Foundation for Resilient Societies

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Comments of
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Submitted for the
Foundation for Resilient Societies

ENVIRONMENTAL AND FINANCIAL BENEFITS OF INCLUDING ADDITIONAL SEVERE ACCIDENT MITIGATION MEASURE ANALYSES IN THE FORTHCOMING FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT 46 TO NUREG-1437 GENERIC ENVIRONMENTAL IMPACT STATEMENT FOR LICENSE RENEWAL OF NUCLEAR PLANTS – REGARDING SEABROOK STATION LICENSE RENEWAL FOR MARCH 2030 – MARCH 2050

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1 Environmental Mitigation and Financial Benefits of SAMA Alternatives via Supplemental Environmental Assessment

We appreciate the opportunity to comment on significant risks to the quality of the human environment. We concentrate upon what we believe are cost-effective mitigation measures as conditions of re-licensure of Seabrook Station No. 1 for a 20 year term from March 2030 to March 2050.

The National Environmental Policy Act serves as an instrumentality to better inform decision-makers, whether they are officials responsible for power plant licensure, or officials responsible for mitigation of foreseeable risks, or owner-operators who have good prospects of increasing capacity utilization rates at better-mitigated power plants. The NEPA process also serves to inform residents in emergency evacuation regions or elsewhere who rightfully expect the Commission will adequately safeguard all of the nation's nuclear power plants. If the public is to be properly informed, the Commission must make sure that all the major risks affected by re-licensure are properly disclosed, analyzed with all other "Severe Accident Mitigation Alternatives," and demonstrated to be or not to be cost-effective.

Our framework for analysis includes a recognition that a wide array of energy resources and technologies contribute to the public welfare. With rigorous risk assessments and timely mitigation of severe risks, plus ongoing safety monitoring, nuclear-electric power plants provide a vital contribution to the production and conservation of energy. Nuclear power reduces dependence upon imported petroleum and petroleum products. Nuclear power provides relatively low-cost base load power, without which wind or solar energy systems with variable supply would offer reduced value. Nuclear energy, which can convert excess fissionable materials from former weapon stockpiles, also reduces the nation's production of greenhouse gases.

Seabrook Station No. 1 has operated for more than 21 years, with high capacity utilization rates and without accidents that would impair public health and safety, with minor, generally rectified exceptions. [1]

We are committed to the analysis of critical infrastructure, for the purpose of protecting functionality, prudently managing risks, and identifying financial benefits of risk mitigation initiatives. Further, we have a particular interest in identifying candidate mitigation measures that would enhance

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[1] We note that on October 5, 2011, Seabrook Station is reported to have experienced a scram event relating to the loss of water for production of steam needed to operate turbines. If water supplies through pipes within aging concrete structures experience flow unreliability, we would request that related risks be explained, and that mitigation measures be included in the Final SEIS for Seabrook Station. An NRC meeting involving proprietary data of the owner-operator is scheduled for October 27, 2011, one day after the close of the public comment period for NEPA site-specific environmental review.

safety at reasonable costs, and produce a positive "benefit / cost" valuation using NRC approved level 3 probabilistic risk assessments (PRAs).

Equally important, for high plant-specific risks that may also be regionally present, such as solar geomagnetic induced currents that are accentuated by eastward electrojets and igneous rock formations in the northeasterly region of the United States, we seek to identify risk-mitigation remedies that offer positive financial returns to both owner-operators and electric ratepayers.

We will later explain why we urge the Commission to perform Severe Accident Mitigation Analyses (SAMAs) for the hardware-protection of high voltage step up transformers, in contradistinction to the temporary "down-rating" of power plant generation to reduce transformer overheating and fire risks, and as a means to reduce cumulative stresses to high voltage transformer operability.[2]

If hardware protections, using capacitors and neutral grounding techniques, can allow safe operation through adverse solar weather, while extending transformer life, then higher overall capacity utilization of existing nuclear plants can produce financial benefits to both owner-operators and to electric consumers.

If the Commission can identify additional severe accident mitigation alternatives that align with reduction in risks to public health and safety, while concurrently increasing net electric generation and net revenues, the incentives of the marketplace can be the primary driver for a more reliable and stable U.S. electric grid. Our comments are designed to encourage the Commission to embrace frontally the risks of adverse solar weather, and to assist the nuclear-electric industry to identify and implement revenue-positive mitigation measures.[3]

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[2] Excerpts from a database prepared by Thomas Popik for a Geomagnetic Disturbance (GMD) Task Force of the North American Electric Reliability Corporation (NERC) are included as an Appendix to these Comments. Efforts to avoid transformer overheating or permanent damage through "down-rating" of generation below rated capacity is sure to reduce revenues from electric sales, but it is less certain to protect extended transformer life. Some large transformers still may have failed as a result of geomagnetic storms; further investigation should be conducted. See Appendix C for a one-page list of nuclear plant down-ratings reportedly impacted by solar geomagnetic induced currents. These forecast-dependent mitigation strategies predictably cost owner-operators significant revenues lost during extended down-ratings. See Appendix C to these Comments, Foundation for Resilient Societies, "Nuclear Power Plant Reductions [from Rated Power] Attributed to Solar Activity." October 26, 2011, 1 page.

[3] Historically, plant-specific measurements of ground-level "geomagnetic-induced currents" (GICs) have been treated as proprietary. Thus, analyses in some of Metatech's Reports and other industry studies that might be overlaid with databases of GIC magnitudes, transformer failures, plant capacity utilization, and changes in plant and company electric production income are now unattainable. Both the NRC and FERC need to consider Rulemaking requirements to collect and make available to interested publics the "black box" data on ground level GICs, high voltage transformer health, and transformer loading. We believe that more efficient "best practices" and higher per plant revenues would be attainable if plant-specific GIC data were required to be made publicly accessible to protect public health and safety and to improve bulk power grid reliability.

The Seabrook Station Final SEIS should identify now-missing severe solar weather-related accident risks, together with cost-effective mitigation alternatives that are absent from the Draft SEIS filed on July 31, 2011.

2 NRC Duties under the National Environmental Policy Act Remain Unfulfilled

Since NRC licensing of Seabrook Station No. 1 in 1990, significant new information has indicated (a) that the U.S. power grid is *substantially more vulnerable* that it was in the 1980s, with rapid growth of extra high voltage transmission systems, which because of lower resistance and longer average line lengths are more susceptible to larger geomagnetic-induced currents; and (b) the northeast region of the U.S. power grid is particularly vulnerable to the Eastward electrojet enhancement of high GICs during major geomagnetic storms ,with its end-of-line and ocean boundary effects, better understood now than before Seabrook's initial licensing; (c) modeling of nuclear plant specific risks of loss of outside power with longer durations, and risk of loss of backup power, available since filing with NRC in March 2011[4], shows, for the Seabrook Station configuration an East-West(Scoobie) 345 kV line orientation, which elevates GIC risks; an end of line effect, which elevates GIC risks; the proximity of ocean waters, which elevates GIC risks; the high latitude of the plant, which elevates GIC risks; the electrical resistance of geological formations in New Hampshire, which elevates GIC magnitudes; and improving knowledge of the accelerating GICs associated with the Eastward electrojet during severe solar weather, based on NASA satellite observations, which increases risks within the Northeast region of the U.S. power grid.[5]

Recently, Jerry Adler's article, "The End of the Black Box: There's a Better Way to Capture Plane Crash Data," Wired, July 2011, proposed near-real-time transmission of relevant performance parameters with remote ground station readouts. NRC's Miller Task Force expressed interest in satellite relay of performance parameters on each NRC licensed power plant. This option sounds attractive until the costs of EMP hardening for a family of spacecraft, uplinks, downlinks, crosslinks, and ground stations are considered. This option could be yet another *common fault failure* pathway.

4 Foundation for Resilient Societies Request for Rulemaking, Proposal for Rulemaking PRM-50-96, NRC Docket NRC-2011-0069.

5 NRC Staff has recently noted in its explanations for the exclusion of severe accident risks that the Federal Energy Regulatory Commission (FERC) and not the Nuclear Regulatory Commission is primarily responsible for setting reliability standards for the (bulk power) grid, nationally and regionally. NRC still retains primary responsibility to protect "public health and safety" when it licenses or relicenses nuclear power plants. FERC's limited regulatory authority under the year 2005 amendments to the Federal Power Act mean that the NRC cannot depend upon the bulk power system as presently configured or operated. FERC cannot guarantee cost recovery for reliability system improvements, unless the Congress once again amends the Federal Power Act. Hence, the risk of prolonged station blackout, and the risks of unexpected delays in restoration of grid power are ever present. If a coal fired plant or a gas fired plant must shut down, there is no significant risk to the plant's fuel. To the contrary, for nuclear fuel assemblies of recent vintage, the loss of grid-provided electricity and the loss of backup on-station power to operate water pumps and temperature controls is a potential disaster in the making. The

Also since year 1990 licensing of Seabrook Station, it has been possible to identify that low cost, cost-effective backup emergency generator types are available; and hardware options to protect generation step-up transformers have become available recently.[6] The latter may prove to produce positive payback of investment through reduced dependence upon "down-rating" of electric generation; and through higher capacity utilization rates for nuclear power plants that opt to install hardware protections for high voltage transformers.

When new information about significant risks to the quality of the human environment, such as severe nuclear accidents, including operational experience from Fukushima, Japan, becomes available, a federal agency – the Nuclear Regulatory Commission included – has a duty to include significant new information in an otherwise required supplemental EIS. That Supplemental EIS should not provide minutia about extremely low probability risks with modest adverse consequences, while excluding altogether a roughly 1 in 12 risk of nuclear fuel assembly (zirconium cladding) fires that could spread radioactive material for considerable distances. If there are common mode failures that include, for example, significant risk of high voltage transformer fire or outage at the nuclear power plant, those risks need to be assessed. It should be mandatory that these higher probability, high consequence, foreseeable events be included in the SAMA analyses within the Final Supplemental EIS for Seabrook Station.

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primary malfunctions at Fukushima were centered in the reactor buildings and their containment systems that failed in the absence of backup power. In the U.S., spent fuel pools are not protected by the same containment shell as protects the main power reactor. The Nuclear Regulatory Commission and not FERC, is primarily responsible to assure the safety of high voltage step-up transformers that are peculiarly vulnerable to solar geomagnetic induced currents. The NRC, and not FERC, is primarily responsible for backup power needed to prevent dangerous buildup of hydrogen gas, and to assure make-up water supplies for spent fuel pools.

The Commission in its September 20, 2011 response to EMP Commission Chairman William R. Graham stresses that NRC expects it could shut down the reactor core of each nuclear power plant safely. Even if this is true under many scenarios, if there is a large regional cascading grid failure, and if grid power is not thereafter restored, we have concerns about the adequacy of on station power once the power plant has been safely scrammed. The remedies proposed in the Petition for Rulemaking, NRC 2011-50-96 provide sufficient power for water pumps to maintain safe temperatures in spent fuel pools. The 4 kW capacity might well suffice to assure, additionally, that hydrogen gases are safely managed inside containment vessels housing the main reactor, or that backup power to expel excess hydrogen through containment vents suffices for the task. But these backup power systems are insufficient to restart and safely operate nuclear power plants if the regional grid is not operational. So after a shutdown, where is the on-site power to restart the plant if outside grid power is unavailable? This Commission must develop mitigation options that work even when NERC reliability standards are unattainable.

[6] In November 2011, EMPrimus and ABB propose to display for the Geomagnetic Disturbance Task Force of NERC a high voltage transformer safeguarding system that includes capacitors and neutral ground shunts. While the cost of this system has not been formally established, cost estimates for similar devices are in the range of $200,000. Installation of transformer protection hardware of this type, or comparable step up transformer hardware protections should be included in a SAMA mitigation option analysis for Seabrook Station No. 1 within the Final SEIS.

Literally and unfortunately, “the perfect storm” for a regional electric blackout of extended duration is projected for the Northeasterly quadrant of the U.S. power grid. The Foundation for Resilient Societies modeling estimates a roughly a 1 in 12 (eight percent or more) cumulative risk – for years 2011 through 2050 -- of zirconium fires with potential to disperse radioactive materials from Seabrook station. [7] If the severe accident events were included in the Final SEIS, the NRC would have the opportunity and duty to address low-cost options to provide for on-station improved backup power.

Backup power using Organic Rankine Combustion Cycle generators would provide reliably 4 kW of on-site backup power for moderate cost. This capability would be relatively invulnerable to solar weather or the loss of outside power. Solar panels with DC current could, for a comparable investment, keep water pumps working so older (less radioactive) fuel assemblies would not become uncovered and so the fuel assemblies stored underwater would not produce zirconium fires. The benefit, measured in protection of human lives valued by NRC at $4 million per life, exceeds the cost of each system by a factor of 110. Even if a solar storm probability were just one tenth the likelihood estimated by Oak Ridge National Laboratory, in conjunction with advice via the R-319 Metatech Report of January 2010, on site backup power for spent fuel cooling would be highly cost-effective.

Because the risks at Seabrook are above the average risks, because of site specific factors, the high latitude causing higher frequency of severe solar weather, adjacency to the Atlantic Ocean, end of the Scoobie 345 kV transmission line, East-West orientation of that line, and ground resistance conditions, the benefit-cost ratio specific to Seabrook Station of GIC-immune backup power systems would be substantially higher than would apply to the average U.S. commercial nuclear power plant.

In year 2004 when the EMP Commission completed its first major report, the NRC decided not to consider as a generic issue high altitude EMP risks to the electric grid of the nation. As of August 31, 2011, the Commission has reiterated its exclusion from consideration of man-made EMP risks that produce such prompt injuries from high altitude nuclear weapons that use of solar storm warning systems is totally ineffective for transformer protection.[8]

In more than three and one half years since the Congressionally-mandated EMP Commission released a supplemental report (April 2008) on the specific electric sector vulnerabilities to EMP and impacts of electric grid collapse on a range of other U.S. critical infrastructures, the NRC has not

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[7] William R. Harris, Comments on Proposed Rulemaking (PRM-50-96), July 20, 2011, at pp. 7-8, filed as ADAMS ML 11209B682.

[8] It is important to note that solar storm warnings will not protect high voltage transformers from high altitude nuclear EMP effects. The so-called E1 wave from a nuclear weapon detonated in the atmosphere would arrive in a matter of nanoseconds, at higher energy levels than E3 induced currents. Nonetheless, proposed hardware protections against E3 geomagnetic induced currents could have additional surge arrestors included to protect against E1 pulses. Were the U.S. electric utility industry to accelerate installation of protective hardware for high voltage transformers, the incentive to launch a high altitude EMP attack against the United States could be rapidly eroded for some nations that have acquired or might in the future acquire nuclear weapons. See the Reports of the EMP Commission (2004, 2008) for further details.

required nuclear power plant operators to install "black box" recorders covering transformer performance parameters, peak and cumulative GIC currents, nuclear reactor health, or spent fuel pool conditions. Nor has NRC required that safety related "black box" data be reported to NRC on peak and cumulative ground-level geomagnetic induced currents impacting large on-station transformers. Data from these "black boxes" could provide the analytic foundation to demonstrate when to replace or repair a transformer, and whether there are positive financial returns to owner-operators who invest or have invested in hardware protections for generation step up transformers (GSUs).[9]

Should the Congress or the Courts accept at face value any future Nuclear Regulatory Commission claim of an inability to perform statistical modeling of risks to nuclear power plants from adverse solar weather? Unless the Commission requires the installation of black boxes for each high voltage transformer at NRC-licensed facilities, with the continuous measurement of GIC peaks and cumulative GIC loadings, the Commission will be failing to fulfill its public safety mandate. [10]

The Draft Supplemental EIS of July 31, 2011 provides Severe Accident Mitigation Analyses (SAMA's) for risks of flooding, risks of earthquakes, risks of tsunamis, risks of short term loss of outside power (LOOP).[11] But one set of events is altogether excluded despite careful Probabilistic Risk Assessment and PRA Level 3 estimation of expected loss of life (somewhat more than 2,000 persons) in the March 14, 2011 Petition for Rulemaking on Backup Power to Protect Spent Fuel storage Facilities. This set of risks includes projections (calculated shortly *before* the Fukushima accidents in March 2011), of the probability of loss of outside power, [not expressly] loss of large step up transformers, loss of power to operate on-site water pumps for cooling spent fuel pools that are *at least two orders of magnitude more likely than the cumulative risk for all of the other severe accidents analyzed in the Seabrook Draft SEIS.*

It is neither appropriate nor lawful to exclude high consequence risks from an Environmental Impact Statement if the risks are reasonably foreseeable. The Council on Environmental Quality

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9 The Federal Aviation Administration required installation of "black box" recorders in U.S. jurisdictional commercial aircraft in the 1950s. Under an International Maritime Convention, registered ships must carry black boxes to understand and reduce risks of accidents at sea. Starting in year 2001, some automobile manufacturers have installed "black box" recorders in automobiles to diagnose and reduce risks of highway accidents.

10 Some large electric utilities in England, Scotland and Wales have embarked on systematic GIC measurement programs. These monitoring systems may have the capacity to demonstrate the financial returns to investments in hardware protections for high voltage generator step-up transformers (GSUs). Data in seconds, or at least minutes as dB/dt is generally preferred to the USGS Dst indices. If comparable data in the U.S. were mandatorily reportable to NRC for nuclear-licensed plants, and to FERC for all bulk power facilities, and if independent contractors could analyze these safety-related data, it should be possible to accelerate improvements in system reliability because of the prospects for increased rates of capacity utilization and higher aggregate owner-operator revenues.

11 See Table F.3.1.1.1-1 in Volume II, "Dominant Initiating Event Contribution to Core Damage." Pages F-14 and F-15.

requires consideration of these low-probability, high-consequence accidents significantly impacting the quality of the human environment.[12] The courts have upheld this duty of a federal agency to consider low probability, high consequence accidents that are reasonably foreseeable.[13]

Further, the refusal of the Commission and its Staff to consider the highest probability of low probability, high consequence events results in an apparent regulatory failure. Specifically, if the Commission will not consider severe accidents for which cost effective mitigation measures now exist, the Commission has no practical means – through education, through public participation, through conditions of re-licensure, or through Commission Orders if necessary – to accelerate mitigation measures that are needed now.

NEPA was not designed as an exercise within which responsible agencies would contract out risk assessments and guide contractors to exclude the most relevant severe accidents[14], hence to avert public consideration of the most consequential unmitigated risks.

A central goal of the environmental review must be to reduce risks and improve prospects for future environments that provide opportunities, within the limits of human feasibility, for safe and healthy living. By excluding all scenarios involving severe solar geomagnetic weather, the Nuclear Regulatory Commission has deprived the public and the Commission staff from considering cost-effective mitigation measures. This must be corrected in the Final SEIS for Seabrook Station, and for all other pending license renewals at licensed power plants with above average risks from geomagnetic induced currents.[15]

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[12] See CEQ Regulations at 40 C.F.R. § 1508.27(b)(5) and § 15022.22(b).

[13] See *Sierra Club v. Watkins*, 808 S. Supp. 852 (1991); *San Luis Obispo Mothers for Peace v. Nuclear Regulatory Commission*, 449 F.3d 1016 (C.A. 9, 2006). For commentaries see P. L. McChesny, "CEQ's 'Worst Case Analysis' Rule for EISs." 13 Environmental L. Rev. 1669 (1983) and Cass R. Sunstein, "Irreversible and Catastrophic," 91 Cornell L. Rev. 841 at 876-77 (2006). A parallel Massachusetts environmental laws known as MEPA also requires consideration of low probability, high consequence accidents. A failure to consider the escape of anthrax pathogens from a proposed Biomedical Laboratory, although of low probability, caused a court to vacate the Final EIR. See *Allen v. Boston Redevelopment Authority*, 877 N.E.2d 904 (2007).

[14] For the Draft SEIS for Seabrook Station No. 1, the NRC Staff provided guidance to Pacific Northwest National Laboratory, operated by Battelle under a renewable contract. The result has been for Pacific Northwest National Laboratory to consider lower probability risks of conventional weather, but to exclude altogether any consideration of the risks of adverse solar weather with a higher probability of significant harm and far higher expected loss of human life if risks are not both analyzed and mitigated.

[15] 35 of NRC licensed commercial power plants of the 104 now-operating have even higher site-specific risks than Seabrook. See the Foundation for Resilient Societies Petition for Rulemaking in NRC Docket 2011-50-96. Assessment of solar weather risks and appropriate mitigation measures, plant by plant, should occur even if the Commission adopts a generic rulemaking process for backup power to protect on-site spent fuel pools. The Commission's Staff has recently informed the Commission that in its recent history the shortest period between commencement of a Rulemaking process and a resulting Commission Order has been 23 months.

With appropriate consideration in the Final SEIS for Seabrook Station, cost-effective mitigation measures could and should be put in place in advance of the projected peaking of solar geomagnetic activity in years 2012-2013. These measures would also protect against risks of additional geomagnetic disturbances within the first several years on the downside of a 10.5 year (short) solar geomagnetic cycle peak.

Among the lessons from the March 2011 disaster at Fukushima highlighted in the NRC's Miller Task Force Report[16] are proposals to emphasize the need for a rigorous reassessment of NRC risk management to cope with *common fault failures.* The augmentation of backup power systems is considered and recommended, but without considering solar geomagnetic risks,[17] nor requiring that on-site backup power be designed for resilience against solar or man-made electromagnetic pulse risks. [18] More importantly, the Task Force urged the Commission to analyze and protect against *common mode failures.* If a common mode risk is triggered by adverse solar weather and a parallel failure to protect generation step-up transformers throughout a regional electric grid, common mode failures are reasonably foreseeable and predictable. The common assumption that grid power will be promptly restored, as in the SAMAs considered in the Draft SEIS for Seabrook, will be simply invalid. If the Commission is to fulfill the renewed purposes and the "defense in depth" philosophy of the Miller Task Force Report, the arbitrary exclusion of foreseeable, mitigatable high-consequence risks should be halted as an NRC procedural practice

Moreover, significant new circumstances or information relevant to the increased risks of environmental concern must be addressed within a Supplemental Environmental Impact Statement.

If the Commission cannot accelerate its implementation of essential public safety protections through Rulemaking and resulting Commission Orders, the substantial majority of 104 NRC-licensed commercial nuclear power plants in the U.S. may proceed into an eleven year (short) peak solar weather hazard in 2012-2013 without availability of mandatory mitigation measures. Hence we explain our recent interest in encouraging analysis of relationships between peak and cumulative GIC insults to generation step up transformers and both capacity utilization and revenue changes for plant owner-operators. Financial self-interest could result in protection of high voltage transformers without assistance of NRC or FERC. Mandatory reporting and public accessibility of reports on GIC peaks and cumulative exposures could allow third party analyses of financial returns for procurement of protective hardware. In short, neutral party analysis of returns on investments in safety and system reliability might well accelerate grid stabilization even without mandatory government standards.

[16] Recommendations for Enhancing Reactor Safety in the 21st Century, Washington, D.C.: NRC, July 12, 211.

[17] Letter, NRC Rulemaking Staff to William R. Harris, July 12, 2011.

[18] Charles A. Miller, et al., Recommendations for Enhancing Reactor Safety, *op.cit.*, Section 4.2, Mitigation, considers "prolonged loss of alternating current power," at pp. 32-33. The Task Force recommends protecting emergency diesel generators (EDGs) so they will function throughout accidents involving loss of outside power. But the Task Force neither recommended design of backup power systems to withstand adverse solar weather, nor recommended extending on-site capabilities for backup power beyond a seven day period.

Regulations promulgated by the Council on Environmental Quality are not optional; they are mandatory for NRC and other federal agencies.[19]

Without consideration of adverse solar weather, the northeast states would suffer projected loss of a substantial number of high voltage transformers. Some transformers are subject to the extra high voltage lines (345, 500, and 765 kV) that with reduced resistance will create higher flows of GIC and are more vulnerable to GICs of high magnitude. Even with transmission lines at the lower level of 345kV, New Hampshire is especially vulnerable to loss of generation step up transformers due to East-West alignment, length of transmission line**,** interconnections with surrounding EHV grid of New England that allows flow of larger GIC**,** proximity to Ocean, resistance of igneous rock formations, and frequency of high energy eastward electrojet channeling in this region.

Disturbingly, Metatech, Inc., under contract to the Oak Ridge National Laboratory, has projected that all of the extra high voltage transformers in the State of New Hampshire are expected to be subjected to 90 Amp per phase insults from geomagnetic induced currents**,** GIC levels which put them at-risk of failure. New Hampshire is the only state in the Union with this projected 100 percent failure outcome at 90 amps per phase. At 30 amps per transformer phase, both East and West Coast high voltage transformers are at risk. On the West Coast, a severe geomagnetic storm at 30 amps per phase is projected to eliminate operability of 100 percent of HV transformers in California, Oregon, and Washington State. On the East Coast only Vermont and New Hampshire are projected to suffer 100 percent transformer losses with these postulated electrical currents.[20]

The Commission's scenarios assume a rapid reconstitution of backup grid power, in all of the severe accidents posited for Seabrook Station. By the Commission's own admission,[21] in responding to the EMP Commission Chairman and staff director, as of September 2011 the Commission has not analyzed the Oak Ridge National Laboratory Report of 2010, estimating an at-risk solar geomagnetic storm with a frequency estimated as 1 in 100 years. [22] Presumably, the same reasoning that led the

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[19] See 40 C.F.R. § 1502.9(c).

[20] John Kappenman, Geomagnetic Storms and Their Impacts on the U.S. Power Grid, Goleta, CA: Metatech Corp. January 2010, Meta-R-319, prepared for Oak Ridge National Laboratory, at Table 4-14. "Of particular concern would be the permanent loss of large GSU (generator step-up) transformers at power plants in the northeast region of the U.S. (i.e. NE Quad). The loss of these transformers causes a compounding of difficulties in that the EHV transmission network is impaired along with the loss of output of vital and usually base load nuclear, coal, and hydro-electric generation sources for the power grid…." Kappenman, at p. 4-16).

[21] Letter signed for Operations Executive Director Borchardt of the NRC to William R. Graham, Chairman, and Peter V. Pry, Staff Director of the Congressionally-mandated EMP Commission, September 20, 2011, reproduced as Appendix B, and found on the ADAMS website as document ML112301365.

[22] The U.S. Geological Survey has been improving, even retrospectively, estimates of the frequency and magnitude of terrestrial geomagnetic storms derived from solar activities. Retrospectives on the magnitude of solar and solar-terrestrial geomagnetic phenomena have been back-fitted to the May 1921 geomagnetic storm,

Commission to exclude consideration of the Oak Ridge year 2010 study also kept the Commission from considering the specific and more severe impacts upon New England and, in particular, transformers in the State of New Hampshire, analyzed in Metatech Report R-319 of January 2010.

3 Duty of the Commission to Assess Low-Probability, High-Consequence Events that Are Reasonably Foreseeable and Subject to Cost-Benefit Analysis

Just because there is more than one cycle involving the frequency of solar storms, a short cycle of about 10.5 years, and a longer cycle, or more than one longer cycle, does not mean that a distribution of frequencies and magnitudes cannot be analyzed for the purpose of designing power plants and for the purpose of back-fitting mitigation measures as needed.

The NRC's apparent reasoning, however convenient, falls afoul of the National Environmental Policy Act of 1969 and the CEQ's mandatory guidelines, which require the Commission to analyze low probability high consequence risks that are reasonably foreseeable. Further, under the Atomic Energy Act, if the Commission determines reasonable cause to improve the safety of previously licensed power plants, to protect "public health and safety," the Commission has authority to require back-fitting of on-station backup power designed to operate through solar geomagnetic storms. And the Commission has the authority to require hardware protection for generation step-up transformers (GSUs) that, if enough of them fail, can cause a cascading failure of the national or regional bulk power systems. The

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with one USGS estimate of -900 nanoTeslas/minute Dst, and a Kappenman retrospective estimate in R-319, cited above, of about -5000 nanoTeslas/minute using a dB/dt index often preferred to the Dst index. A retrospective re-estimate of the GIC of the Carrington event of September 1-2, 1859 is -1760 nanoTeslas/minute Dst. The highest level of magnetic current in recent years involved the March 13/14, 1989 event, which collapsed part of the North American grid at just over -400 nanoTeslas/minute before surging to about -589 nanoTeslas/minute using the Dst index. Back-fitting to prior centuries, before Russian observatories commenced measuring geomagnetic currents in the 1840s, is feasible to some extent by the analysis of ice core samples containing nitrates and other byproducts of solar geomagnetic events covering a time scale of at least 450 years. Hence, it is unreasonable to claim that it is retrospectively *possible* to analyze earthquake magnitudes before modern seismology (used by the NRC in the Seabrook Draft SEIS), yet *impossible* to backfit geomagnetic induced currents over the past four or five centuries. Relevant literature on the frequency and magnitude of solar coronal mass ejections and terrestrial impacts includes: J. J. Love and J. L. Gannon, "Revised Dst and the epicycle of geomagnetic disturbance: 1958-2007," at www.ann-geophys.net/27/1/2009; J. L. Gannon and J. J. Love, "USGS 1-min Dst index," J. Atmospheric and Solar-Terrestrial Physics 73 (2011), 324-334; N. G. Ptitsyna, M. I. Tyasto, and B. A. Khrapov, "Very Intense Magnetic Storms in 1841-1870 Registered by the Russian Geomagnetic Network," Geocosmos (2010); E. W. Cliver and L. Svalgaard, "The 1859 Solar-Terrestrial Disturbance and Current Limits of Extreme Space Weather Activity," Solar Physics, 224 (2004); 407-422.

Commission only has jurisdiction over the NRC-licensed nuclear facilities, but these operate nearly 50 percent of the higher voltage GSU transformers in the nation, and a higher percentage of those in New England.

Resources that can assist NRC in fulfilling its severe accident risk assessment duties include:

- The Geomagnetic Disturbance Task Force of the North American Electric Reliability Corporation (NERC;
- The members and staff of the EMP Commission;
- The technical staff of the Defense Threat Reduction Agency of DoD;
- The Defense Science Board;
- The JASONS, who are nearing the completion of an assessment of electromagnetic pulse phenomena coordinated through the MITRE Corporation; and
- The National Laboratories of the U.S. Department of Energy.

It is reasonably foreseeable that solar-terrestrial geomagnetic induced currents will affect NRC-jurisdictional nuclear power plants. It is reasonably foreseeable that some sites will have above average risks at that site or in that region. These sites will have greater benefit to cost ratios of mitigation measures. These more at risk *sites* require unique analysis in a Supplemental EIS for that site and that specific reactor.

Given the reasonably foreseeable geomagnetic induced currents during solar storms, given the patterns of solar storms over the past 450 years, given the recording of solar coronal activity via space observatories globally since the 1840s, and an increasingly broad array of land and space based monitoring of solar activity and terrestrial impacts, the Nuclear Regulatory Commission is long overdue for mandatory consideration of geomagnetic storm-related severe accidents, and the search for cost-effective mitigation options.

As an illustration of the reasonable foreseeability of impacts of solar weather upon terrestrial geomagnetic induced currents, see the 50 year time-spiral produced by the Staff of the U.S. Geological Survey. Fifty years of (short) solar geomagnetic cycles are spaced in a spiral with cyclic duration of 10.5 years. Magnetic flux with Dst magnitude above 30 nanoTeslas/minute are shown in **red**. Magnetic flux between 20 and 30 nanoTeslas/minute are shown in **black**. Magnetic flux under 20 nanoTeslas/minute are shown in **green**. The short term solar cycle indicates a peak period within one quadrant of the epicycle, but also a related risk of high magnitude GICs on the downside of the cyclic peak.

See on the following page the time-spiral described above, reported in J. J. Love and J. L. Gannon, “Revised Dst and the Epicycle of geomagnetic disturbance: 1958–2007”:

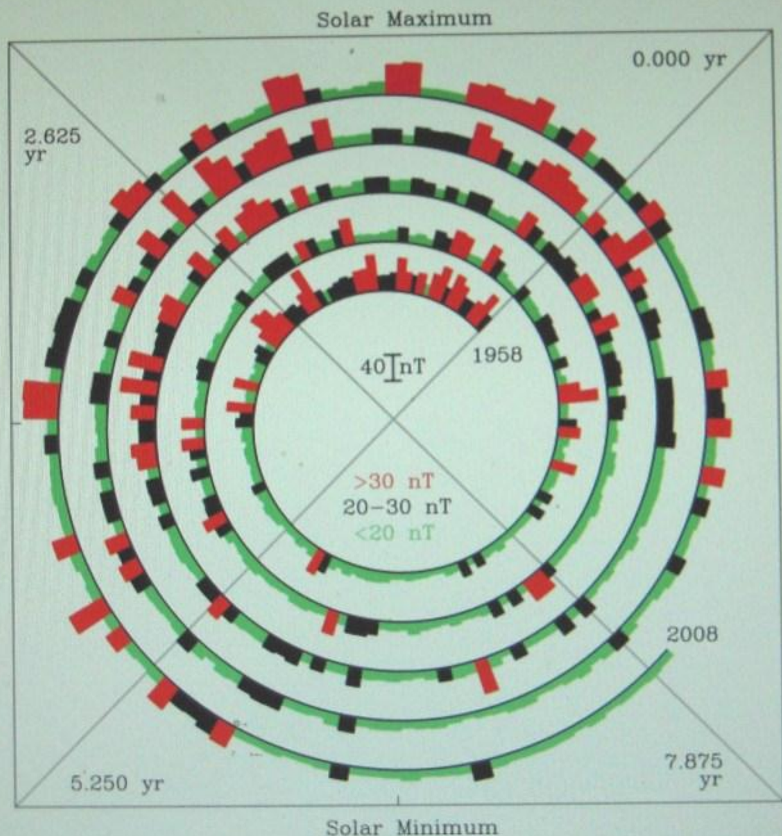

Fig. 20. Time-spiral plot with a period of 10.5 years showing monthly root-mean-square D_{st} and the solar-cycle waxing and waning of global magnetic activity from 1958–2007.

4 Specific Severe Accident Mitigation Alternatives (SAMAs) Proposed for Analysis in the Final SEIS for Seabrook Station

4.1 Back-Up on Site Power for Spent Fuel Cooling

The Foundation for Resilient Societies' Petition for Rulemaking, filed in the Commission's ADAMS database on March 15, 2011 remains as just a Petition. Even if the Commission proceeds to a proposed Rulemaking to require augmented on-site backup power for all NRC-licensed reactors, site specific Supplemental Environmental Impact Statements should consider Severe Accident Mitigation Alternatives for each plant site with above average risks of loss of outside power and above average risk of loss of on-site generation step-up transformers (GSUs). Seabrook is such a site.

Because the probabilities of a regional grid blackout are higher for New England and adjoining regions of Canada, and because the likelihood of loss of all 345 kV transformers is as great or greater in New Hampshire than in any other state (as previously explained), we request that the Commission evaluate, using SAMA methodology with cost-benefit calculations: (A) the installation of backup on-station power that utilizes, *inter alia*, an Organic Rankine Generator capable of operating with either fossil fuel or thermal energy; (B) the combination of 4 kW capacity of a Rankine Organic Cycle Generator of 4 kW capacity together with a 4 kW capacity solar system that is *not* connected to the regional grid to avert E3 pulses; and (C) a higher capacity on-site backup system if needed, to fulfill both demand for operation of water pumps to protect spent fuel pools *and* to provide backup power to operate reliably (i) hydrogen recombination equipment inside the main reactor containment vessel, and (ii) hydrogen gas venting equipment to expel hydrogen gases from the containment vessel if a risk of hydrogen burnup or explosion were to require emergency venting of accumulated hydrogen gases. See section 4.2 below.

This proposed sub-set of Severe Accident Mitigation Alternatives include aging related elements because (a) the structure housing the spent fuel pool may experience reduced protective strength as it ages over the decades since construction[23]; (b) the spent fuel requirements for make-up water pumping are aging related, with reduced power demand as the radioactivity rates decrease over time, offset by projections for the increased density over time of fuel assembly storage in onsite pools if no central or regional storage sites become available; and (c) if the aging of concrete in the main reactor containment vessel increases the risks of hydrogen explosions inside the main reactor containment vessel – comparable to the explosions of hydrogen gases at Fukushima Dai-ichi. Hydrogen gas explosions,

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[23] The heating of zirconium beyond fuel assembly design temperatures foreseeably produces hydrogen gas buildup. Absent adequate backup power to operate water pumps for spent fuel pool water makeup, hydrogen buildup in the spent fuel storage building creates some risk of hydrogen gas burnup or explosion. The aging of the building structure is relevant to these risks.

following the loss of all onsite backup power, caused severe damage to containment vessels and partial obliteration of the containment vessel protecting Fukushima Dai-ichi Reactor No. 3. Hence, these SAMA mitigation sub-options need to be considered in the Final SEIS for Seabrook Station.

4.2 Back-Up Power for Hydrogen Gas Recombination Devices and Hydrogen Gas Venting

Zirconium clad fuel rods provide extra strength, but when temperatures inside a power reactor exceed design specifications it is foreseeable that hydrogen (and perhaps some tritium) gas will accumulate. Retrospectively, the accident at the Three Mile Island nuclear power plant in 1979 is recognized to have involved fast burning of hydrogen gases together with possible in-containment system explosion. The accidents at several of the Fukushima Dai-ichi reactors remain under analysis.

The Miller Task Force working for the Commission, recommends: "as part of the longer term review, that the NRC identify insights about hydrogen control and mitigation inside containment or in other buildings… through further study of the Fukushima Dai-ichi accident."[24]

Controlled hydrogen igniters within containment structures might be required. Alternatively, for pressurized water reactors, it may still suffice to maintain functionality of equipment designed to recombine hydrogen with oxygen, and to retain the option of power venting excess hydrogen gas buildup from within the containment vessel to the outside of that vessel. All of these safety systems should have backup power capacity onsite, capable of operating these gas control systems in the absence of outside power from the electric grid, i.e. under LOOP conditions.

The Commission has a duty to consider these Severe Accident Risks and the variations of proposals for augmented backup power systems (identified in Section 4.2 above) and the cost-effective of these mitigation alternatives.

Because of the substantially above average risk that, following a severe solar storm the Northeast Quadrant of the U.S. bulk power system will experience prolonged outage of high voltage transformers, and delays in fulfilling replacement transformers (absent additional hardware protections for existing transformers[25]), hydrogen gas accumulations may well occur within the main containment vessel and within the spent fuel storage building at Seabrook Station. Since the ability to contain hydrogen gas explosions relate to the aging of these buildings' pressure tolerances, this is an aging relating issue that requires SAMA analysis.

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24 See the Miller Task Force Report, July 12, 2011, at Section 4.2.3 on "Combustible Gas Control. St pp. 41-

25 See Section 4.4. of these comments.

4.3 Back-Up On-Site Power for Other Station Power, Control Rooms, SCADA Systems, and Facility Security.

Backup power to sustain the restart ("black start") and continuing station power operating needs of Seabrook Station following a loss of outside power would require onsite generating capacities beyond those we propose in Sections 4.1 and 4.2. At the present time, we do not know of available and cost-effective backup power capacity required for all the other station power requirements, via equipment retrofits that would be cost-effective when subjected to SAMA analysis.

It is our understanding that many nuclear power plants in Europe are designed so that they are capable of utilizing heat exchangers to generate substantial "station power" electricity. It is our understanding, but without personal expertise in the matter, that the NRC-licensed plant at Calvert Cliffs, Maryland also has a design that allows the reuse of thermal energy from the power reactor to provide station power even if the regional electric grid is inoperable.

Because of the need for engineering designs and evaluations before "back-fitting" options might be ripe for consideration for existing NRC-licensed commercial power plants, we do not recommend SAMA analysis of large heat exchanger retrofits at this time.

What we do ask the Commission and its Staff to consider is the conditioning of any license renewal for the period March 2030 through March 2050 on a duty to re-evaluate "back-fitting" of heat exchange options to backup station power needs before the start date of the license renewal period.

Between now and the March 15, 2030 license renewal start date for Seabrook Station, electric system operators worldwide are likely to experience at least two (short) epicycle peaks derived from solar coronal mass ejections, in roughly the periods 2012-2013 and 2023-2024. If the experience of electric system operators with future solar weather is less favorable than many system operators anticipate, it may be necessary for the Commission to mandate retrofits of heat exchange systems to augment on-site station power to better cope with grid instability resulting from adverse solar weather.

An owner or operator of an NRC-licensed power reactor should not be able to argue, in the future, that the prior issuance of a renewal license constitutes a property right; and that it would be an undue hardship to require retrofitting of heat exchange systems to augment self-provision of additional station power to cope with adverse solar weather

4.4 High Voltage Transformer Protective Hardware

With an increasing array of hardware options to protect high voltage step up transformers (GSUs) for peak and cumulative insults from geomagnetic induced currents, the Commission has a duty to evaluate severe accident mitigation alternatives. The business-as-usual mitigation option is to reduce nuclear station generation from 100 percent of rated capacity to 80 percent or as low as 65 percent of rated capacity, given forecasts of future solar weather. This method of mitigation is totally useless in defending against man-made EMP weapons (which the Commission has excluded from its consideration since the EMP Commission first reported in year 2004).

At an EPRI Conference on Geomagnetic Induced Currents in June 1992, Greg A. Cucchi of PJM Interconnections, in a Paper entitled "Solar Magnetic Disturbance: An Operator's Wish List," estimated the cumulative system cost over a three year period from March 1989 to nearly June 1992 if the system operator were forced to "down-rate" capacity utilization every time a solar storm of magnitude K5 or higher were forecast.[26] If down-ratings had occurred for all solar storm warnings of K5 or higher, the system operator estimated system operating losses to PJM and its partners of "over $100 million in excess incremental operating costs" in just a three year period.[27]

With acquisition costs for hardware protections of high voltage, three-limb transformers in the range of about $0.2 million per transformer, and assuming another $0.2 million of investments for shipping, installation, and staff training, we consider that hardware protection of on-station step-up transformers must be evaluated as SAMA mitigation. We anticipate a robustly positive return on investment for these systems. Since transformer age is a factor in the (increasing) risk of transformer fire or generation plant outage, this is an age related SAMA option the Commission must include in the Final SEIS for Seabrook Station.

Any transformer fire or sustained high voltage transformer outage increases risks of environmental harm, including release of transformer fluids. Currently, transformer fires risk the dispersion of SF6, one of the most potent of all greenhouse gases. Geomagnetic storms create major risks of transformer fire at Seabrook Station.

We would anticipate but cannot at this time prove positive returns on investment for utility firms that purchase hardware protection systems for their high voltage transformers. We can roughly project an upper bound of the revenue enhancements per NRC-licensed nuclear power plant. These

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[26] The K-scale is logarithmic, with the severe storms within the range of K8 to K9. Because insults to transformers can shorten their life or cause system outages at substantially lower K values, PJM Interconnections had concerns about a "down-rating only" option to protect long term system efficiencies.

[27] G.A. Cucchi, "Solar Magnetic Disturbances: An Operator's Wish List," <u>EPRI Proceedings: Geomagnetically Induced Currents Conference</u>, June 1992, EPRI TR-100450, Paper 18, at page 18-7.

projections suggest but do not prove a fast payback for utility firms that invest in transformer hardware protection systems.[28]

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[28] Is it feasible to estimate a rough upper bound of potential annual revenue enhancements for the nuclear-electric power industry through industry-wide investments in hardware protections for large transformers and any related vulnerable equipment? Were the entire electric utility industry to adopt hardware protections for all high and extra high voltage transformers, and if, over time, these investments and adoption of changed "best practices" allowed the electric industry to achieve higher annual capacity utilizations for electric generation, what might the upper bound of these savings be?

We have reviewed the Energy Information Administration's Annual Energy Review 2010, released Oct 19, 2011, at www.eia.gov/totalenergy/. We reviewed the annual capacity utilization rate for all U.S. nuclear-electric generation in the eleven years 2000 through 2010, the last available full year. Next, we compared the annual capacity utilization rate for the two years with most active geomagnetic induced currents, year 2003 and year 2000. Comparing the annual capacity utilization rate for these two years, 88.0 percent, with the annual utilization rate for the nine years with reduced GIC activity, we learned that the average capacity utilization rate, utilizing U.S. nuclear-electric net generation, was 91.3 percent for years 2001, 2002, 2004m, 2005, 2006, 2007, 2008, 2009, and 2010. If investment in transformer hardware protection and changes in "best practices" to capture efficiencies from these hardware protections explained all of the difference in average annual utilization rates, we next projected the maximum potential revenue gain if solar GICs and impacts via transformers accounted for all (100%) of the loss of revenues resulting from unprotected system operations during solar storms. Using year 2010 electric generation and average revenue per kWhr of 9.82 cents in year 2010 dollars, we estimated total potential incremental nuclear-electric revenues for the years 2000 and 2003. Then we derived an annual potential maximum savings over the full eleven year period. Dividing the annual potential benefits by the number of NRC-licensed and operating commercial nuclear power plants, we estimated a savings per nuclear plant of about $4.36 million per year, based solely on revenue losses due to lost generation, but not including losses due to transformer failure and replacement.

Moreover, we exclude from potential net revenue gains the avoided costs of third party claims by electric distributors who incur higher costs to replace lost power due to outages or down-ratings. For example, a transformer fire at Vermont Yankee in year 2004 resulted in successful claims by Central Vermont Public Service against Entergy Vermont Yankee for both losses for higher-cost replacement power and losses during the down-rating. These third party claims were upheld in Vermont Public Service Commission Docket 7321 (2007-2008).

But we know our methods are only approximations of the upper bound of additional revenues resulting from higher capacity utilization throughout the nuclear-electric industry. Still, if transformer hardware protection costs are about $0.4 million per transformer (purchase, installation, training), *if* improved protection against adverse solar weather captures only about 12 percent of an improved capacity utilization goal of 2.5% per peak solar disturbance years, then the payback period for investing in EHV and HV transformer hardware protections would be just one year. Thus, while we acknowledge these projections do not constitute proof of positive financial returns, we nonetheless anticipate high returns on capital investment from hardware protections for high voltage generation step up transformers at U.S. nuclear electric power plants. Indirectly, these industry-wide investments in the hardware protection of EHV and HV transformers, decisions to be made in the self-interest of participating firms, would strengthen the reliability and stability of the entire U.S. electric grid.

4.5 Providing Ground-Level Radiation Monitor Wireless Reporting Systems

At our request, the C-10 Research and Education Foundation [hereafter C-10 Foundation]provided to us ground level monitoring system descriptions, technical specifications for now-active radiation monitoring equipment, and the method of reporting radiation levels at 16 ground sites in northeastern Massachusetts (as of September 2011). This system has been operational since the year 1991, but it does not cover the larger area in southeastern New Hampshire that is within the ten mile emergency evacuation zone of Seabrook Station. Power requirements for the monitoring equipment include operation of 12V DC equipment requiring only 1 mAmp (at typical loads) to 20 mAmp (at maximum loads).

The current monitoring system depends upon reporting of radiation readings from all 14 stations via the internet. The data recipient is presently the Massachusetts Department of Public Health.

We hypothesize as the largest risk of loss of outside power (LOOP) a solar geomagnetic storm that prevents prompt restoration of outside power. With present backup diesel power at Seabrook Station designed to last seven (7) days, we hypothesize a potential overheating of spent fuel pools in a building that is not nearly as well protected as is the main reactor in its massive containment shell. If after 8 to 10 days, without backup power beyond systems now in place, pumps for the addition of makeup water into spent fuel pools are not available, zirconium fires in spent fuel pools might arise in a period roughly 30 days after a regional loss of power via the electric grid. By day 30, there is a substantial risk that, if the regional electric grid has not been fully restored, the internet will not be a viable means of reporting elevated radiation readings at ground stations within the Seabrook evacuation zone.

The Nuclear Regulatory Commission has emplaced ground-level monitors within a five (5) mile radius of Seabrook Station. The cumulative readings from these monitor sites can be read by site visits every three months. These closer-to-Seabrook monitoring sites are not designed for the purpose of enabling an Incident Commander to compare *in situ* sheltering versus staged evacuation from regions downwind of the Seabrook plant that may experience radiation hot spots.

As a reminder, the experience in the region surrounding the Three Mile Island nuclear plant in the year 1979 was that, without a large-area radiation monitoring network and without public broadcasting of instructions on *in situ* sheltering versus staged evacuations, much of the regional population evacuated concurrently. This resulted in massive congestion of arterial highways in the region, which, had there been high levels of radiation, would have resulted in needless loss of life.

Accordingly, we recommend that the C-10 Foundation apply for grants to augment the ground station monitoring system. In particular, we recommend enlarging the system to include at least 20 ground stations in southern New Hampshire. Further, we recommend equipping at least 35 sites with wireless communications that would have backup power to report regional radiation readings. A more sophisticated system might employ near-real time unmanned telemetry reporting to one or more regional reception sites. Recipients of ground level radiation monitoring reports should also include the U.S. Department of Homeland Security and the Nuclear Regulatory Commission. Homeland Security has in the past had grant programs that might be available to support an improved ground monitoring system for the region around Seabrook Station.

If the Commission fails to include in the SAMA Analyses for Seabrook in its Final SEIS the loss of outside power and concurrent loss of onsite power production, and a failure to install backup power systems that have reduced vulnerability to geomagnetic disturbances from solar storms, then the risk of a zirconium fire from an unmitigated Seabrook Station is quite high. The Foundation for Resilient Societies' Rulemaking Petition) indicates an estimated risk of zirconium fires with resulting offsite radiation as roughly 1 in 12 likelihood over the period 2012-2050, without mitigation. [29] Hence, the costs of an augmented ground level radiation monitoring network and augmented telemetry read-out system would most likely be cost-effective, given NRC's valuation of saved human lives at $4 million per life. This is because a staged evacuation with *in situ* sheltering of persons outside any high radiation regions would be likely to save a substantial number of lives.

NRC should apply SAMA analysis to an upgrading of the C-10 Foundation's ground level monitoring and reporting system. The roughly doubling of regional population and the saturation of vehicular traffic at coastal beaches in the summertime provide significantly different and new information since the Governor of Massachusetts found the Seabrook regional evacuation plans unacceptable in the year 1990.

Yet, by the year 2016, Interstate 95 modernization and a new Whittier Bridge across the Merrimack River will result in a 10 lane vehicular corridor (counting breakdown lanes) compared to just six lanes at the (old) Whittier Bridge without breakdown lanes. With *contraflow* evacuation management, vehicular throughput could be significantly expanded. An Incident Commander, with near-real-time radiation data, could manage a more efficient evacuation and a more efficient cleanup, but only if the data are timely.

Overhead sensing of radiation patterns, as was done in the Fukushima Prefecture in March 2011, is less reliable. In that disaster, the Prime Minister's office actually ordered disaster victim evacuations into a pathway of high radiation. Hence, a SAMA analysis would be likely to demonstrate cost-effectiveness of regional ground level radiation monitoring.

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[29] Comments of William R. Harris, July 20, 2011, at pp. 7-8, filed as ADAMS ML 11209B682.

5 Conclusion

In summary, the risks from severe solar weather and associated geomagnetic disturbance far exceed other risks addressed in the Draft Supplemental EIS and the Severe Accident Mitigation Alternatives for Seabrook Station. There is a significant probability that damage to high-voltage transformers in the commercial electric grid and resulting long-term loss of outside power would result in radiation releases. Radiation releases could come from either the reactor core or the spent fuel pool, or both. These potential events are not speculative and are reasonably foreseeable. Backup power sources and hardware protection for high-voltage transformers are moderate-cost means of mitigation and prevention.

Severe risk mitigation alternatives are identified; preliminary calculations indicate likely cost effectiveness of specific measures, but not all measures the Commission is asked to analyze. Backup power for cooling of spent fuel pools even during a regional electric blackout is available at moderate cost. They can prevent fires in the cladding of spent fuel assemblies that remain of special concern. Without augmented on-site backup power, spent fuel fires could create safety risks to downwind communities and leave these cities and towns at risk of long-term environmental contamination.

Only by including these solar storm-related risks in the class of “severe accidents” to be assessed can the Commission and its contractors identify the mitigation measures that are either essential or otherwise justifiable. The cost and benefits of these mitigation and prevention measures should be examined by the NRC and plant operator as part of the Seabrook Station environmental review. Finally, only with full disclosure of the more significant risks and a review of mitigation options can a record of Commission decisions inform a public with increasing concerns about nuclear safety.

William R. Harris and Thomas S. Popik

Foundation for Resilient Societies
52 Technology Way
Nashua, NH 03060

Appendix A

Letter from EMP Commission Chairman William R. Graham and Staff Director Peter V. Pry to NRC Chairman Gregory B. Jaczko on EMP Safeguarding,

August 1, 2011, filed as ADAMS No. ML 11279A118

Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack

Established by Congress through Title X, National Defense Authorization Act for Fiscal Year 2006

The Honorable Gregory B. Jaczko
Chairman
U.S. Nuclear Regulatory Commission
Mail Stop O-16G4
Washington, D.C. 20555-0001

08/25/2011
76FR 47612
7

Dear Chairman Jaczko:

I am writing you as the Chairman of the Congressionally mandated Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack as well as the former Science Advisor to the President and Director of the Office of Science and Technology Policy in the Executive Office of the President from 1986 to 1989. This letter is to urge you, as you form plans to protect U.S. nuclear reactors from Fukushima-type disasters where electric power to support nuclear plant operations is lost for a protracted period, to take account of the very real threats from a great geomagnetic storm and from a nuclear EMP attack.

An EMP can be generated naturally by a solar flare or coronal mass ejection from the Sun, which can produce a great geomagnetic storm on the Earth similar to some aspects of an EMP attack from a high-yield nuclear weapon, with similar catastrophic consequences. A great geomagnetic storm could cause the collapse of the electric grid and other critical infrastructures--transportation, communications, banking and finance, food and water--for a protracted period of months or years. A study by the National Academy of Sciences independently confirmed the EMP Commission's assessment that, if a great geomagnetic storm like the 1859 Carrington Event recurred today, recovery of the national electric power grid would take 4 to 10 years.

Such an event could also cause operators of the 108 nuclear plants in the United States to lose the ability to perform a safe, controlled shutdown of their power reactors, producing a Fukushima-like disaster on a large scale.

Although great geomagnetic storms are rare, estimated to occur about once a century, most experts assess that we are probably overdue. Indeed, many scientists are concerned that the approaching solar maximum in 2012-2013, characterized by increased solar flares and coronal mass ejections, may produce great geomagnetic storms. The solar maximum recurs every eleven years.

Moreover, there is no doubt that all the capabilities exist for an EMP to be generated by a terrorist or rogue state nuclear-armed missile, perhaps launched off a ship near our shores to preserve anonymity, and burst at high-altitude over the United States. In this manner, a single crude nuclear weapon, lofted by a primitive short-range missile, could generate an EMP that would disable and/or destroy electronics and electric power systems across large, highly populated areas of the continental United States, where many more nuclear power reactors are located than found at Fukushima. Such an attack would also collapse the critical infrastructures, leaving nuclear power plants isolated from external support, including from the electric power grid, for a protracted period of at least months and probably years. Given the current state of unpreparedness, a nuclear EMP attack could cause Fukushima-like disasters nationwide.

Review Complete

E-RIDS= ADM-2

Therefore, I urge you to implement the policies, planning, emergency control system protection, and technical safeguards that are so urgently needed to protect nuclear reactors from natural and manmade disasters--including EMP events.

Please inform me of the response you and the NRC plan to take in response to this letter and the threat of both natural and adversary-induced EMP damage to the nuclear power reactors of the United States.

Sincerely,

William R. Graham

Dr. William R. Graham
Chairman
Commission to Assess the Threat to the United States
from Electromagnetic Pulse (EMP) Attack

Peter Vincent Pry
co-signed by
Dr. Peter Vincent Pry
President
EMPact America
301-481-4715

cc: The Honorable Steven Chu, Secretary of Energy
The Honorable John P. Holdren, Director, Office of Science and Technology Policy, The White House
Thomas E. Donilon, National Security Advisor to the President
Senator Jeff Bingaman, Chairman, Committee on Energy and Natural Resources
Senator Lisa Murkowski, Ranking Member, Committee on Energy and Natural Resources
Senator Joseph Lieberman, Chairman, Committee on Homeland Security and Governmental Affairs
Senator Susan Collins, Ranking Member, Committee on Homeland Security and Governmental Affairs
Senator Carl Levin, Chairman, Senate Armed Services Committee
Senator John McCain, Ranking Member, Senate Armed Services Committee
Rep. Fred Upton, Chairman, Committee on Energy and Commerce
Rep. Henry Waxman, Ranking Member, Committee on Energy and Commerce
Rep. Peter King, Chairman, Committee on Homeland Security
Rep. Bennie Thompson, Ranking Member, Committee on Homeland Security
Rep. Buck McKeon, Chairman, House Armed Services Committee
Rep. Adam Smith, Ranking Member, House Armed Services Committee
Rep. Roscoe Bartlett, Co-Chair, Congressional Caucus on EMP
Rep. Trent Franks, Co-Chair, Congressional Caucus on EMP
Rep. Yvette Clarke, Co-Chair, Congressional Caucus on EMP

Appendix B

Responsive Letter from R. W. Borchardt, NRC Executive Director for Operations to Drs. Graham and Pry

September 20, 2011, filed as ADAMS ML112301365

September 20, 2011

Dr. William R. Graham
EMPact America
P.O. Box 124
Elma, NY 14059

Dear Dr. Graham:

On behalf of the U.S. Nuclear Regulatory Commission (NRC), I am responding to your letter of August 4, 2011, about safeguarding nuclear reactors from natural and manmade disasters and in particular from electromagnetic pulse (EMP). Specifically, you requested that as the NRC reviews its regulations and programs aimed at protecting U.S. nuclear reactors that the NRC take into account geomagnetic storms and manmade EMPs.

The NRC is aware of the potential significance of EMP to the Nation's critical infrastructure and has reviewed the "Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack," issued in 2004. In the late 1970s, concerns with EMP-induced large currents and voltages in electrical systems led the NRC to undertake a research program to study the effects of EMP on nuclear power plant safe-shutdown systems. The NRC conducted this study and documented the results in NUREG/CR-3069, "Interaction of Electromagnetic Pulse with Commercial Nuclear Power Plant Systems," issued in February 1983. That report concluded that the safe-shutdown capability of nuclear power plants would, in general, survive the postulated manmade EMP event. In 2007, the NRC revisited this earlier study in light of the modernization of nuclear plants with digital systems, which potentially could be more susceptible to EMP. The new study, completed in 2009, also concluded that nuclear power plants can achieve safe shutdown following a manmade EMP event. In addition, a supplemental study, completed in 2010, which analyzed and compared the potential impacts on nuclear power plants from solar or geomagnetically-induced current events to those of the EMP events previously analyzed, led to the same conclusion.

The NRC is also aware of the potential damage to the electric grid that can occur from geomagnetically-induced currents resulting from a significant solar storm. In response to the strong geomagnetic storm on March 13, 1989, which caused major damage to electrical power equipment in Canada, Scandinavia, and the United States, the NRC issued Information Notice 90-42, "Failure of Electrical Power Equipment Due to Solar Magnetic Disturbances," dated June 19, 1990, to inform nuclear power plant licensees of the potential for damage to transmission systems and other components of the power grid from severe solar activity events.

The NRC does not have direct regulatory authority over the electric transmission systems, except with regard to nuclear power plants. The Federal Energy Regulatory Commission (FERC) has direct regulatory authority over these systems and the North American Electric Reliability Corporation (NERC) has the authority to develop and enforce reliability standards for these systems. The NRC collaborates closely with FERC and NERC on electric grid reliability and cyber security issues. The NRC has entered into separate Memorandum of Agreements with FERC and with NERC that commits each agency to share information, and coordinate on matters of mutual interest pertaining to the Nation's electric grid reliability and nuclear power plants.

In October 2010, the Oak Ridge National Laboratory (for FERC, in joint sponsorship with the U.S. Department of Energy and Department of Homeland Security) published a report assessing the vulnerability of the U.S. electric power grid to severe space weather. This report estimated that severe solar storms, occurring at a frequency of once every 100 years, could cause long-term (1–2 years) grid outages affecting about two-thirds of the nuclear power plants in the United States. The NRC staff has not yet evaluated these recent reports.

On March 15, 2011, the NRC docketed a petition for rulemaking (PRM-50-96) requesting that the NRC amend its regulations to ensure long-term cooling and makeup water for spent fuel pools at U.S. power reactors because of the possibility of a widespread and long-term loss of the electric power grid due to natural geomagnetic disturbances. The petition states that self-sufficiency is necessary since fuel resupply deliveries cannot be assured after a large induced current in the bulk power transmission system because of the disruption of petroleum and natural gas infrastructures caused by widespread and long-term loss of the electric power grid. The NRC is in the process of reviewing PRM-50-96. The petition and other documents related to the review of PRM-50-96 are available at http://www.regulations.gov/ under Docket ID NRC-2011-0069.

The NRC staff is participating in and monitoring NERC's activities for protecting critical infrastructure from EMPs. Potential resolutions include hardening large power transformers from potentially damaging geomagnetic-induced currents and developing a strategy for obtaining spare parts. The staff is monitoring congressional activities on this issue, such as House Resolution 668 (the Secure High-Voltage Infrastructure for Electricity from Lethal Damage Act or SHIELD Act) to amend the Federal Power Act to protect the bulk-power system and electric infrastructure critical to the defense of the United States against natural and manmade EMP threats and vulnerabilities.

In summary, the NRC is considering all information available to date about the threats from a great geomagnetic storm and from a manmade EMP that could have potential adverse effects on the safe operation of nuclear power plants.

The NRC is committed to the safe and secure operation of all U.S. nuclear power plants, while at the same time promoting the effective and efficient regulation of NRC licensees. We will continue to work with all stakeholders to ensure that the concerns discussed in this letter are addressed properly.

Sincerely,

/RA by Martin J. Virgilio for/

R. W. Borchardt
Executive Director
for Operations

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Appendix C

NRC Power Reactor Status Report Analysis by Foundation for Resilient Societies
October, 26, 2011

Nuclear Plant Power Reductions Attributed to Solar Activity

Date of Report	Unit Name	Power	Reason
3/31/2001	HOPE CREEK	65%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE'S
4/1/2001	HOPE CREEK	65%	HOLDING POWER DUE TO SOLAR MAGNETIC DISTURBANCE'S
4/2/2001	HOPE CREEK	80%	HOLDING POWER DUE TO SOLAR MAGNETIC DISTURBANCE'S
4/12/2001	HOPE CREEK	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE
4/13/2001	HOPE CREEK	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE
4/18/2001	HOPE CREEK	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES ON "C" MAIN POWER TRANSFORMER
10/2/2001	HOPE CREEK	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES AFFECTING THE MAIN TRANSFORMER
10/3/2001	HOPE CREEK	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES AFFECTING THE MAIN TRANSFORMER
10/4/2001	HOPE CREEK	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES AFFECTING THE MAIN TRANSFORMER
11/24/2001	HOPE CREEK	78%	SOLAR MAGNETIC DISTURBANCE
10/29/2003	HOPE CREEK	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES
10/30/2003	HOPE CREEK	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES
10/31/2003	HOPE CREEK	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES - WILL REASSESS HOLD AT 1100 EST AND, IF NO PROBLEMS, ESCALATE POWER
10/30/2003	POINT BEACH 1	83%	INCREASING POWER FOLLOWING A DECREASE IN POWER DUE TO GRID GEO-MAGNETIC DISTURBANCES
10/31/2003	POINT BEACH 1	84%	REDUCED POWER DUE TO GRID GEO-MAGNETIC DISTURBANCES
7/16/2000	SALEM 1	80%	REDUCED POWER DUE TO GRID DISTURBANCE CAUSED BY SOLAR MAGNETIC DISTURBANCE
11/6/2001	SALEM 1	75%	HOLDING POWER AT THIS LEVEL DUE TO SOLAR MAGNETIC DISTURBANCES
11/24/2001	SALEM 1	76%	SOLAR MAGNETIC DISTURBANCE
10/29/2003	SALEM 1	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES
10/30/2003	SALEM 1	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES
10/31/2003	SALEM 1	80%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES - WILL REASSESS HOLD AT 1100 EST AND, IF NO PROBLEMS, ESCALATE POWER
11/8/2004	SALEM 1	77%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE
7/16/2000	SALEM 2	80%	REDUCED POWER DUE TO GRID DISTURBANCE CAUSED BY SOLAR MAGNETIC DISTURBANCE
11/6/2001	SALEM 2	76%	HOLDING POWER AT THIS LEVEL DUE TO SOLAR MAGNETIC ACTIVITY
11/24/2001	SALEM 2	75%	SOLAR MAGNETIC DISTURBANCE
11/8/2004	SALEM 2	78%	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE