Statement of

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on the

Fukushima Nuclear Disaster and its Implications for U.S. Nuclear Power Reactors

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Introduction

Madam Chair and members of the Committee, thank you for providing the Natural Resources Defense Council (NRDC) and me the opportunity to present our views on the nuclear disaster at the Fukushima Daiichi Nuclear Power Station and its implication for nuclear power reactors in the United States. NRDC is an international, non-profit organization of more than 350 scientists, lawyers, and environmental specialists, dedicated to protecting public health and the environment. Founded in 1970, NRDC serves more than 1.3 million members, supporters and environmental activists from offices in New York, Washington, Los Angeles, San Francisco, Chicago and Beijing.

Scale of the Fukushima Accident

After Chernobyl, the Fukushima nuclear accident ranks as the second most disastrous civil nuclear power reactor accident to date.

On March 22, 2011, L'Institut de Radioprotection et de Sûreté Nucléaire (IRSN) in France published an assessment of radioactivity released at Fukushima Daiichi. IRSN estimated the releases through March 22were on the order of 10 percent of the releases from Chernobyl, but also cautioned against drawing a similar comparison regarding consequences because of differences in population distribution (Fukushima is on the coast) .and meteorology. We believe this release estimate is highly speculative. In the years to come a great deal of effort will be expended in estimating the radioactive “source term.”

My colleague, Dr. Matthew McKinzie, and I have made a rough preliminary estimate of the collective radiation dose from external exposure based on radiation monitoring data from Japan. (Attached). We should be mindful that the uncertainties in the estimated exposures are quite large, the releases are still ongoing, the external gamma exposure dose excludes dose via inhalation, ingestion of water and dietary intake pathways, and *there is a lot that we simply do not know*. With these cautionary notes, we find the collective dose from external exposure *to date*—and consequentially excess cancers that are projected to result from this exposure pathway—appears to be roughly one to two orders of magnitude, *i.e.*, ten to one hundred times, greater than the collective radiation dose resulting from the Three Mile Island (TMI) accident, which was on the order of 2,000 person-rem.

The collective dose from the Fukushima accident appears to be in the neighborhood of two orders of magnitude less than that from the Chernobyl accident. Similarly, the long term human health consequences of the nuclear disaster are one to two orders of magnitude less than the immediate non-nuclear consequences of the earthquake and tsunami. In sum, in terms of radiological consequences our preliminary estimate at this time is that the Fukushima disaster is two to three orders of magnitude worse than TMI (probably closer to two) and one to two orders of magnitude less than Chernobyl (probably closer to two). This preliminary comparison of Fukushima with TMI and Chernobyl may change as we learn more.

I hesitate to guess what the economic toll from Fukushima will be, and in any case it will be difficult to separate the economic consequences of the nuclear accident from the widespread devastation caused by the tsunami and earthquake. Nevertheless, one cost directly attributable to the accident will be the cost of replacement fossil power generation, which alone will cost several billion dollars per year. Other economic consequences will be global in reach and also far exceed the economic consequences of TMI. Beyond the yen and dollars, the human cost is, if anything, more severe. The widespread radioactive contamination has ripped farmers from their livelihoods and lands that in some cases have been in their families for generations. By any accounting, Fukushima is a nuclear disaster.

Japan continues to respond to this disaster in a forceful manner. Efforts to halt the spread of radioactive contamination and bring the reactors and spent fuel pools under control continue as we speak. On April 5, 2011, the Japan Atomic Energy Commission (JAEC) announced that: “We are gravely concerned about this accident which can fundamentally undermine public trust in safety measures, not only in Japan but also in other countries.” JAEC also indicated that it would suspend for the foreseeable future its deliberation process of new Framework for Nuclear Energy Policy which had been underway since last December. Some other leading economies are doing the same.

German Chancellor Angela Merkel announced a temporary shutdown of Germany's oldest plants and a three-month review period to run tests and reassess nuclear technology. Subsequently, on April 8, 2011, the German Association of Energy and Water Industries (BDEW), which represents about 1,800 utilities, approved the following statement: “The catastrophe at the Fukushima reactors marks a new era and the BDEW therefore calls for a swift and complete exit from using nuclear power.” BDEW had been fully behind nuclear energy prior to the Fukushima disaster, and EON and RWE, two biggest operators of nuclear plants in Germany, opposed the BDEW Board decision. Nevertheless, some observers believe it is likely that that seven or eight of Germany's 17 reactors will never resume activity.

What does this nuclear disaster mean for the United States? Before addressing this question I offer some observations regarding the frequency of so-called “beyond the design basis” accidents.

Reassessing the frequency of partial core melt accidents

There have been enough partial core-melt accidents that we can ask whether the operational nuclear power plants throughout the world are safe enough as a group. As we see from Table 1, 12 nuclear power reactors have experienced fuel-damage or partial core-melt accidents: The Sodium Reactor Experiment (SRE), Stationary Low-Power Reactor No. 1 (SL-1), Enrico Fermi Reactor-1, Chapelcross-2, St. Laurent A-1 and A-2, Three Mile Island-2, Chernobyl-4, Greifswald-5 and Fukushima Daiichi-1, -2 and -3.

Eleven of these (all except SL-1) produced electricity and were connected to the grid during some period of their operation, and all are now permanently shut down. In assessing the historical core melt frequency among nuclear power reactors, the number counted depends on how the issue is framed. SL-1 is excluded because it was an experimental reactor, and the design was abandoned after the accident. Although it was the first U.S. reactor to supply electricity to the grid, the SRE could be excluded because it was primarily a research reactor. Chapelcross-2 and St. Laurent A1 and A2 were dual use military reactors, producing plutonium for weapons and electricity for civilian use. From the data available to this author it is unclear whether any fuel actually melted in Greifswald-5. In five cases then, *i.e.*, SRE, Chapelcross-2, St. Laurent A1 and A2, and Greifswald-5, the fuel melt or damage did not result in immediate closure of the plant; rather the damage was repaired and the reactor was restarted.

Worldwide, there have been 137 nuclear power plants that have been shut down after becoming operational with a total generating capacity of about 40,000 MWe and 2,835 reactor-years of cumulative operation.[1] Thus, one in twelve [137/11 = 12.5] or fourteen [excluding SRE: 136/10 = 13.6] shut down power reactors experienced some form of fuel damage during their operation. Of the power reactors that have been shut down one in 23 [137/6 = 22.8] were shut down as a direct consequence of partial core melt accidents; one for every 500 reactor-years [2,835/6 = 472.5] of operation. Only about seven of eight giga-watts (GW) [40,000-5,250.5)/40,000 = 0.87≈ 7/8] of nuclear power plant capacity have been closed without experiences a fuel damage accident. One out of 13 GW [40,000/3,011 = 13.3] of nuclear power plant capacity have been closed as a direct result of a fuel melting accident.

Worldwide, there have been 582 nuclear power reactors that have operated approximately 14,400 reactor-years.[2] Thus, to date, the historical frequency of core-melt accidents is about one in 1,300 reactor-years [14,400/11 = 1,309], or excluding SRE, about one in 1,400 reactor-years.

Worldwide, there have been 115 Boiling Water Reactors (BWRs) that have operated approximately 3,100 reactor-years. Thus, to date, the historical frequency of core-melt accidents in BWRs is about one in 1,000 reactor-years [3,100/3 = 1,033].

Worldwide, there have been 49 BWRs with Mark 1 containments (the type at Fukushima) and 12 with Mark 2 containments. Five with Mark 1 containment (Millstone Unit 1 and Fukushima Daiichi Units 1-4) have been permanently shut down. These 61 BWRs have operated for 1,900 reactor-years to date. Thus, to date, the historical frequency of core-melt accidents in BWRs with Mark 1 and 2 containments is about one in 630 reactor-years [1,900/3 = 633].

In July 1985, the U.S. Nuclear Regulatory Commission's (NRC) Advisory Committee on Reactor Safeguards (ACRS) stated:[3]

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[1] This sum excludes the US reactors, SL-1, Ml-1, PM-1, PM-2A, PM-3A, SM-1, SM-1A and Sturgis. The German KNK-I and KNK-II reactors are treated a one reactor.

[2] *Ibid.*

3 ACRS letter from D. A. Ward to N. J. Palladino, Subject: ACRS comments on proposed NRC safety goal evaluation report (17 July 1985); cited in David Okrent, "The Safety Goals of the Nuclear Regulatory Commission, *Science*, **236**, 296-300 (17 April 1987).

> We believe that the Commission should state that a mean core melt frequency of not more than 10^{-4} per reactor year [one in 10,000 reactor-years] is an NRC objective for all but a few, small, existing nuclear power plants, and that, keeping in mind the considerable uncertainties, prudence and judgment will tend to take priority over benefit-cost analysis in working toward this goal.

On August 4, 1986, the NRC published a final policy statement on safety goals, which said:[4]

> Severe core damage accidents can lead to more serious accidents with the potential for life-threatening offsite release of radiation, for evacuation of members of the public, and for contamination of public property. Apart from their health and safety consequences, severe core damage accidents can erode public confidence in the safety of nuclear power and can lead to further instability and unpredictability for the industry. In order to avoid these adverse consequences, the Commission intends to continue to pursue a regulatory program that has as its objective providing reasonable assurance, while giving appropriate consideration to the uncertainties involved, that a severe core damage accident will not occur at a U.S. nuclear power plant.

The NRC cites core-melt frequency estimates from probabilistic risk assessment (PRA) studies in the ranges from 2×10^{-5} to 1×10^{-4} event/reactor-year,[5] *i.e.*, from 1 to 5 per 10,000 reactor-years; and for Peach Bottom Unit 2, a GE BWR with Mark 1 containment, 1.202×10^{-5},[6] *i.e.*, 1 in 10,000 reactor-years.

Clearly, the historical frequency of core melt accidents worldwide does not measure up to the safety objectives of the NRC. On the whole the operational reactors worldwide are not sufficiently safe. If nuclear power is to have a long-term future greater attention must be given to the safety of current operational reactors worldwide. Older obsolete designs should be phased out rather than having their licenses extended. We should also revisit whether the newer reactor designs currently under construction worldwide and those on the drawing board are safe enough?

Implications for U.S. Nuclear Power Reactors

There are a host of concerns raised by the Fukushima nuclear disaster that bear directly on the safe operation and regulation of U.S. nuclear power reactors. While others will add to this list, our immediate concerns include:

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[4] Nuclear Regulatory Commission, *Federal Register* **51**, 28044 (4 August 1986); cited in David Okrent, "The Safety Goals of the Nuclear Regulatory Commission, *Science*, **236**, 296-300 (17 April 1987).

[5] http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0933/sec3/065r1.html

[6] http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0933/sec3/158r2.html

- Are old GE BWRs with poorly designed Mark 1 and Mark 2 containments and subsequent upgrades imposed by the NRC safe enough to continue operation or have their licenses extended?
- What additional improvements should be made to cope with hydrogen production in the event of fuel clad interaction with steam?
- What improvements must be made to extend the time reactors can cope with loss of off-site power?
- The NRC is overdue in requiring that spent fuel be removed from wet pools to hardened dry casks as soon as the spent fuel has cooled sufficiently to be passively cooled in air.
- Which reactor sites are located in areas that cannot be adequately evacuated?
- Which reactor stations impose an undue economic risk to the local, state or U.S. economy in the event of a partial core melt accident?
- Which U.S. reactors should be upgraded or phased out due to the risk of an earthquake, flooding or tornado that is beyond the design basis?
- Potential radiological accidents caused by earthquake or tsunami should be addressed in emergency response plans for US reactors.
- Nuclear plant owners/operators must assume a larger share of the financial risk in the event of a catastrophic nuclear accident. Should the Price Anderson Act (which defines the federal government's assumption of liability and economic burden in the event of catastrophic nuclear accident) be repealed or, at a minimum, significantly revised?
- What are the implications of predicted sea-level rise due to climate change on the safety of nuclear reactors near coasts?
- What are the implications of continued failure of the NRC to finalize and implement a fire protection rule?
- What changes should be implemented regarding radiation monitoring during routine plant operations and following an accident?
- And perhaps most importantly, what is the best process for addressing these concerns?

I now offer a few observations regarding several of these concerns, beginning with the process issue—the last question above.

What is the best process for addressing the concerns outlined above?

The NRC has initiated a two-pronged short and longer term review of U.S. nuclear power plant safety in the aftermath of the Fukushima disaster. In the interim the NRC maintains all of its licensed reactors are safe. This review is appropriate and we support this effort, but it is woefully inadequate to the larger task of ensuring nuclear safety given the grave concerns raised by the accident. Any review must be an open, transparent process that permits public participation and that creates public trust. It is not credible to expect the NRC staff to perform an unbiased review of its own past failings. An independent review by an unbiased committee is essential. We are under no illusions that the NRC review will lead to adoption of all the safety improvements that are needed.

Since it was created out of the old Atomic Energy Commission (AEC) in 1974, the NRC staff, like the previous AEC staff, has been largely captive of the industry it regulates. It is also equally true that the NRC staff is comprised of highly professional dedicated public servants. Moreover, no President has been willing to appoint, and no Senate willing to confirm, NRC commissioners without ensuring that the majority of commissioners are strongly supportive of the use of nuclear power. These two factors have resulted in the NRC taking actions that have placed the economic interest of the industry ahead of safety, and have over the years stripped public participants in the licensing process of adjudicatory rights they were previously afforded.

On March 11, 2011, NRDC President Frances Beinecke wrote President Obama, requesting that “The administration should appoint a truly independent commission, similar to the Kemeny Commission that investigated the Three Mile Island accident in 1979, that can help to engender public confidence by thoroughly examining nuclear safety issues, including assessing the conclusions and proposed corrective actions arrived at by both the nuclear industry and the NRC in its ‘90-day safety review’.” [full letter attached]. NRDC has received no response to this request from the Administration. The Administration appears to favor limiting the safety review to the NRC, no doubted recognizing that this is the “safer” course if one objective is to insulate future use of nuclear power in the United States from the potential implications of a genuinely independent review of the safety implications of Fukushima in which the public is invited to participate.

In this instance, we are seeking a truly independent, expert panel like the Kemeny Commission that reviewed the TMI accident. So if the Administration is unwilling to lead on this matter, we expect the Senate to insist on an independent, unbiased review.

Are the old GE BWRs with poorly designed Mark 1 and Mark 2 containments and subsequent upgrades imposed by the NRC safe enough to continue operation or have their licenses extended?

Before the Fukushima disaster I said—and I still believe—that a most important factor concerning the safety of a nuclear power reactor is establishment and presence of a culture of safety at the plant. On the whole the safety culture at U.S. nuclear plants has improved since the TMI accident. I am also on record saying that on this basis I believed the next major nuclear accident would more likely occur abroad, rather than in the United States. This turned out to be the case.

The Fukushima events have caused me to reassess my view as to the relative importance of safety cultures versus plant design. There are 23 operational U.S. GE-designed boiling water reactors (BWRs) with Mark 1 containments and the 8 operational U.S. BWRs with Mark 2 containments. The U.S. BWRs with Mark 1 containments are similar to Fukushima Daiichi Units 1-4, and the Mark 2 containments are similar to the Mark 1s. The design of the BWRs with Mark 1 containments by GE grew out of an effort to reduce construction costs by reducing the volume of the containment structure and rely more heavily on controlled venting of steam and radioactive contaminants in the event of reactor core fuel melting to prevent a larger disaster. This design was highly controversial when it was proposed for licensing by the AEC, and has been subjected to review and subsequent upgrades required by the NRC.

My preliminary view is that the nuclear disaster at Fukushima illustrates the inherent design deficiencies in these 31 operational U.S. BWRs—a significant fraction of the 104 operational nuclear power reactors in the United States. In my opinion none are sufficiently safe despite upgrades that have been imposed by the NRC.

Others will argue that the BWR Mark 1s and 2s are safe noting that a) these U.S. reactors will not experience the same type of earthquake and tsunami as occurred on Japan, b) the NRC has a good handle on the magnitude and frequency of accident precursors, and c) upgrades to manage hydrogen releases in the event of a core-melt accident make controlled venting of steam and radioactive contaminates more acceptable. In other words, the claim is that it will not happen here, and if something comparable does happen we can cope with it. Still others will say that we should await a careful independent Kemeny-style review of the issues and not rush to judgment.

I do not think that the 31 older BWRs in the United States should be shut down forthwith. Rather, they should not have their licenses extended. The current course of safety review and reactor relicensing charted by the NRC and Department of Energy (DOE) is unacceptable. After a limited safety review, sometimes taking less than 18 months, the NRC has been routinely handing out 20 year license extensions, including license extensions to these older BWRs, *e.g.*, Vermont Yankee which received its license extension on March 21, 2011, as the events at Fukushima were unfolding. In addition, other older BWR units are undergoing, or are soon scheduled to undergo, thermal power uprates, which only compound the residual heat removal and radioactive gas venting problem in the event of a station blackout. Meanwhile, DOE is engaged in an R&D effort with industry to see if licenses can be extended beyond 60 years. On this course we could be saddled for years with inherently unsafe reactors—a potential commitment of more than one thousand reactor-years of operation using old reactor designs with inherent safety deficiencies.

In sum, the 20-year license extensions already granted to 20 U.S. operational BWRs with Mark 1 containments and the 3 extensions granted to BWRs with Mark 2 containments should be revisited and the their license extension periods should be shortened. Similarly, no 20 year license extension should be granted to the remaining three BWRs with Mark 1 containments and the five with Mark 2 containments, which have not yet received 20 year license extensions.

What improvements must be made to extend the time reactors can cope with loss of off-site power?

At Fukushima, in what is termed a “common mode failure,” the tsunami took out both the off-site power and the backup diesel generators. The backup battery power was designed to last for eight hours. After battery power expired the operators could no longer maintain core cooling. At some U.S, reactors backup battery power is only designed to last four hours. Clearly, battery backup energy requirements should be increased from hours to days, or other forms of portable on-site power generators must be stored out of harm's way and kept available for use in a crisis.

The NRC is overdue in requiring that spent fuel be removed from wet pools to hardened dry casks as soon as the spent fuel has cooled sufficiently to be passively cooled in air.

The Fukushima disaster provides further evidence that the safety of spent fuel storage would be improved if spent fuel were removed from wet pools to hardened dry casks as soon as the spent fuel has cooled sufficiently to be passively cooled in air. This was NRDC's position prior to Fukushima. In May 25, 2010, testimony before the Blue Ribbon Committee on America's Nuclear Future, we said, and we still believe:

> There is a need for a new spent power reactor fuel storage policy that ends the practice of dense compaction of spent fuel assemblies in wet pools, and moves spent fuel into interim hardened dry cask storage. Fuel pools were originally designed for temporary storage of a limited number of irradiated fuel assemblies in a low density, open frame configuration. Since it is going to be decades before there is a geologic repository, to improve the safety of wet storage of spent fuel we should bite the bullet and decide as a matter of policy to end the practice of dense compaction of spent fuel in wet pools. The Commission should recommend that the Nuclear Regulatory Commission (NRC) establish appropriate licensing criteria for this purpose.
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> While dry cask storage of spent fuel at existing reactor sites is relatively safer than the operation of the reactors, dry cask storage can be made even safer by storing the dry casks in a hardened building such as the Ahaus Spent Fuel Storage Facility in Germany. The Commission should recommend that the Ahaus approach be adopted at most operational reactor sites and any new off-site interim spent fuel storage facility. The added security of such hardened enclosed storage is worth the small additional cost.
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> NRDC believes it makes sense to provide for consolidated dry storage of spent fuel from permanently shut down reactors that are not at sites with reactors still operational. This would facilitate decommissioning of shut down reactor sites. NRDC is opposed to off-site consolidation of spent fuel from any reactors at sites where there are operational reactors, because a) it is unnecessary, b) it does not reduce significantly security risks at the reactor sites, c) it increases risks associated with transportation of spent fuel, and d) it reduces the pressure to obtain a geologic repository.

Which reactor sites are located in areas that cannot be adequately evacuated?

At Fukushima immediately following the earthquake and tsunami residents within 10 kilometers (km) (6.2 miles) were advised to evacuate by the Japanese National Industrial Safety Agency (NISA). By the next day, Saturday afternoon, NISA advised everyone within 20 km (12. 4 miles) to evacuated, and those between 20 and 30 km (12.4 to 18.6 miles) were advised to remain in their homes as shelter or voluntarily evacuate. Subsequently, the Japanese government considered extending the evacuation zone to 30 km. Also notably, shortly after the Fukushima accident began to unfold the NRC was so concerned regarding how the accident might progress that it recommended that U.S. citizens stay at least 50 miles away. Based on Japanese census data, we estimate that before evacuation there were 69,000 people within 20 km, 160,000 within 30 km, and 2 million within 50 miles of the Fukushima Daiichi reactor station. Let us examine how many people reside within the same distances from U.S. reactors.

There are 104 U.S. operational nuclear power plants at 65 generating stations at 64 sites in 63 counties. (Salem and Hope Creek Generating Stations are treated as a single site.) The NRC's planning zone for evacuation around a nuclear power plant is 10 miles. Using U.S. census data projected to 2010, my colleague, Dr. Matthew McKinzie, has estimated the number of people living with 10 miles, 20 km, 30 km and 50 miles of the 64 commercial nuclear sites in the United States. These data are reproduced in Table 2. As seen from this table, the number of people living near several U.S. operational nuclear power stations is quite large.

There are eight U.S. nuclear power plant sites where the population within 20 km is from 200,000 to 433,000—Indian Point, Three Mile Island, Limerick, Catawba, McGuire, St. Lucie, Turkey Point and Oyster Creek. At 30 of the 64 U.S. nuclear power plant sites the population within 20 km exceeds 69,000 people, *i.e.*, exceeds the population within 20 km of Fukushima Daiichi.

There are nine U.S. nuclear power plant sites where the population within 30 km ranges from 500,000 to 980,000—Indian Point, Limerick, McGuire, Catawba, Three Mile Island, San Onofre, Turkey Point and Shearon Harris. An addition 11 plants have populations between 300,000 and 500,000. At 31 of the 64 U.S. nuclear power plant sites the population within 30 km exceeds 160,000 people, *i.e.*, exceeds the population within 30 km of Fukushima Daiichi.

The Indian Point site has a whopping 17 million people within 50 miles, more than 5 percent of the entire U.S. population. There are six U.S. nuclear power stations where the population within 50 miles ranges from 5 million to 8.5 million—San Onofre, Limerick, Dresden, Peach Bottom, Salem/Hope Creek and Braidwood. An addition 18 plants have populations between 2 million and 10 million. At 25 of the 64 U.S. nuclear power plant sites the population within 50 miles exceeds 2 million, *i.e.*, exceeds the population within 50 miles of Fukushima Daiichi. Clearly, the NRC admonition to Americans in Japan could not be carried out at any of these sites.

Some of these reactors have recently been granted 20 year license renewals, *e.g.*, the two units at St. Lucie and the two units at Turkey Point. Indian Point Unit-2's license expires on 28 September 2013, and Unit 3's license expires on 12 December 2015. Entergy has applied for a 20 year license renewal for the two reactors. One might reasonably find it startling were the NRC to renew these licenses given what we now know. What is more surprising though is that the NRC is already on record saying the events at Fukushima will not affect ongoing license extension reviews!

Which U.S. reactors should be upgraded or phased out due to the risk of an earthquake, flooding, or tornado that is currently beyond the design basis?

The magnitude 9.0 earthquake and resulting tsunami that hit the Fukushima Daiichi reactors was very significantly larger than the design basis earthquake and tsunami for these reactors. This was also the case with respect to the Niigataken Chuetsu-oki earthquake that damaged the seven-unit Kashiwazaki Kariwa Nuclear Power Station on July 16, 2007. That quake too very significantly exceeded the design basis of the reactors. These events call into question the adequacy of the designs of several U.S. reactors in earthquake prone areas, most notably Diablo Canyon given that the U.S. Geological Survey (USGS) found a previously unknown fault along the central California coast, near the plant. As recently reported in the *Los Angeles Times*, California state Senator Sam Blakeslee (R-San Luis Obispo), who is testifying here today and who has a doctoral degree in earthquake science and whose district includes Diablo Canyon, claims the fault could be half a mile away, or a few hundred yards, or even under the reactors. The California Energy Commission has recommended a three-dimensional imaging study—a sort of geological CT scan—be conducted to determine the precise location of the Shoreline Fault and learn more about it, and the California Public Utilities Commission has also requested such a study. Because there may be similar surprises at other reactor sites the USGS should be directed to take a comprehensive assessment of the earthquake risk at all reactor sites, beginning with those in areas of known high seismic risk. These studies and assessments should be conducted before further reactor license extensions are granted and the results should be part of any relicensing review by the NRC.

Nuclear plant owners/operators must assume a larger share of the financial risk in the event of a catastrophic nuclear accident.

Congress should repeal, or at a minimum significantly revise the Price Anderson Act, which defines the federal government's assumption of liability and economic burden in the event of catastrophic nuclear accident, to increase the owner/operator share of the financial risk in the event of a catastrophic nuclear accident.

What changes should be implemented regarding radiation monitoring during routine plant operations and following an accident?

The radiation monitoring in Japan following the Fukushima accident was less than comprehensive and on at least one occasion was reported erroneously but corrected the next day. Here in the United States there have been criticisms regarding the failure of selected EPA monitors on the West Coast, failure to report readings taken with more sensitive instrumentation and failure to deploy some mobile radiation monitors. I do not have firsthand knowledge of these EPA monitoring issues and will not comment further on them. Rather, I wish to offer two recommendations.

First, the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), the international agency established to monitor for nuclear tests under the Comprehensive Test Ban, currently maintains 60 radionuclide particulate monitoring stations throughout the world. These stations monitor the air continuously, and thus provide extensive data on any radionuclides detected during a nuclear test or accident, including the Fukushima disaster and the data is transmitted daily to its member states, including the United States. The U.S. government should take the necessary steps to promptly release to the public the data it receives from the CTBTO.

Second, the EPA and NRC should insure that continuous air monitoring data recorded by air monitors around nuclear power plants and by the national network of EPA stations are available to the public on the internet in real time. Today on the internet and you can check the weather at the beach by logging onto a web-cam, but if you live near a nuclear plant you cannot go on the internet to see what the air monitor is reading. The added cost of making these data available on the web in real time should be small. Some government officials may be reluctant to provide such data in real time for reasons related to quality control, but this seems a flimsy excuse. After all, the agency could post on the web which monitors it feels are not functioning or calibrated improperly.

Principal Conclusions

The historical frequency of core melt accidents worldwide does not measure up to the safety objectives of the NRC. On the whole the operational reactors worldwide are not sufficiently safe. Because of differences in the reactor safety cultures and the quality of regulatory oversight the next nuclear power plant disaster is more likely to occur abroad than in the United States. If nuclear power is to have a long term future greater attention should be given to current operational reactors. Older obsolete designs should be phased out rather than having their licenses extended. We should also revisit whether the newer reactor designs currently under construction worldwide and those on the drawing board are safe enough?

The administration should appoint a truly independent commission, similar to the Kemeny Commission that investigated the Three Mile Island accident in 1979, that can help to engender public confidence by thoroughly examining nuclear safety issues, including assessing the conclusions and proposed corrective actions arrived at by both the nuclear industry and the NRC in its “90-day safety review.”

The 20-year license extensions already granted to 20 U.S. operational BWRs with Mark 1 containments and the 3 extensions granted to BWRs with Mark 2 containments should be revisited and the their license extension periods should be shortened. Similarly no 20 year license extension should be granted to the three BWRs with Mark 1 containments and the five with Mark 2 containments, which have not yet received 20 year license extensions.

The NRC is overdue in requiring that spent fuel be removed from wet pools to hardened dry casks as soon as the spent fuel has cooled sufficiently to be passively cooled in air. Dry cask storage should be made safer by storing the dry casks in a hardened building such as the Ahaus Spent Fuel Storage Facility in Germany. The Ahaus approach should be adopted at most operational reactor sites and any new off-site interim spent fuel storage facility.

In light of an improved scientific understanding of the full range of natural and man-made “beyond design basis” events that could strike 40 + year reactors, the risk of core melt followed by failure of containment should be stringently reevaluated for the two Indian Point units and all other existing reactors located in areas of high population density. The feasibility of an adequately protective evacuation, under these revised conditions and extending beyond the current 10-mile radius for the emergency planning zone, should be explicitly reassessed in the context of the relicensing proceeding. The severity of the resulting radiological and other risks to life, property, and natural resources should inform NRC and state-level decisions regarding which units should be denied license or permit renewals, or have their existing license extensions shortened or revoked.

The USGS should be directed to take a comprehensive assessment of the earthquake risk at all reactor sites, beginning with those in areas of known high seismic risk. These studies and assessments should be conducted before further reactor license extensions are granted and the results should be part of any relicensing review by the NRC.

Potential radiological accidents caused by earthquake or tsunami should be addressed in emergency response plans for US reactors.

Congress should repeal, or at a minimum significantly revise the Price Anderson Act, which defines the federal government’s assumption of liability and economic burden in the event of catastrophic nuclear accident, to increase the owner/operator share of the financial risk in the event of a catastrophic nuclear accident.

The U.S. government should take the necessary steps to promptly release to the public the data it receives from the CTBTO. The EPA and NRC should insure that continuous air monitoring data recorded by air monitors around nuclear power plants and by the national network of EPA stations are available to the public on the internet in real time.

Table 1. List of Nuclear Power Reactors That Have Experienced Fuel Melt or Failure.

1. **Sodium Reactor Experiment (SER)**
   Location: Santa Susana Field Laboratory, California, USA
   Reactor type: sodium-cooled graphite-moderated thermal power reactor
   Power: 20 MWt; 6.5 MWe
   History: initial criticality: April 25, 1957; first produced electricity July 1957; operated 2 years, partial core melt accident between 12 and 26 July 1959, resulting in melting of as much as one-third of the fuel; shutdown 26 July 1959 [It appears to have been operated for several days with its core partially melted.]; converted to HEU-Th fuel; second core operations began September 1960; permanently shutdown February 1964.

2. **Stationary Low-Power Reactor No. 1 (SL-1)**
   Location: National Reactor Testing Station (now Idaho National Laboratory)
   Reactor type: experimental, gas-cooled, water-moderated
   Power: 3.3 MWt; 300 kWe
   History: initial criticality March 1961; prompt criticality accident 3 January 1961; shut down May 1964

3. **Enrico Fermi Unit 1 Reactor**
   Location: Newport, Lagoona Beach, Frenchtown Township, Monroe County, Michigan, USA
   Reactor Type: Liquid Metal Fast Breeder Reactor (LMFBR)
   Power: 200 MWt; 65 MWe (gross); 61 MWe (net)
   History: initial criticality 23 August 1963; commercial operations began August 1966; partial fuel melt accident 5 October 1966, two of the 105 fuel assemblies melted, but no contamination was recorded outside the containment vessel; closed November 1972

4. **Chapelcross Unit 2 Nuclear Power Plant**
   Location: Annan, Dumfreshire, Scotland, United Kingdom
   Reactor Type: gas-cooled, graphite moderated; Magnox
   Power: originally 180 MWt, up-rated progressively to 265 MWt, originally 23 MWe (gross) progressively up-rated to 60 MWe (gross); 50 MWe (net)
   History: startup May 1959; while under evaluation for the commercial reactor program experienced a partial blockage in a single fuel channel May 1967, contamination was limited to one region of the core; shut down 29 June 2004

5. **Saint-Laurent A-1 Nuclear Power Plant**
   Location: St. Laurent-Nouan, Loir-et-Cher, Centre, France
   Reactor Type: gas-cooled, graphite moderated
   Power: 1570 MWt; 405 MWe (gross), 390 MWe (net)
   History: grid connection 14 March 1969; commercial operation June 1969; 50 kg of uranium began to melt 17 October 1969; permanently shut down 27 May 1992

6. **Saint-Laurent A-2 Nuclear Power Plant**
   Location: St. Laurent-Nouan, Loir-et-Cher, Centre, France
   Reactor Type: gas-cooled, graphite moderated
   Power: 1690 MWt; 465 MWe (gross) [uprated to 530 MWe (gross)], 450 MWe (net)

History: started November 1970; grid connection 9 August 1971; commercial operation November 1971; heat excursion causing some fuel melting 13 March 1980; permanently shut down 27 May 1992

7. **Three Mile Island Unit 2 Nuclear Power Plant**
   Location: Londonderry Township; Dauphine County, Pennsylvania, USA
   Reactor Type: Pressurized Water Reactor (PWR)
   Power: 2,568 MWt, 808 MWe (gross); 776 MWe (net)
   History: initial criticality December 1978; partial core melt accident March 1979; decommissioned 1979

8. **Chernobyl Unit 4 Nuclear Power Plant**
   Location: Pripyat, Ukraine SSR (now Ukraine)
   Reactor Type: RBMK-1000 (graphite-moderated water-cooled)
   Power: 3,200 MWt; 1,000 MWe (gross); 925 MWe (net)
   History: destroyed in full-core melt accident 26 April 1986

9. **Greifswald Unit 5 (KGR-5) Nuclear Power Plant**
   Location: Lubmin, GDR (now Germany)
   Reactor Type: VVER-440, Model V-230, Pressurized Water Reactor (PWR)
   Power: 1,375 MWt; 440 MWe (gross); 408 MWe (net)
   History: grid connection 24 April 1989; commercial operation 1 November 1989; near core melt with 10 fuel elements damaged 7 December 12975; permanent shutdown 24 November 1989

10. **Fukushima Daiichi Unit 1 Nuclear Power Plant**
    Location: Ohkuma, Fukushima Prefecture, Japan
    Reactor Type: Boiling Water Reactor (BWR), GE BWR/2, Mark 1 Containment
    Power: 1,380 MWt; 450 MWe (gross); 439 MWe (net)
    History: initial criticality 10 October 1970; grid connection 17 November 1970; commercial operation 26 March 1971; partial core meltdown following earthquake on 11 March 2011

11. **Fukushima Daiichi Unit 2 Nuclear Power Plant**
    Location: Ohkuma, Fukushima Prefecture, Japan
    Reactor Type: Boiling Water Reactor (BWR), TOS1 [GE BWR/4], Mark 1 Containment
    Power: 2,381 MWt; 794 MWe (gross); 760 MWe (net)
    History: initial criticality 10 May 1973; grid connection 24 December 1973; commercial operation 18 July 1974; partial core meltdown following earthquake on 11 March 2011

12. **Fukushima Daiichi Unit 3 Nuclear Power Plant**
    Location: Ohkuma, Fukushima Prefecture, Japan
    Reactor Type: Boiling Water Reactor (BWR), TOS1 [GE BWR/4], Mark 1 Containment
    Power: 2,381 MWt; 794 MWe (gross); 760 MWe (net)
    History: initial criticality 28 January 1978; grid connection 24 February 1978; commercial operation 12 October 1978; partial core meltdown following earthquake on 11 March 2011

Table 2. Population within 10 miles (mi), 20 kilometers (km) (12.4 mi), 30 km (18.6 mi) and 50 mi. of U.S. nuclear power stations and the Fukushima Daiichi Nuclear Power Station in Japan. [Calculated by Dr. Matthew McKinzie, NRDC Nuclear Program.]

Nuclear Reactor Site **Population**	**< 50 mi**	**< 30 km**	**<20 km**	**< 10 mi**
Arkansas Nuclear One	300,875	85,118	56,562	46,665
Beaver Valley Power Station	3,136,087	386,818	195,304	115,185
Braidwood Generating Station	5,058,878	139,413	48,994	37,419
Browns Ferry Nuclear Plant	964,440	166,229	91,396	35,574
Brunswick Steam Electric Plant	447,204	125,455	41,134	28,098
Byron Generating Station	1,263,788	209,381	37,583	27,967
Callaway Nuclear Power Station	533,393	38,769	21,431	9,380
Calvert Cliffs Nuclear Power Station	3,265,942	133,018	66,815	35,732
Catawba Nuclear Station	2,583,890	842,304	336,079	216,684
Clinton Power Station	796,220	47,672	19,264	12,807
Columbia Nuclear Generating Station	440,870	122,151	24,473	4,212
Comanche Peak Steam Electric Station	1,763,739	68,039	46,026	33,584
Cook (Donald C.) Nuclear Power Station	1,229,031	129,972	83,371	52,335
Cooper Nuclear Station	158,357	15,900	7,930	3,688
Crystal River Nuclear Power Station	1,068,039	98,249	33,238	20,328
Davis-Besse Nuclear Power Station	1,765,945	77,506	22,855	15,540
Diablo Canyon Nuclear Power Plant	441,494	134,743	68,045	22,837
Dresden Generating Station	5,968,730	278,110	88,993	60,561
Duane Arnold Energy Center	663,337	222,916	186,729	112,515
Enrico Fermi Atomic Power Plant	4,921,862	318,112	137,964	90,230
Fort Calhoun Station	939,025	284,348	28,936	19,382
Grand Gulf Nuclear Station	323,731	21,270	11,734	8,412
H.B. Robinson Nuclear Power Station	892,571	82,207	39,719	32,483
Hatch (Edwin I.) Nuclear Power Station	419,726	50,951	19,186	10,129
Indian Point Nuclear Power Station	17,310,391	978,945	433,603	252,828
James A. FitzPatrick Nuclear Power Plant	884,703	89,086	42,727	31,722
Joseph M. Farley Nuclear Plant	422,000	83,846	18,344	11,357
Kewaunee Nuclear Power Station	766,265	70,032	21,655	10,025
La Salle County Generating Station	1,941,089	90,859	47,514	16,337
Limerick Generating Station	7,907,943	944,872	352,527	245,899
McGuire (W.B.) Nuclear Station	2,887,444	874,252	329,848	189,378
Millstone Nuclear Power Station	2,890,682	250,354	133,056	100,780
Monticello Nuclear Generating Plant	3,026,547	210,588	101,362	59,159
Nine Mile Point Nuclear Station	882,346	88,009	42,717	31,876
North Anna Nuclear Power Station	1,879,826	121,567	38,086	23,228
Oconee Nuclear Power Station	1,402,463	181,908	104,956	74,546
Oyster Creek Generating Station	4,346,015	369,541	204,833	122,628

Palisades Nuclear Power Station	1,344,455	102,087	44,726	31,298
Palo Verde Nuclear Power Station	2,127,628	40,433	6,058	3,798
Peach Bottom Atomic Power Station	5,406,288	350,043	81,614	46,202
Perry Nuclear Power Plant	2,270,346	248,902	125,073	82,525
Pilgrim Nuclear Station	4,536,218	237,115	104,292	65,881
Point Beach Nuclear Power Station	772,560	77,493	29,808	20,446
Prairie Island Nuclear Generating Plant	2,998,068	108,151	46,013	29,545
Quad Cities Generating Station	654,537	219,947	56,458	31,692
River Bend Station	950,101	103,067	39,648	23,979
Robert E. Ginna Nuclear Power Station	1,247,344	496,302	101,764	61,697
Salem and Hope Creek Generating Stations	5,348,293	392,762	79,003	42,125
San Onofre Nuclear Generating Station	8,509,157	600,809	159,101	85,877
Seabrook Nuclear Station	4,208,014	373,439	158,386	117,522
Sequoyah Nuclear Power Station	1,080,727	427,297	161,789	95,419
Shearon Harris Nuclear Power Plant	2,588,936	501,496	186,579	91,925
South Texas Project Electric Generating Station	265,091	31,633	11,854	2,224
St. Lucie Nuclear Power Station	1,194,373	376,216	265,315	182,511
Surry Nuclear Power Station	2,188,711	370,414	176,842	116,947
Susquehanna Steam Electric Station	1,744,486	277,445	100,719	53,197
Three Mile Island Generating Station	2,818,044	813,589	403,845	183,680
Turkey Point Power Station	3,426,334	579,857	251,892	156,705
Vermont Yankee Generating Station	1,418,842	126,257	46,010	34,447
Virgil C. Summer Nuclear Power Station	1,179,156	132,963	30,076	12,360
Vogtle (Alvin W.) Nuclear Power Station	721,893	36,853	10,158	5,171
Waterford Generating Station	2,005,593	332,637	113,956	87,231
Watts Bar Nuclear Power Station	1,173,601	92,982	29,569	19,971
Wolf Creek Generating Station	177,920	11,515	6,603	4,992
Fukushima Daiichi Nuclear Power Station	1,964,725	159,859	69,162	51,925