficient staff to conduct inspections of all sealed-source licensees that are expected to receive security orders.[34]

V-9. If provided with relevant information about the design of commercial irradiators, and the security measures that are in effect at these facilities, independent analysts could assess the vulnerability of these facilities to potential acts of malice or insanity. That assessment could be performed in a manner such that sensitive information is not publicly disclosed. The

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[29] Environment Hawai'i, 2005a.
[30] NNSA, 2005.
[31] NRC, 1983.
[32] GAO, 2003, page 17.
[33] GAO, 2003, page 28.
[34] GAO, 2003, page 31.

assessment could, for example, assess the vulnerability of irradiators to shaped charges.[35] Also, the assessment could examine the NRC's undocumented assertion that it has "preliminarily determined that it would be extremely difficult for someone to explode a cobalt-60 source in a way that could cause widespread contamination".[36] As explained in paragraph V-2, above, explosive dispersal of an intact Cobalt-60 sealed source is one, but not the only, mechanism whereby Cobalt-60 could be brought into proximity to targeted populations.

VI. ALTERNATIVE OPTIONS

VI-1. The currently-proposed design and mode of operation of the Pa'ina Hawaii irradiator implies a risk of harm to people and/or the environment, arising from potential acts of malice or insanity. Assessment of the nature and scale of that risk must await the provision of more information about the facility than is now publicly available. It is, however, already clear that lower-risk options exist. These options could be systematically examined in an EIS.

VI-2. Two options are available that could eliminate the risk. One such option would be to adopt non-irradiative methods of treating fresh fruit and vegetables. The second option would to use an irradiator that does not require radioactive material such as Cobalt-60. In this context, it is noteworthy that an existing commercial irradiator in Hawai'i employs electron-beam technology. This facility, known as Hawai'i Pride, was built at Kea'au in 2000. Some observers question whether two irradiators, or even one, can be economically viable in Hawai'i.[37]

VI-3. If the Pa'ina Hawaii irradiator were to be built and operated, using Cobalt-60, its design, location and mode of operation could be modified to reduce the risk of harm arising from potential acts of malice or insanity. For example, site security and the robustness of the facility

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[35] Walters, 2003.
[36] NRC, 2004b.
[37] Environment Hawai'i, 2005c.

could be enhanced. Alternative locations could potentially reduce the risk in two ways. First, the currently-proposed location might be especially attractive to attackers because of the proximity of military and symbolic targets including Hickam Air Force Base and Pearl Harbor. Second, the currently-proposed location at Honolulu International Airport might facilitate attack from the air by, for example, an explosive-laden general aviation aircraft. Full delineation of potential modifications, and assessment of their costs and contributions to risk reduction, must await the provision of more information about the facility than is now publicly available.

VII. CONSIDERATION OF ACTS OF MALICE OR INSANITY IN A LICENSE PROCEEDING, EA, OR EIS

VII-1. During an open session of a license proceeding, or in the published version of an EA or EIS, it would be inappropriate to disclose information that could assist the perpetrator of an act of malice or insanity that affects a nuclear facility. It does not follow, however, that acts of malice or insanity cannot be considered in a license proceeding, an EA, or an EIS. Well-tested procedures are available whereby this consideration could occur without publicly disclosing sensitive information. In the context of a license proceeding, some of the sessions, and the accompanying documents, could be open only to authorized persons. Similarly, an EA or EIS could contain sections or appendices that are available only to authorized persons. Interested parties, including public-interest groups, could nominate representatives, attorneys and experts who can become authorized persons on their behalf.

VIII. MAJOR CONCLUSIONS

VIII-1. It would be prudent, in the licensing and regulation of a range of nuclear facilities, to consider the implications of potential acts of malice or insanity. Commercial irradiators, such as that proposed by Pa'ina Hawaii, are among the facilities for which this consideration would be prudent.

VIII-2. The currently-proposed design and mode of operation of the Pa'ina Hawaii irradiator implies a risk of harm to people and/or the environment, arising from potential acts of malice or insanity. Assessment of the nature and scale of that risk must await the provision of more information about the facility than is now publicly available. It is, however, already clear that lower-risk options exist. These options could be systematically examined in an EIS.

VIII-3. Well-tested procedures are available whereby acts of malice or insanity could be considered in a license proceeding, an EA, or an EIS related to the proposed Pa'ina Hawaii irradiator.

I declare under penalty of perjury that I have read the foregoing declaration and know the contents thereof to be true of my own knowledge.

Dated at Cambridge, Massachusetts, 3 October 2005.

GORDON R. THOMPSON

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NNSA NEWS
National Nuclear Security Administration
U.S. Department of Energy

For Immediate Release
April 13, 2005

Bryan Wilkes
202-586-7371

NNSA Removes Radioactive Sources From University Facility

WASHINGTON, DC – Radioactive materials that could be used in a dirty bomb were recently removed from at a University of Hawaii facility and have arrived safely at a secure National Nuclear Security Administration (NNSA) facility, the agency said today.

NNSA removed a substantial quantity of radioactive cobalt-60 from a research irradiator at the university. The removal is part of a national effort by NNSA's U.S. Radiological Threat Reduction Program to recover and secure radiological materials that could be used to make a dirty bomb.

"The removal of these radiological sources has greatly reduced the chance that radiological materials could get into the wrong hands," said NNSA Deputy Director for Nonproliferation Paul Longsworth. "The University of Hawaii, its surrounding neighbors and the international community are safer today as result of this effort."

The U.S. Department of Energy in the 1960s produced cobalt-60 sources and lent 100 of those sources to the university for agricultural research. When the facility stopped conducting agricultural research, the remaining sources stored at the facility became a security and safety concern.

To reduce this threat, NNSA facility contractors and subcontractors with expertise in removing, packaging and transporting cobalt-60 completed removing the materials on March 28, 2005. The material arrived at a secure NNSA facility on April 12 and has been permanently disposed.

The program is part of the Bush administration's Global Threat Reduction Initiative (GTRI), which works to identify, secure, remove and/or facilitate the disposition of vulnerable, high-risk nuclear and other radiological materials around the world as quickly and expeditiously as possible.

GTRI has initiated radiological threat reduction efforts in 40 countries in Europe, Asia, Africa, and South and Central America. NNSA recovers high-risk radioactive sealed sources declared excess and unwanted by domestic licensees and securely stores them at NNSA sites. To date, NNSA has recovered more than 10,500 high-risk sealed sources within the United States.

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NA-05-07

Public Interest Report
Journal of the Federation of American Scientists
Volume 55, Number 2
March/April 2002

Dirty Bombs: Response to a Threat

Henry Kelly testified before the Senate Foreign Relations Committee on March 6, 2002 on the threat of radiological attack by terrorist groups. This excerpt is taken from the text of his written testimony, based on analysis by Michael Levi, Robert Nelson, and Jaime Yassif, which can be found at www.fas.org.

Surely there is no more unsettling task than considering how to defend our nation against individuals and groups seeking to advance their aims by killing and injuring innocent people. But recent events make it necessary to take almost inconceivably evil acts seriously. Our analysis of this threat has reached three principle conclusions:

1. Radiological attacks constitute a credible threat. Radioactive materials that could be used for such attacks are stored in thousands of facilities around the US, many of which may not be adequately protected against theft by determined terrorists. Some of this material could be easily dispersed in urban areas by using conventional explosives or by other methods.

Continued on page 6

In This Issue

Making Sense of Information Restrictions After September 11

By Steven Aftergood and Henry Kelly

The Bush Administration introduced a series of new restrictions on public access to government information following the terrorist attacks of last year. Under the new policy, agencies have removed thousands of pages from government web sites and withdrawn thousands of government documents and technical reports from public libraries. In one case, government depository libraries around the country were ordered to destroy their copies of a recently issued USGS CD-ROM on US water resources.

The new restrictions have alarmed scientists, public interest groups, and concerned citizens because they interfere with the conduct of research and limit legitimate access to information needed for public discussion of key policy issues. Continued growth of restrictions without any clear end in sight creates understandable concern that we are watching a veil of indiscriminate security descending on significant portions of the American policy process.

Without debating the merits of any particular case, it is clear that the new information restrictions have been undertaken in a largely ad hoc fashion. While the unprecedented emergency required quick action in the short term, the inconsistent and often arbitrary policies that have emerged are clearly not satisfactory over the long term. While terrorist threats require reshaping some standards, they do not call for wholesale abandonment of existing processes and safeguards. Few of the issues raised are new. The challenge of drawing a line between what should be protected and what should not has been the subject of years of debate that has

Continued on page 2

The FAS Public Interest Report
The FAS Public Interest Report (USPS 188-100) is published bi-monthly at 1717 K St. NW Suite 209, Washington, DC 20036. Annual subscription is $50/year.

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"Dirty Bombs" *Continued from page 1*

2. While radiological attacks would result in some deaths, they would not result in the hundreds of thousands of fatalities that could be caused by a crude nuclear weapon. Attacks could contaminate large urban areas with radiation levels that exceed EPA health and toxic material guidelines.
3. Materials that could easily be lost or stolen from US research institutions and commercial sites could contaminate tens of city blocks at a level that would require prompt evacuation and create terror in large communities even if radiation casualties were low. Areas as large as tens of square miles could be contaminated at levels that exceed recommended civilian exposure limits. Since there are often no effective ways to decontaminate buildings that have been exposed at these levels, demolition may be the only practical solution. If such an event were to take place in a city like New York, it would result in losses of potentially trillions of dollars.

Background

Significant amounts of radioactive materials are stored in laboratories, food irradiation plants, oil drilling facilities, medical centers, and many other sites. Cobalt-60 and cesium-137 are used in food disinfection, medical equipment sterilization, and cancer treatments. During the 1960s and 1970s the federal government encouraged the use of plutonium in university facilities studying nuclear engineering and nuclear physics. Americium is used in smoke detectors and in devices that find oil sources.

With the exception of nuclear power reactors, commercial facilities do not have the types or volumes of materials usable for making nuclear weapons. Facility owners provide adequate security when they have a vested interest in protecting commercially valuable material. However, once radioactive materials are no longer needed and costs of appropriate disposal are high, security measures become lax, and the likelihood of abandonment or theft increases.

We must wrestle with the possibility that sophisticated terrorist groups may be interested in obtaining these materials and with the enormous danger to society that such thefts might present. Significant quantities of radioactive material have been lost or stolen from US facilities during the past few years and thefts of foreign sources have led to fatalities. In the US, sources have been found abandoned in scrap yards, vehicles, and residential buildings.

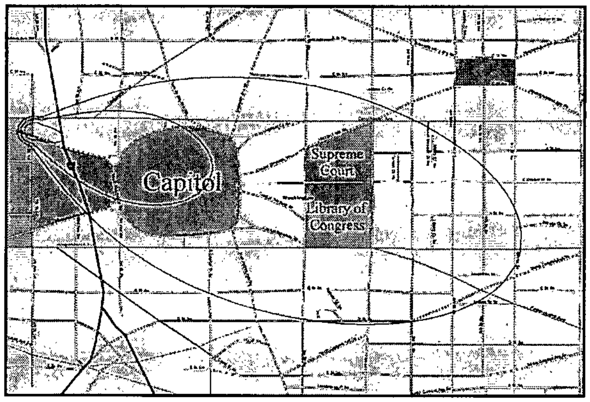


Figure 1. Long-term Contamination Due to Cesium Bomb in Washington, DC

Inner Ring: One cancer death per 100 people due to remaining radiation

Middle Ring: One cancer death per 1,000 people due to remaining radiation

Outer Ring: One cancer death per 10,000 people due to remaining radiation; EPA recommends decontamination or destruction

If these materials were dispersed in an urban area, they would pose a serious health hazard. Intense sources of gamma rays can cause acute radiation poisoning, or even fatalities at high doses. Long-term exposure to low levels of gamma rays can cause cancer. If alpha emitters, such as plutonium, americium or other elements, are present in the environment in particles small enough to be inhaled, these particles can become lodged in the lungs and damage tissue, leading to long-term cancers.

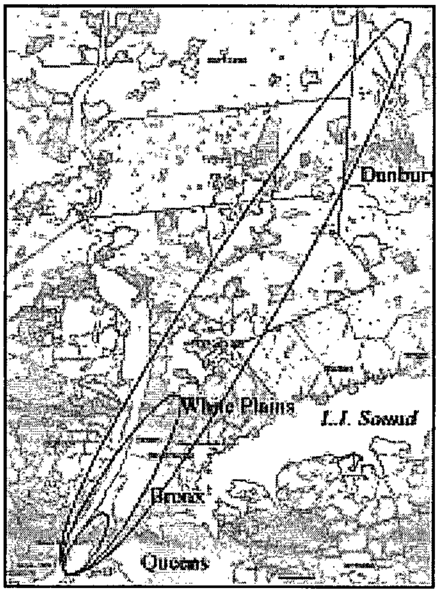
Case Studies

We have chosen three specific cases to illustrate the range of impacts that could be created by malicious use of comparatively small radioactive sources: the amount of cesium that was discovered recently abandoned in North Carolina, the amount of cobalt commonly found in a single rod in a food irradiation facility, and the amount of americium typically found in oil well logging systems. The impact would be much greater if the radiological device in question released the enormous amounts of radioactive material found in a single nuclear reactor fuel rod, but it would be quite difficult and dangerous for anyone to attempt to obtain and ship such a rod without death or detection. The Committee will undoubtedly agree that the danger presented by modest radiological sources that are comparatively easy to obtain is significant as well.

The impact of radioactive material release in a populated area would vary depending on a number of factors, such as the amount of material released, the nature of the material, the details of the device that distributes the material, the direction and speed of the wind, other weather conditions, the size of the particles released (which affects their ability to be carried by the wind and to be inhaled), and the location and size of buildings near the release site. Uncertainties inherent in the complex models used in predicting the effects of a radiological weapon mean that it is only possible to make crude estimates of impacts; the estimated damage we show might be off by an order of magnitude.

In all three cases we have assumed that the material is released on a calm day (wind speed of one mile per hour) and that the material is distributed by an explosion that causes a mist of fine particles to spread downwind in a cloud. People will be exposed to radiation in several ways.

- They will be exposed to material in the dust inhaled during the initial passage of the radiation cloud, if they have not been able to escape the area before the dust



◀ **Figure 2. Long-term Contamination Due to Cobalt Bomb in NYC - EPA Standards**

Inner Ring: One cancer death per 100 people due to remaining radiation

Middle Ring: One cancer death per 1,000 people due to remaining radiation

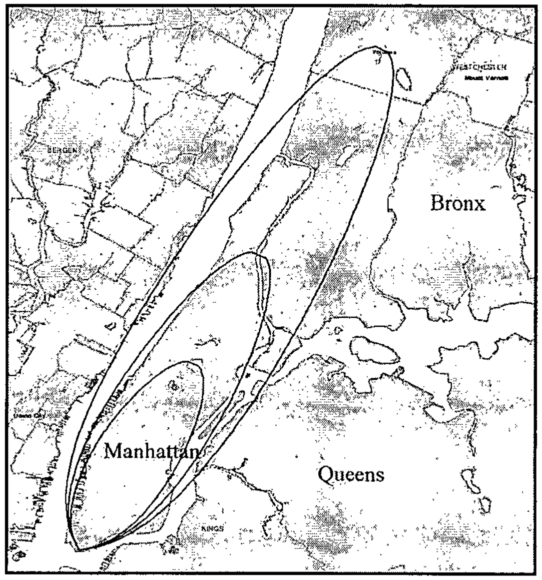
Outer Ring: One cancer death per 10,000 people due to remaining radiation; EPA recommends decontamination or destruction

Figure 3. Contamination Due to Cobalt Bomb in NYC - Chernobyl Comparison ▶

Inner Ring: Same radiation level as *permanently closed zone* around Chernobyl

Middle Ring: Same radiation level as *permanently controlled zone* around Chernobyl

Outer Ring: Same radiation level as *periodically controlled zone* around Chernobyl



cloud arrives. We assume that about twenty percent of the material is in particles small enough to be inhaled. If this material is an alpha emitter, it will stay in the body and lead to long term exposure.

- Anyone living in the affected area will be exposed to material deposited from the dust that settles from the cloud. If the material contains gamma emitters, residents will be continuously exposed to radiation from this dust. If the material contains alpha emitters, dust that is pulled off the ground and into the air by wind, automobile movement, or other actions will continue to be inhaled, adding to exposure.
- In a rural area, people would also be exposed to radiation from contaminated food and water sources.

The EPA has a series of recommendations for addressing radioactive contamination that would likely guide official response to a radiological attack. Immediately after the attack, authorities would evacuate people from areas contaminated to levels exceeding those guidelines. People who received more than twenty-five times the threshold dose for evacuation would have to be taken in for medical supervision.

In the long term, the cancer hazard from the remaining radioactive contamination would have to be addressed. Typically, if decontamination could not reduce the danger of cancer death to about one-in-ten-thousand, the EPA would recommend the contaminated area be eventually abandoned. Several materials that might be used in a radiological attack can chemically bind to concrete and asphalt, while other materials would become physically lodged in crevices on the surface of buildings, sidewalks and streets. Options for decontamination would range from sandblasting to demolition, with the latter likely being the only feasible option. Some radiological materials would also chemically bind to soil in city parks, with the only disposal method being large scale removal of contaminated dirt. In short, there is a high risk that the area contaminated by a radiological attack would have to be deserted.

Example 1: Cesium (Gamma Emitter)

Two weeks ago, a lost medical gauge containing cesium was discovered in North Carolina. Imagine that the cesium in this device was exploded in Washington, DC in a bomb using ten pounds of TNT. The initial passing of the radioactive cloud would be relatively harmless, and no one would have to evacuate immediately. However, residents of an area of about five city blocks, if they remained, would have a one-in-a-thousand chance of getting cancer. A swath about one mile long covering an area of forty city blocks would exceed EPA contamination limits, with remaining residents having a one-in-ten thousand chance of getting cancer. If decontamination were not possible, these areas would have to be abandoned for decades. If the device was detonated at the National Gallery of Art, the contaminated area might include the Capitol, Supreme Court, and Library of Congress, as seen if Figure 1.

Example 2: Cobalt (Gamma Emitter)

Now imagine if a single piece of radioactive cobalt from a food irradiation plant were dispersed by an explosion at the lower tip of Manhattan. Typically, each of these cobalt "pencils" is about one inch in diameter and one foot long, with hundreds of such pieces often being found in the same facility. Admittedly, acquisition of such material is less likely than in the previous scenario, but we still consider the results, depicted in Figure 2. Again, no immediate evacuation would be necessary, but in this case, an area of approximately one-thousand square kilometers, extending over three states, would be contaminated. Over an area of about three hundred typical city blocks, there would be a one-in-ten risk of death from cancer for residents living in the contaminated area for forty years.

Continued on page 8

Figure 4. Immediate Effects Due to Americium Bomb in New York City
Inner Ring: Everyone must receive medical supervision
Middle Ring: Maximum annual dose for radiation workers exceeded
Outer Ring: Area should be evacuated before radiation cloud passes

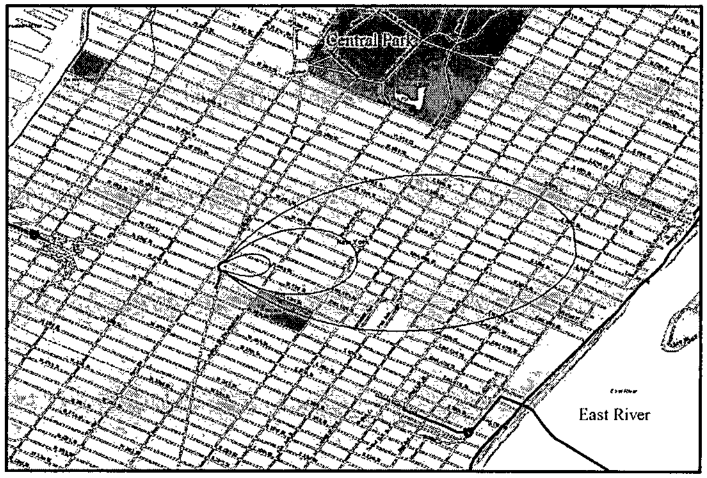


Figure 5. Contamination Due to Americium Bomb in New York City.
Inner Ring: One cancer death per 100 people due to remaining radiation
Middle Ring: One cancer death per 1,000 people due to remaining radiation
Outer Ring: One cancer death per 10,000 people due to remaining radiation; EPA recommends decontamination or destruction

"Dirty Bombs" *Continued from page 7*

The entire borough of Manhattan would be so contaminated that anyone living there would have a one-in-a-hundred chance of dying from cancer caused by the residual radiation. It would be decades before the city was inhabitable again, and demolition might be necessary.

For comparison, consider the 1986 Chernobyl disaster, in which a Soviet nuclear power plant went through a meltdown. Radiation was spread over a vast area, and the region surrounding the plant was permanently closed. In our current example, the area contaminated to the same level of radiation as that region would cover much of Manhattan, as shown in Figure 3. Furthermore, near Chernobyl, a larger area has been subject to periodic controls on human use such as restrictions on food, clothing, and time spent outdoors. In the current example, the equivalent area extends fifteen miles.

Example 3: Americium (Alpha Emitter)

If a typical americium source used in oil well surveying were blown up with one pound of TNT, people in a region roughly ten times the area of the initial bomb blast would require medical supervision and monitoring, as depicted in Figure 4. An area thirty times the size of the first area (a swath one kilometer long and covering twenty city blocks) would have to be evacuated within half an hour. After the initial passage of the cloud, most of the radioactive materials would settle to the ground. Of these materials, some would be forced back up into the air and inhaled, thus posing a long-term health hazard, as illustrated by Figure 5. A ten-block area contaminated in this way would have a cancer death probability of one-in-a-thousand. A region two kilometers long and covering sixty city blocks would be contaminated in excess of EPA safety guidelines. If the buildings in this area had to be demolished and rebuilt, the cost would exceed fifty billion dollars.

Recommendations

A number of practical steps can be taken that would greatly reduce the risks presented by radiological weapons. Since the US is not alone in its concern about radiological attack, and since we clearly benefit by limiting access to dangerous materials anywhere in the world, many of the measures recommended should be undertaken as international collaborations.

1. Reduce access to radioactive materials

Measures needed to improve the security of facilities holding dangerous amounts of these materials will increase costs. In some cases, it may be worthwhile to pay a higher price for increased security. In other instances, however, the development of alternative technologies may be the more economically viable option. Specific security steps include the following:

Fully fund material recovery and storage programs. Hundreds of plutonium, americium, and other radioactive sources are stored in dangerously large quantities in university laboratories and other facilities. In all too many cases they are not used frequently, resulting in the risk that attention to their security will diminish over time. At the same time, it is difficult for the custodians of these materials to dispose of them since in many cases only the Department of Energy (DoE) is authorized to recover and transport them to permanent disposal sites. The DoE Off-Site Source Recovery Project, which is responsible for undertaking this task, has successfully secured over three-thousand sources and has moved them to a safe location. Unfortunately, the inadequate funding of this program serves as a serious impediment to further source recovery efforts. This program should be given the needed attention and firm goals should be set for identifying, transporting, and safeguarding all unneeded radioactive materials.

Review licensing and security requirements and inspection procedures for all dangerous amounts of radioactive material. Human Health Services, the DoE, the Nuclear Regulatory Commission and other affected agencies should be provided with sufficient funding to ensure that physical protection measures are adequate and that inspections are conducted on a regular basis. A thorough reevaluation of security regulations should be conducted to ensure that protective measures apply to amounts of radioactive material that pose a homeland security threat, not just those that present a threat of accidental exposure.

Fund research aimed at finding alternatives to radioactive materials. A research program aimed at developing inexpensive substitutes for radioactive materials in functions such as food sterilization, smoke detection, and oil well logging should be created and provided with adequate funding.

2. Early Detection

Expanded use of radiation detection systems. Systems capable of detecting dangerous amounts of radiation are comparatively inexpensive and unobtrusive. The Office of Homeland Security should act promptly to identify all areas where such sensors should be installed, ensure that information from these sensors is continuously assessed, and ensure adequate maintenance and testing. High priority should be given to key points in the transportation system, such as airports, harbors, rail stations, tunnels, highways. Routine checks of scrap metal yards and land fill sites would also protect against illegal or accidental disposal of dangerous materials.

Fund research to improve detectors. A program should be put in place to find ways of improving upon existing detection technologies as well as improving plans for deployment of these systems and for responding to alarms.

3. Effective Disaster response

An effective response to a radiological attack requires a system capable of quickly gauging the extent of the damage, identifying appropriate responders, developing a coherent response plan, and getting the necessary personnel and equipment to the site rapidly.

First responders and hospital personnel need to understand how to protect themselves and affected citizens in the

Continued on page 10

FAS Conclusions

Radiological attacks constitute a credible threat. Radioactive materials that could be used for such attacks are stored in thousands of facilities around the US, many of which may not be adequately protected against theft by determined terrorists. Some of this material could be easily dispersed in urban areas by using conventional explosives or by other methods.

Radiological attacks would not result in the hundreds of thousands of fatalities that could be caused by a crude nuclear weapon, though they could contaminate large urban areas.

Materials that could easily be lost or stolen could contaminate tens of city blocks at a level that would require prompt evacuation and create terror in large communities even if radiation casualties were low. But, since there are often no effective ways to decontaminate buildings that have been exposed at these levels, demolition may be the only practical solution.

FAS Recommendations

Reduce access to radioactive materials
1. Fully fund material recovery and storage programs.
2. Review licensing and security requirements and inspection procedures for all dangerous amounts of radioactive material.
3. Fund research aimed at finding alternatives to radioactive materials.

Early Detection
1. Expanded use of radiation detection systems.
2. Fund research to improve detectors.

Effective Disaster response
1. First responders and hospital personnel need to understand how to protect themselves and affected citizens.
2. Research into cleanup of radiologically contaminated cities.

Just In! Results of the FAS Member Survey

In early 2002, FAS conducted a survey of our members. Our purpose was to better understand member interests, document expertise, and engage members in helping affirm old priorities and set new ones.

The survey's results profile a highly educated membership with in-depth expertise in such sciences as physics, biology, and chemistry, and who work either full-time in these fields or are retired from positions in academic institutions. FAS members share the concerns of civil rights, environmental, and human rights organizations, and are active supporters of Environmental Defense, the Natural Resources Defense Council, the ACLU, People for the American Way, and Human Rights Watch. The largest percentage of our members joined FAS in the 1970s. When asked how members came to join FAS, 60% said that they had "known about FAS forever." While half of FAS' responding members are over 70 years of age, a growing number of individuals under the age of 50 are joining up. We were pleased to learn that 68% of our members find the Public Interest Report "informative, timely and relevant;" 20% agreed that the PIR "is perfect as is;" and 19% would like us to cover more energy and environmental issues.

FAS' members are a group with mutual concerns, common backgrounds, and scientific interests. Their survery responses do differ, though. Let's take a closer look.

"My fields of expertise are..."

FAS was founded by physicists working on the Manhattan Project in 1945 and was known back then as the "scientists lobby" and the social conscience of the nation's scientists. When we asked members to identify the fields in which they worked, sciences such as physics, biology and engineering outnumbered the fields of foreign policy, economics, law and finance. Nearly 30% of survey respondents identified themselves as physicists. The

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"Dirty Bombs" *Continued from page 9*

event of a radiological attack and be able to rapidly determine if individuals have been exposed to radiation. There is great danger that panic in the event of a radiological attack on a large city could lead to significant casualties and severely stress the medical system. While generous funding has been made available for this training, the program appears in need of a clear management strategy. Dozens of federal and state organizations are involved, and it is not clear how materials will be certified or accredited.

Research into cleanup of radiologically contaminated cities has been conducted in the past, primarily in addressing the possibility of nuclear war. Such programs should be revisited with an eye to the specific requirements of cleaning up after a radiological attack.

Conclusion

The events of September 11 have created a need to very carefully assess our defense needs and ensure that the resources we spend for security are aligned with the most pressing security threats. The US has indicated its willingness to spend hundreds of billions of dollars to combat threats that are, in our view, far less likely to occur than a radiological attack. This includes funding defensive measures that are far less likely to succeed than the measures that we propose in this testimony. The comparatively modest investments to reduce the danger of radiological attack surely deserve priority support.

In the end, however, we must face the brutal reality that no technological remedies can provide complete confidence that we are safe from radiological attack. Determined, malicious groups might still find a way to use radiological weapons or other means when their only goal is killing innocent people, and if they have no regard for their own lives. In the long run our greatest hope must lie in building a prosperous, free world where the conditions that breed such monsters have vanished from the earth. ***PIR***

"Survey" *Continued from page 9*

next largest fields represented were medicine (18%), biology (15%), engineering (15%) and chemistry (13%).

It is especially interesting to compare fields represented by FAS earliest members with more recent members. Nearly half of FAS members who joined before 1955 are physicists. FAS newest members, who joined since 2000, are also physicists (21%), but 29% said their field of expertise is national security, 25% said aerospace, and 22% said computer science. This reflects significant growth in security-related fields over the past decades—and an increasingly diverse membership. Other fields were environmental science, psychology, public policy, finance, law and transportation. Nearly half of responding members work in nonprofit or academic institutions as opposed to private industry (13%) or in government (8%).

Based on survey results, [FAS] members' priorities are right on target with FAS' agenda.

"The highest level of education I have attained is..."

FAS continues to attract highly educated scholars and analysts, and the composition of members' level of education does not change as the fields of expertise do from one age group to another. Among all respondents, 63% have Ph.Ds. Individuals with professional doctoral degrees such as doctors or lawyers account for 14%. A master's degree is the highest level of education attained by 12%, and 7% have a bachelor's degree. Two percent of members are high school students or graduates. These two latter goups are our most recent members, having come to us through our website.

"Go to <www.fas.org>..."

In addition to giving access to technical information and policy analysis, the FAS website is our most effective member recruitment tool. Since 2000, 85% of FAS newest members joined over the web. More than half of these members also use the website once a month; more than a third use it every week. The survey also shows that among FAS' earliest members (members who joined between 1945 and 1970), 43% use the website once a month or less. For members who joined in the 1980s and 90s, we see a modest increase in members' use (46%). Only 7% of our members have no access to the Internet.

The feature of the website that FAS members use most often are the technical details about weapons technologies and arms control treaties, and the country-by-country weapons sales and possessions tables. Eighteen percent refer to the site for this information, while 15% use the site to keep up to date on FAS findings and projects. This does not capture the hundreds of thousands of hits that the website receives daily from non-member users. Surprisingly, one third of our members were not aware of the site at all.

"I subscribe to..."

The survey offered members a wide range of choices of journals and trade magazines, including Bulletin of Atomic Scientists, Foreign Affairs, Fortune, Time, Science, Scientific American, and US News and World Report. By far, the most subscribed to magazines were Science (48%) and Scientific American (36%). Subscribers to the Bulletin of Atomic Scientists and New Scientists each account for 21% of member respondents. While subscription to Science and Scientific American is steady among FAS members throughout the generations, only 6% of our most recent members subscribe to the Bulletin.

"I am also a member of..."

Our survey shows that FAS members live up to their reputation as scientists with a conscience. They support numerous causes, working to protect the world's environmental resources, eliminate weapons of mass