Christopher Allen Slocum, Vice President, Arizona Oil & Gas

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A Theory for Human Extinction: Mass Coronal Ejection and Hemispherical Nuclear Meltdown

In theory, any dose of radiation has the potential to produce an adverse effect. Accordingly, exposure to any radioactive substances, is, by definition, hazardous (EPA 10-23).

This is the beginning of the nuclear era, an era marked by poison, which begins with the Army Air Corps developing and testing nuclear explosive devices. It pushes into the introduction of the first nuclear chain reaction for power that promises to be safe, abundant, and inexpensive, and it persists with the irremediable consequences of Three Mile Island's 1979 partial nuclear reactor core melt, Chernobyl's 1986 partial core melt, and the partial core melt in three of Fukushima Daiichi's reactors. The science of nuclear reaction, criticality events, nuclear waste, and radiation can demonstrate a greater understanding of the immutable nature of these catastrophes, but it cannot demonstrate nuclear power's economic unviability. Nor can it demonstrate nuclear power's proclivity to proliferate nuclear arsenals, nor can it predict the unpredictable. Earthquakes can be larger than engineering projections and flood waters can be higher than predictions. Furthermore, an electromagnetic pulse (EMP), emitted from the sun, has not yet been sufficiently modeled, projected or predicted, but there is scientific certainty that a comparable high-altitude weaponized EMP would debilitate the electric grid and cause blackout in every U.S. state except Hawaii and Alaska. A nuclear power plant in blackout will melt down;

a nation's fleet of nuclear power plants in blackout will melt down. In the case of a large x-class coronal mass ejection from the sun, a hemisphere's fleet of nuclear power plants in blackout will melt down. The fallout from over 100 simultaneous *full* reactor core melts, is a powerful premise for a theory of human extinction. Humanity can not afford nuclear power.

On December 7, 1941 the island of Oahu wakes as if still dreaming in the euphoria of living in a veritable paradise, a dream that trades the morning hum of the ocean surge for the lumbering drone of bombers slowly crossing the harbor under the concealment of an undisclosed hostility. The American naval base is destroyed. On December 8th, a nation of declared neutrality, moves with swift ferocity, entering a war for the fate of the world. Its military-industrial complex ramps-up with intensity only rivaled by its ingenuity. At the University of Chicago, a team of scientists led by Enrico Fermi produces a self-sustaining chain reaction at the *Chicago-Pile 1* site. A reactor core of cadmium control rods and uranium/graphite fuel rods is constructed. The cadmium absorbs neutrons, limiting the energy available for a chain reaction. As the cadmium rods are removed from the pile, the first self-sustaining chain reaction is achieved (The History of Nuclear Energy 6-7), laying scientific foundations and providing the raw materials for the United States Air Corps to fire the Trinity Shot at the Almagordo Bombing Range in New Mexico in July 1945. A destructive force imagined only in science fiction emerges as a scientific fact. A primary explosion around a plutonium core detonates a chain reaction equivalent to 21 kilotons of TNT (Johnson et al.). On August 6, 1945 Little Boy drops from the Enola Gay, devastating Hiroshima with a 15 kiloton TNT equivalent-the world's second atomic blast (Little Boy). On August 9th, the world's third atomic bomb detonates over Nagasaki-21 kiloton Fat Man (Fat Man). With its detonation, the fiery nexus of imperialistic ambition is driven from the free world, and the irremediable passions of nuclear ambition, have just begun to ignite. Enrico Fermi achieved nuclear fission. America’s atomic bomb program was hungry for the plutonium byproduct of fissile uranium reactions. The heat from the chain reaction promised an alternative energy that would be safe, abundant and inexpensive.

In the quest to provide the military with plutonium, and to harness the unparalleled power of splitting atoms, fission was honed and scaled to commercial power plants. The generation of electricity begins with a *radioisotope,* which is a radioactive form of an element that has a different number of electrons than the base element. Uranium 235 is a radioisotope that emits electrons. As these extra electrons are emitted, they can split the nucleus of an atom, *nuclear fission*, producing heat and creating lighter elemental by-products, *fission-products,* like plutonium. When enough uranium is situated in the right circumstances, emitted neutrons continue to split neighboring uranium atoms, resulting in *self-sustained chain reaction*. (The History of Nuclear Energy ii – iii). “The amount of uranium needed to make a self-sustaining chain reaction is called a *critical mass”* (The History of Nuclear Energy 5). Pellets of 3% Uranium 235 and ceramic are placed in a linear series, a *fuel rod*. Those fuel rods are interspersed with mobile control rods, which can stop the chain reaction by absorbing neutrons. These two parts make up the reactor core. The core is submerged in water to cool the chain reaction. The heated water, in a closed-circuit, interfaces with generator water that is also in a closed circuit. The generator, water turns to steam which propels the generator turbine (Ulmer-Scholl). The generation of electricity through nuclear fission unleashed inconceivable power, but it also discharged inconceivable consequences.

The irremediable consequences of nuclear fission began to become apparent during a series of 67 atomic shots over the Marshall Islands in the Pacific between 1946 and 1958 (Guyer 1372). In 1946, the U.S. military asked the 146 residents of Bikini Atoll in the south Pacific to relocate so they could fire (1371) the one kiloton nuclear test Able (Johnson et al.). Also fired in 1946, 8 kiloton Baker was a military exercise to test the effects of underwater detonation near a fleet of naval ships. The fleet was imbued with invisible poison. The military could not scour, power-wash or sandblast the radiation from the fleet. Because the fleet could not be remediated, it was retired to the ocean floor (Guyer 1371). Also notable for its irreversible consequences was the 1954 Bravo shot. Utilizing fission to create nuclear fusion, *thermonuclear*, the 15 megaton explosion was the largest in U.S. history (Johnson et al.). The Bravo shot was so powerful that it vaporized two islands at Bikini Atoll "and part of Nam, the island at which it was detonated. (Today Nam remains so contaminated that during the mid-1990's, the Bikini Council entertained-but eventually rejected-lucrative proposals to make it a permanent U.S. nuclear dump" (Guyer 1372). Unfortunately, the winds changed direction prior to the shot, covering Bikini Atoll with radioactive fall-out, and exposing Bikinians to immediate adverse health effects from radiation poisoning (1372). From vaporized islands to radiation poisoning, the Baker shot proved the nuclear era to be anything but safe.

Examination of the science of nuclear reactor core melt demonstrates a threat more varied than military detonation of thermonuclear devices. A computer model of a hypothetical loss-of-coolant accident at the Laguna Verde power plant in Veracruz, Mexico, describes the meltdown process inside of a nuclear reactor for electricity generation. When a loss of coolant occurs, the control rods are thrust into position between the fuel rods to absorb neutrons and stop the chain reaction. Even though the neutrons are not bombarding the fissile fuel rods with enough neutrons to create a chain reaction, the loss of coolant allows the radioactive byproducts to produce decay heat. This heat begins to melt the control rods and form structural damage to the fuel rods. Explosive hydrogen starts to be produced as the core breaks down water. The melted control rods allow neutron transmission between the fuel rods, so they begin to chain react uncontrollably, a *criticality event*. The whole slurry of molten material then drops to the reactor floor, and if the pressure inside the reactor is low, the fuel containing mass will melt through the floor and drop to the lower levels of the complex: If the pressure is high, the molten material will be ejected through the reactor floor violently (Camargo-Camargo 2). This simulated loss of coolant accident is an analogue to what happened to the reactor core in Ukraine's Chernobyl in 1986, and it is analogous to what happened when three of Fukushima Daiichi's reactor cores melted down in Japan in 2011.

Fukushima Daiichi was a model of best practices in emergency operations. When the earthquake shook Japan the seismic alarms sounded, and the control rods were immediately inserted into the reactor cores, shutting down the chain reactions and bringing the power plant into a safe condition. Loss of power meant that back-up generators fired to circulate coolant in the reactor. The generators came online with precision and the safety of the plant was maintained until a wall of ocean inundated Japan's coast, knocking the generators off-line. While engineers had accounted for seismic activity and tsunamis, this wave was taller than the sea-wall that had been constructed around the plant. Without electricity to circulate coolant within the reactor core, decay heat from the reactor's byproducts began to compromise the control rods, which created pathways for neutrons to bombard the uranium in the fuel rods. An uncontrollable chain reaction occurred in three of Fukushima's reactors (Anshari 320-321). The partial core melt in three of Fukushima Daiichi's reactors was the unparalleled amplification of a natural disaster by the ingenuity of humankind. Nature's worst, was nothing compared its amplification by human design.

"The Japanese government reported that… approximately 4.3 million curies of radioiodine and 410,000 curies of radiocesium had been released to the atmosphere" (Alvarez 79). "Aerial radiological surveillance done by the U.S. Department of Energy… indicated that roughly 175 square kilometers had contamination at levels comparable to those in the exclusionary zone around the reactor ruins at Chernobyl, in the Ukraine region of the former Soviet Union" (Alvarez 79). 125,000 people have been displaced from the 18 square mile area around the plant (Beech par. 12). Trash bags full of nuclear waste litter school parking lots, because no one wants a central nuclear waste dump in their backyard (par. 21). Areas deemed safe for reentry officially exceed the 1mSv per year maximum safe level, and decontamination efforts suffer from a lack of personnel. While $13 billion U.S. has been designated for decontamination, TEPCO has already paid $40 billion in claims to 2 million claimants, with approximately 200,000 claims pending and a class action suit has been filed by over 4,000 people from 39 countries against the manufacturers of the nuclear facility (Schneider 9-10). Japan shut down all 48 of its nuclear power plants in the days following the disaster (Beech par. 5) and the estimated annual impact from the meltdown is $35.4 billion (par. 19). The current situation at Fukushima Daiichi is a compelling counterpoint to the idea that nuclear energy is safe and inexpensive, and these first four years after the accident only marks the beginning of the cost.

"Tokyo Electric Power Company has yet to achieve cold shutdown at the Dai-Ichi site. The Japanese government currently estimates that it may take 30 years to remove and store nuclear and other contaminated material, at an estimated cost of $14 billion" (Alvarez 79). Other projections say the cleanup will take 40 years (Matos 319), but these projections are nothing short of political mitigation. If Chernobyl can be used as an example, thirty years after the incident, there is no plan for the final removal and storage of its fuel containing materials. If anything, 30-40 years is an estimate provided to placate the Japanese public, and the world at large. There is no plan for final remediation. Nuclear waste cannot be remediated. It can only be stored with a final solution of hope and prayer; hope and prayer that nature will be merciful for thousands of years, while the nuclear waste decays to a safe condition.

> So much radiation still pulses inside the crippled reactor cores that no one has been able to get close enough to survey the full extent of the destruction. Every 2 ½ days, workers deploy a new giant storage tank to house radioactive water contaminated after passing through the damaged reactors. We wander past a forest of some 1,300 of these tanks, each filled with 1,000 tons of toxic water. (Beech par 3)

On site, 75% of the spent fuel rods from the damaged reactor 4 have been moved to a common pool where they are cooled with circulating water and neutron absorbents. Unfortunately conditions in reactors 1-3 are so radioactive, that it is nearly impossible for humans to enter (Beech par. 9). The reactors are not under control. Around the clock, water with neutron absorbent boron is pumped into reactors 1-3 under the assumption that the coolant will follow the path of the fuel material that melted through the floor to prevent the reemergence of a criticality event by cooling the fuel containing mass, wherever it ended up, in whatever state it exists. This coolant constantly washes radioisotopes out of the reactor. The water is then circulated from the lower level of the facilities and recycled to the extent possible (Schneider 68). The water that is used to cool the reactor cores is increasingly difficult to recycle as the recycling systems are plagued with mechanical failures. As of July 14, 2014, over 500,000 tons of unrecyclable waters is stored on site (67). To complicate matters, ground-water is flooding the lower floors of the reactors at an estimated rate of 800 tons per day, and an underground stream is estimated to flood the lower levels with 400 tons of water per day, pushing 600 tons of water out to sea (68). TEPCO has reached a settlement with the fishermen's union, allowing for groundwater which is flooding the reactor basements to be pumped down before entering the basement, disposing of in the ocean before it becomes contaminated (70). To further complicate the disaster, many skilled workers have reached their maximum allowable lifetime radiation dose, so a lot of work is being left in unskilled hands (Beech par. 12). Mistakes are mounting, and there are reports of the homeless being recruited to supplement a dwindling labor pool (par. 22). TEPCO's official remediation plan is to build water containment walls around each of the reactor buildings and flood the structures to their rooves, so that the volatile cores can be removed to the common pool. The government has asked TEPCO to consider a gaseous coolant to eliminate the profound production of contaminated water, but TEPCO has implemented the containment vessel around reactor 4, and completed removal of 75% of the fuel rods (Schneider 67).

Ukraine's Chernobyl power plant partial reactor core melt was similar to the loss of coolant simulation at Laguna Verde, and the meltdown at Fukushima Daiichi, except that it did not require the indomitable hand of nature to push the disaster. On April 26, 1986 "Two powerful explosions tore through Unit 4 of the Chernobyl nuclear power plant, flipping the reactor's giant 2,000-ton lid into the air like a coin… Remnants of the core burned for 10 days, churning a thick plume of radioactive isotopes equivalent to 400 Hiroshima bombs high into the atmosphere… Chernobyl contaminated half the planet with fallout" (Featherstone 59). The cause of the accident was a power surge inside the reactor which caused the steam explosion. The release of steam allowed for a more significant power surge within the reactor which melted the graphite core in an uncontrollable chain reaction that burned until May 6, 1986 (Report of the

U.N. 25). In a rush to contain the disaster the Russian government cobbled the *Shelter* around Unit 4, a structure containing 7,300 tons of steel, 480,000 tons of concrete, and “held together mostly by friction and luck” (Featherstone 60). Designed to only last 15 years, the Shelter has holes in the concrete, the steel beams are buckling from water corrosion, and the west wall is buckling. In order to safely deconstruct the Shelter, it must be isolated from the environment (60).

The molten core burned through four feet of concrete on the reactor floor and sits in the lower level of the shelter as a 2,000 ton crystalline mass of fuel containing materials, *FCMs* (60-61). The FCM’s give off *fuel dust*, which is the major threat to internal radioactive dose through respiratory contamination. Once a year, the Shelter is sprayed with chemicals that bind with the dust, suppressing the threat. “Scientists estimate that the Shelter contains 33 tons of the stuff…” The smallest particles don’t settle with gravity… but stay suspended in the air” (61). In order to remediate the FCMs the Shelter must be stabilized and deconstructed. Towards this end, the G-7 committed 1.3 billion to construct the New Safe Confinement structure (60). Designed to only last 100 years (64), it will be largest mobile structure in the world. An arch capable of housing a college football stadium with the statue of liberty standing at the 50 yard line will be deployed along rails for a quarter mile to isolate the Shelter (61-62). Before the arch can be deployed, however, Unit 4’s 40-story smoke stack will have to be removed. While the plan is to remove it in seven pieces, it is so highly radioactive that workers will have to work limited shifts (62). Furthermore, the FCMs are fissile, which means that if a rock falls on the FCMs at any time during deconstruction, the FCMs could enter a criticality event. Even if the deployment of the arch is successful, nearly thirty years after Chernobyl’s partial nuclear core melt, no one yet has a plan for what to do with the FCMs, as “Nuclear and radiological waste cannot be cleaned up. It cannot be eradicated. It can only be sealed in drums or concrete coffins and moved from one place to another, or buried in pits and surrounded by razor wire" (64). It is important to remember that this dire and irremediable humanitarian, ecological and financial crisis was the result of an unplanned power surge. Given the unparalleled consequences of a nuclear core melt, the risks of operating nuclear power are great, because it is impossible to predict every possible mechanical failure.

Three Mile Island's partial core melt was just such a mechanical failure. Like Fukushima Daiichi, the human processes executed after an overpressure event were flawless. The control rods were inserted in the reactor core and everything was accounted for except a stuck control valve. When the core reached temperatures of 4,200 degrees, it did not create an uncontrollable chain reaction. Water escaped from the reactor core through the stuck valve which allowed the zirconium clad fuel pellets to burn through the zirconium, breaking steam molecules into hydrogen atoms (Leishear 45). Because the reaction was over pressuring the reactor, a relief valve was opened and hydrogen escaped into another room. The water in the core was replaced, and the chain reaction was under control, but there was an explosion 7 hours later in the building. Spontaneous combustion was caused by one of the simplest theories of plumbing, *water hammer*, yet extensive engineering calculations and safety protocols failed to predict the possibility that an explosion outside the reactor could be attributed to the compression of water, steam, hydrogen and air (46). Three Mile Island cost $1 billion and over fourteen years to clean up (Matos 318). The U.S. Department of Energy claims that the Three Mile Island accident caused no over-exposure to radiation (18), and continues "1990 April 19. The final shipment of damaged fuel from the Three Mile Island nuclear plant arrives at a DOE facility in Idaho for research and interim storage. This ends DOD's 10-year Three Mile Island research and development program" (The History of Nuclear Energy 20). Fourteen years of remediation efforts to remove the FCMs from the reactor are euphemistically restated as a *research and development program,* and the idea of *interim storage* is also misleading. When the DOE made the statement in the 1990's, they had reason to believe it to be true.

Interim storage of spent fuel rods in cooling pools have the potential to pose more danger than a reactor meltdown.

> [S]pent nuclear fuel (SNF)… [is a] highly toxic byproduct of nuclear fuel, [and] remains radioactive for thousands of years after it is removed from a nuclear reactor core. Since SNF emits lethal amounts of radiation and generates intense heat following its removal from the reactor, it must be isolated in massive pools of water. At each nuclear power plant site, tons of SNF are awaiting long-term safe disposal. (Matos 307)

As of 2003, 49,000 metric tons of radioactive waste was stored at 131 U.S. sites. Current storage is in cooling pools which circulate water and neutron absorbing chemicals. If a natural or man-made disaster caused a loss of coolant accident at a cooling pool, the environmental disaster would be worse than the release of radioaerosols from Chernobyl's meltdown (Case 937).

> SNF is highly hazardous: close proximity to a single 10 year-old spent fuel assembly would deliver a fatal whole-body radiation dose in about three minutes. Each year the… industry produces 2,000 to 2,400 metric tons of spent fuel… Spent fuel pools were built with the understanding that … [they] would be temporary. SNF has been stored in pools for decades, and as of January 2012 amounted to… 110 million pounds. (Matos 312-313)

Current worldwide available technology only provides two options for the storage of spent nuclear fuel, neutron absorption chemicals in circulating water or dry storage in a concrete cask surrounded with steel. The dry storage casks only maintain their structural integrity for about 100 years, so there is no long term safe storage method for spent nuclear fuel (Matos 313). A loss of coolant accident in a spent fuel pool would cause the spent fuel and byproducts to catch fire, spreading radioaerosols (Alvarez 81) such as cesium 137, which makes up 40% of the pools (80). NRC research has estimated a large pool fire would contaminate 188 square miles around the reactor, cause up to 28,000 cancer deaths, and $59 billion in damage. Nearly all of the cesium-137 would be released into the atmosphere (81).

Hardly the inexpensive or safe energy supply envisioned by Enrico Fermi, the high costs must be maintained indefinitely. The spent fuel from nuclear reactors may have to be monitored for thousands of years. In the U.S., there are three classifications for spent fuel: low level waste, consisting of low concentrations of long lived radionuclides and high concentrations of short lived radionuclides; medium level waste, consisting of long lived radionuclides that do not emit heat; and high level waste that is heat emitting and highly radioactive (Macfarlane 30). To account for the scale of stored nuclear waste, Chernobyl's "total area of temporary radioactive waste facilities is about 8 km^2 with a total volume of disposed radioactive waste estimated to be over 10^6 m^3 (Report of the U.N. 230). There are also approximately "800 trench facilities each with waste-disposal volumes in the range of 800 to 2 x 10^6 m^3" (231). The cooling pond covers 23 km^2 (83). The half-life of fuel containing materials is about 30 years. It will take at least 60 years for the material to be reduced to one quarter of its volume (85). These highly vulnerable pools litter the planet, waiting for a final solution to safely store their irremediable waste, however, there is no plan for the long term deep geological storage (233). "The United States' nuclear waste should be stored in a permanent facility like Yucca Mountain in the near future because of the safety and protection such a facility would provide relative to the 131 temporary storage locations currently holding the nuclear waste around the country" (Case 959).

Unfortunately, the irremediable and deleterious nature of nuclear waste makes the risk of a central storage facility incalculable.

All commercially produced nuclear waste is stored on the grounds of the power plants that produce them. There is no repository for high level nuclear waste anywhere in the world (Macfarlane 31), other than the WIPP (Waste Isolation Pilot Project), in Carlsbad, NV which is a depository for military transuranic waste related to national defense (33). The U.S. explored many ideas for long term storage of nuclear waste including sub-sea bed, deep hole, outer-space, and ice-sheet, but rejected all of these ideas for a stable, deep geological deposit (Case 938). Congress mandated that a long term deep geologic storage facility be designated, and in 1987, they revised the mandate to focus exclusively on Yucca Mountain, located in the Nevada National Security Site, (formerly the Nevada Proving Ground). The site was deemed appropriate because of its proximity to the old nuclear bomb test site, and it was to begin receiving waste by 1998. The NRC proceeded with Yucca Mountain studies, ensuring that nuclear fuel and waste storage would be safe for 1,000,000 years (Matos 314). Yucca Mountain was considered ideal because it is composed of largely impermeable volcanic tuff and the annual rainfall is one of the lowest in the U.S., which means that erosion should be limited. Furthermore, the water table is at a depth 500-800 meters, which should limit infiltration of the dump site by ground water (Case 938-939).

The NRC issued permits for the construction and life-extension of nuclear power plants based on the assumption that the wastes could be mobilized to indefinite geologic deep storage (Matos 346), however, the earth is given to geologic change. Yucca Mountain is no exception. In 2002, a 4.4 magnitude earthquake struck the region. The tuff of the mountain itself is subject to faults and fractures, and there is faulting and volcanism in the area (Case 938-939). It is precisely the veritable implication of an ever-changing planet that makes long-term predictions impossible. For this reason, EPA calculated long-term storage at Yucca Mountain as safe for 10,000 years, prompting Nuclear Energy Institute, Inc. to litigate. The District of Columbia Appellate court determined that the standards set forth for storage at Yucca were unsatisfactory as they failed to follow the recommendations of the National Academy of Sciences by calculating safety for 10,000 years of storage, instead of the recommended 1 million years (934), "because peak radiation risk is likely to occur at some unknown time after ten thousand years and before one million years after disposal" (941). EPA justified its 10,000 year projection based on uncertainty, including:

> [1 F]uture human behavior and lifestyles, (2) future climate, (3) geological changes, (4) the natural variability of the radionuclide transport at Yucca Mountain, and (5) the rate of failure of waste packages. Furthermore, the measurements of current conditions may not be completely accurate. (Case 948)

The Yucca Mountain project has been plagued by litigation. Among the legal maneuvers to prevent indefinite storage of spent nuclear fuel and low level waste at Yucca Mountain, Senators Harry Reid and John Ensign introduced the No Yucca bill to Congress, and the federal court ruled that Nevada had no obligation to provide the project with water. If the project ever does get built, it will be capable of holding 70,000-120,000 metric tons of waste (Case 958). It remains to be studied if a breach of the proposed Yucca Mountain long term geologic storage facility would be a catastrophe of less or greater significance or probability than loss of coolant accidents across the national distribution of fuel rod coolant pools. The NAS, NRC and EPA cannot calculate 1,000,000 years into the future. If worst-case scenarios at Yucca Mountain calculates less-adverse than worst-case scenarios at fuel rod coolant pools, the Yucca Mountain project should proceed, through national security measures and/or Executive Order if necessary, but it should not be a pay-to-play shelter for the irremediable consequences of continued nuclear power operations. The U.S. fleet of nuclear power plants needs to be shut down and decommissioned, its current stockpiles of waste removed to the mountain, and active management of the repository should be planned for the duration of the decay of the radionuclides. The human risk of lethal radiation contained in nuclear waste is too long-lived to seal Yucca Mountain and pray for the best.

The lethal radiation component of radioisotopes is known as *ionizing radiation.* It is created when radioactive atoms undergo spontaneous nuclear transformations, releasing excess energy. As one element is transformed into another, *radioactive decay*; the newly formed element is called a *decay product.* The decay product will possess physical and chemical properties different from those of its parent, and may also be radioactive. A radioactive species of a particular element is referred to as a *radionuclide* or *radioisotope.* A fundamental and unique characteristic of each radionuclide is its radioactive *half-life*, defined as the time required for one half of the atoms in a given quantity of the radionuclide to decay (Risk Assessment Guidance 10-3). Of the radionuclides produced by the nuclear energy industry, "[I]odine-131 decays to safe levels within a few weeks. Cesium and strontium, which mimic potassium and calcium, two minerals critical to the function of healthy ecosystems, persist in the soil and water, in the plants and animals for decades" (Featherstone 60). Plutonium has a half-life of 24,000 years (Matos 313-314). The two methods of exposure to ionizing radiation are internal and external. Internal radiation exposure is caused by breathing or ingesting radioisotopes, and external exposure is caused by proximity to radionuclides that emit penetrating radiation. Among the external exposure threats, penetrating radiation includes *Beta Particles,* which are emitted electron streams caused by a neutron spontaneously converting into a proton and an electron. Beta Particles are similar to powerful x-rays and cause damage when in close proximity to the body. A more powerful ionizing toxin is *Gamma Radiation* which is comprised of photons emitted from the nucleus of a radioactive atom. The photons excite the atoms they contact and have a depth of penetration to do considerable harm to the human body. *Neutron* radiation emitted during fission emits both beta radiation and gamma radiation. All three of these particles are capable of external and internal damage. *Alpha particles* and *positrons*, pose only internal exposure risks, and contamination occurs through breathing or ingestion (Risk Assessment Guidance 10-4). When radiation is external, exposure stops when the body is removed from the radiation source. When a radionuclide is internal, it attaches itself to the tissue and bombards the tissue over the long-term (10-7). As radionuclides decay, turning into different radioactive materials (10-16), biological and chemical changes to the radionuclide do not alter its radioactivity (10-24). The risks to human health are cited in EPA's Toxicity Assessment of Radiation Risk Assessment Guidance which sets forth health effects ranging from carcinogenicity, to the ability to produce cancer, to *mutagenicity,* producing genetic mutations either in the body or in the reproductive cells, and *teratogenicity*, producing birth defects (10-28). The ecological implications of Chernobyl's fallout caused birth defects, heart disease, cancer, and thyroid cancer in children (Case 933). "Acute toxicity may occur at a mean lethal dose of 3-5 Sv with a threshold in excess of 1 Sv" (Risk Assessment Guidance 10-31). Exposure pathways include soil, ground water, surface water, air and biota (10-15), including the food-chain.

The food-chain is the transmission pathway of greatest risk for the lethal irradiation of the human species. This is seen in the history of the U.S. weapons program and in the history of the nuclear fallout at Chernobyl. Similarities in the composition and distribution of radionuclides from fall-out from atomic explosions and nuclear melt downs are demonstrated by Russia's analysis of the Nevada Test Site to draw long-term predictions for Chernobyl's nuclear fallout (Report of the U.N. 151). Returning to the DOD's thermonuclear Bravo Shot over the Marshall Islands, shifting winds, placed Bikini Atoll directly in line with the radioactive fall-out. "Radioactivity entered the atmosphere, the water, and the soil and worked its way up both terrestrial and oceanic food-chains" (Guyer 1373). In 1972, the U.S. declared Bikini Atoll safe and moved the natives back to the island. Then in 1978, it forced a subsequent evacuation because the land was too poisonous. In particular, the coconut trees take cesium-137 up in its roots, and concentrate it in the fruit. The sea has been diluted by time, but the land is the subject of a $563 million judgement against the U.S. for remediation (1371). The remediation plans include removing radioactive topsoil in specific areas, and utilizing potassium fertilizer that will compete with the cesium for uptake in the roots of plants (1374).

The Report of the U.N. Chernobyl Forum Expert Group "Environment" (EGE) of 2005 draws a detailed analysis of almost 20 years of research to show how the nuclear melt down at Chernobyl had dire consequences on the food-chain. "Some radionuclides are environmentally mobile and transfer readily… to foodstuffs" (44). 80% of the total radiation dose exposure occurs in plants and animals within three months of a meltdown (195). Of particular concern in the days following the meltdown was radioiodine. Because of its short half-life (45), 0.8-1.2 years (60), its significant impact was short lived. Cesium and strontium continue to be a concern to the food supply (45). These radionuclides mimic potassium and calcium, and are taken up by the roots of plants (52). For Iodine-131, high levels of contamination last from a few weeks to a few months. Cesium contamination will persist in the food-chain in plant and animal products for a long time, if not remediated (60). Pine trees are devastated by radiation, and pests populate the unhealthy trees, spreading to healthy populations in unaffected areas (197). Because of the impracticality of remediating forests, mushrooms, fruits, and game animals will be contaminated for decades (69). In forests, the fallout washes to the forest floor, impacting rodents and invertebrates. In the exclusion zone, invertebrates were decreased by an order of 30. Teratogenicity is common. Three quarters of the species were decimated. Repopulation occurs by migration of animals from non-affected areas (198).

The fall-out immediately contaminated exposed bodies of water. Those with sufficient flow saw radioactivity subsided rapidly, while closed bodies of water remain contaminated (Report of the U.N. 76). Cesium content in water and biota in closed systems will persist for several decades (94). The aquatic life became highly contaminated with radioiodine, but the levels quickly subsided, and radiocesium remains a persistent contamination in fish meat (85). Large predatory fish did not exhibit uptake of cesium until 6-12 months after the fallout (86). Remediation efforts included feeding farm-raised fish clean food-stocks (141). Groundwater has remained relatively unaffected by cesium because the radioisotopes chemically bind to soil as they migrate down the soil column (48), however sites within Chernobyl's exclusion zone have showed rapid migration of strontium into the ground water, especially under buried radioactive waste, and under the Shelter. While maximum penetration of groundwater is expected from strontium within 33-145 years, plutonium migrates more slowly (91). Given its half-life of 24,000 years, however, it is a concern of long term contamination (92). Belarus' laws have mandated the exclusion zone remain economically unproductive for 1,000 years (116). Within the exclusion zone, mass excavation of animals began directly after the accident. 20,000 farm and domesticated animals were slaughtered and buried. Difficulties led to the slaughter of an additional 95,500 cattle and 23,000 swine in the month after the accident (119). Condemnation of meat led to contaminated waste, so remediation shifted to feeding livestock non-contaminated forage. While cesium was reduced in cattle in a couple of months, there was not an abundant supply of uncontaminated forage (120). Mammals are the most sensitive to radiation effects, with mortality occurring at ten times the dose as teratogenicity (121). “Decontamination by removal of the top soil layer was not found to be appropriate for agricultural lands because of its high cost, destruction of soil fertility and severe ecological problems related to burial of contaminated soil” (121). Deep plowing to push the cesium under the root uptake depth, and potassium saturation of soils to compete with cesium for uptake were found to be cost-effective methods for large agricultural operations, however repeated applications are necessary to keep cesium levels low (124). When left untreated in 1995 and 1996, cesium levels increased more than 50% (125). Contamination contributes to sterility and production declines in some species of agricultural products. For winter wheat, growth, development and reproductive abnormalities exceeded 40% of the crops (197). In cities, the military engaged in the removal of trees, cleaning of streets, washing of structures, and removal of topsoil in yards and gardens as major decontamination efforts. Also, plowing the radionuclides below the depth that gardens could take them up contributed to reduced consumption of radioisotopes. Furthermore, areas were chemically sprayed to prevent inhalation of suspended radionuclides. Because of the high costs, implementation was less than desirable, and the effective reduction of external dose averaged 10-20% (116-117). Chernobyl has cost hundreds of billions to clean up (Case 933), and the costs of nuclear power are more than health and environmental impact. The numbers of the industry do not work.

There is no economic viability for nuclear power (Solkoski 55). In the 1960s, 4,000 reactors were planned to be online by the year 2020. The reality is, however, that operational problems such as fires, cracks, the Three Mile Island accident and Chernobyl, served to push back these plans (54). Even with a resurgence in the call for carbonless energy, there is no economic viability without government subsidies (55). The Obama Administration's proposed a $36 billion loan guarantee for new projects, production tax credits, limited liability to production companies for terrorist attacks, and minimum third-party insurance liabilities as subsidies, obscure the true costs of nuclear power (55-56). World Nuclear Association's vice chairman says "investing in new nuclear generating capacity would not make sense until both natural gas prices rise and stay above $8.00 dollars per 1,000 cubic feet *and* carbon prices or taxes rise and stay above $25 a ton" (56). The cost increases for construction of new nuclear power plants over the last decade have risen from approximately $1,000/Kw to $8,000/Kw. Inflation on operating costs and major repairs have many nuclear power plants operating at costs slightly below, or even above competitive electricity rates. This is demonstrated by numerous shutdowns, including five reactors in the U.S., and income deficits of $2billion for France's state run utility EDF, $3.8 billion deficit for Germany's RWE, and a combined debt load for France and Germany's two largest utilities of $173 billion (Schneider 9). It was assumed when most of the world's nuclear power plants were built, that they would have a 30 to 40 year life, and then be replaced with less expensive replacements. Political currents, however, have made construction costs skyrocket, making plant operators seek life extension permits (Solkoski 33-34). The U.S. has one of the oldest fleets in the world, and the NRC holds life-extension permits to the standards under which the plant was built, not the most current safety standards (36). France's fleet is held to the most modern standards of safety as dictated by the European stress-test for nuclear reactors, and has estimated that upgrading their fleet, which is newer than America's, in order to meet the latest standards would cost from $500 million - $5.5 billion per reactor (39) causing generation costs over the extended life of the plant to be $100-180/MWh (40). In the early 1990's a number of U.S. nuclear power plants were retired early because of the volatility of gas prices. They were so low that it cost lest to build and operate a gas fired plant than it cost to operate a nuclear power plant, especially in plants that needed repairs. At the same time in the UK, an attempt to privatize nuclear power plants failed as it was analyzed that the reactors would require a subsidy of $1.7 billion annually (Schneider 34). Though prices rebounded, and the privatization took place, 2013 gas prices and abundant wind generation caused Dominion Energy to close the Kewanee plant because prices for electricity were between $30-$50/MWh (35). With wind showing an annual increase of 25%, and solar showing an annual increase of 40% over the last decade, it is interesting that renewables have in a way redefined some of the base-load requirements of nuclear power, generating more electricity than the grid can take in at certain times, making nuclear power operate at losses, because it cannot be easily shut down. Another interesting fact, is that Germany has become a net exporter of electricity after their decision to shut down their nuclear capacity (11).

Why would the U.S. subsidize an aging fleet of dangerous reactors? A credible explanation is that the U.S. government has been unwilling to express the true economics of the nuclear industry because of its close history of creating a plutonium supply for the fulfillment of DOD needs. Another reason could be that the long standing history of subsidies for the industry make the continued practice seem logical, and political willingness leans towards investing in losers, rather than admitting mistakes. In countries where the government has more control than in the U.S., these practices are stronger (Solkoski 60). Nuclear power is not the cheap energy that has been promised, and it is too dangerous to promote proliferation of nuclear technology internationally because its fuel byproducts can be used for manufacture of nuclear explosive devices (53). Isolating nuclear energy from true market forces encourages their proliferation overseas, where countries can experiment with fuel byproducts towards deployment of their own nuclear weapons (62). The "IAEA acknowledges that it cannot reliably spot hidden facilities and annually loses track of many bombs' worth of material at declared plants" (Sokolski 63).

If the irremediable nature of partial core melts and spent nuclear fuel pool fires are not reason enough to abandon worldwide nuclear ambitions; if the economic unviability is not reason enough to abandon worldwide nuclear ambitions; then perhaps, preventing nation states from pursuing their own nuclear and thermonuclear arsenals is reason enough to abandon worldwide nuclear ambitions.

It is bad enough that that nature cannot be controlled. Conservative estimates predict the sea level will rise 6' by the year 2,100 because of climate change. The large amount of water needed to cool reactors and spent fuel rod pools necessitate building all nuclear power near large bodies of water (Kopyoto 29). Those that are close to the ocean pipe water from the ocean for coolant and risk a loss of coolant when debris from storms blocks the inlets (30). There is also the risk of severe weather floods knocking the plants' power offline. Power plants do not draw on their own power so that the systems are functional when the production capacity is offline. A *station blackout* (31) is planned for by keeping emergency generators on site, but as the case of Fukushima Daiichi demonstrates, generators inundated by the sea do not operate. This risk is particularly dire for power plants in Florida (30). With permanent storage at Yucca Mountain looking more and more like a political impossibility, indefinitely storing SNFs in cooling pools, places coastal plants at ever-present risk for a pool fire. Nature has proved it can be more devastating than the greatest feats of engineering, and can strike with more speed and ferocity than calculated or predicted. The human spirit, however, is even less predictable. The consequences of a high altitude nuclear explosion over Kansas would devastate America's electric grid, and thus, it could devastate the power necessary to operate the cooling systems in all reactor cores and cooling ponds in the contiguous U.S.

The U.S. military first became aware of the electromagnetic pulse (EMP) when it fired its Starfish nuclear shot in the atmosphere over (Maize 51) Johnston Island in the South Pacific (Kramer 25). The residual effects of the EMP were felt in Hawaii 900 miles to the east, where streetlights burned out, burglar alarms were set off, and microwave telecommunications devices failed (Maize 51-52). The military has spent hundreds of millions of dollars over the decades to harden their own electronic infrastructure against EMP, but 90% of their operations rely on the civilian electric grid. Congress convened a commission in 2001 which produced a report of grid vulnerability to EMP, and reconvened to issue another report in 2008 (52), however the Starfish shot was not the first time the earth saw a significant EMP. Mike Hapgood, advisor to the UK on space weather, and Lloyds of London on insurance risks associated with space weather, cites three major EMP incidents, one in 1859, shocked telegraph workers and "sparked fires in telegraph offices" (311). The source of the *Carrington event*, was a plasma ejection from the sun, a *coronal mass ejection (CME).* The CME weakened the condition of earth's electromagnetic field making it less resistant to subsequent bombardment by CMEs (Slade 22), and "caused U.S. telegraph lines to glow and spark and created brilliant auroras visible even in tropical locations" (Kramer 24). Another event in 1921 burned down a telegraph office in Karlstad, Sweden, and the most recent CME in 1989 caused power-grid failure in Quebec, Canada, causing $2 billion in economic losses due to 5 million people living without power for 9 hours. During the two day space-storm, a $12 million U.S. transformer was damaged beyond repair, and 1,200 spacecraft were lost track of (Hapgood 311). The effects of mass coronal ejections are known to industry. Quebec installed equipment to make its grid less susceptible to power fluctuations, and transpolar flights shift to a lower altitude when geomagnetic storms are predicted to decrease the risk of exposure to radiation, and to decrease the risk of overloading the air-craft's circuitry. GPS satellites, which timestamp global coordinates and trades at high-frequency investment desks are also at risk from CMEs (313). "If the May 1921 storm happened today, it would shut down all electric service to at least 130 million people in North America and burn 350 transformers in the U.S. beyond repair" (Slade 22). There are over 100,000 transformers on the grid of all sizes (Kennedy 11), that step up and step down power before and after long-distance transmission of electricity (Kramer 25), however it only takes crippling a couple of dozen of the largest ones to paralyze the grid (Kennedy 11). Protecting the grid would require shielding about 5,000 transformers (Kramer 25). Estimates to equip the U.S. grid with surge suppressors run from $1-2 billion and the value of hardening the grid is supported by U.S. daily GDP $41+ billion, and Canadian daily GDP of $5+ billion (Slade 23-24). After analyzing how critical the grid is, from hardwiring the communications industry, to heating homes in winter, to pumping water to cities, Slade discusses the cooling systems on 104 nuclear reactors in the U.S. He cites a recent report on the nuclear hazards from an EMP attack which concludes that only 33 reactors in the U.S. would not be vulnerable to complete grid failure. When the zirconium in the core fails to be cooled with water, then an uncontrollable fire will result. With a U.S. National Academy of Sciences estimate of $2 trillion damage to U.S. communications infrastructure, (Slade 23-24) and a timeline of 4-10 years to repair the grid (Kramer 25), the nation would hardly be able to rise to the test of 71 simultaneous nuclear melt-downs.

In order to understand the mechanics of an EMP from coronal mass ejection, it helps to begin with a weaponized EMP. An electromagnetic pulse from a high altitude nuclear explosion would cripple the U.S. electric grid. A blast 300 miles above the surface would affect a circle whose radius is nearly 3,000 miles, effectively blacking out the entire U.S., and a large part of Canada and Mexico (Maize 50). In an electromagnetic pulse, gamma radiation is produced by the explosion, "which interacts with the atmosphere to create an instantaneous intense electromagnetic energy field that is harmless to people as it radiates outward, but which can overload computer circuitry with effects similar to, but causing damage much more swiftly than, a lightning strike" (Wilson 6). There are three phases of energy surge from nuclear detonation that would create nearly continental electronic failure from a high altitude electromagnetic pulse. The first two are common to all nuclear detonations. The third, is dependent upon the size of the explosion (Wilson 7-8).

> The first energy component is the initial energy shockwave which lasts up to 1 microsecond, and is similar to extremely intense static electricity that can overload circuitry for every electronic device that is within line of sight of the burst. A secondary energy component then arrives, which has characteristics that are similar to a lightning strike. By itself, this second energy component might not be an issue for some critical infrastructure equipment, if anti-lightning protective measures are already in place. However the rise time of the first component is so rapid and intense that it can destroy many protective measures, allowing the second component to further disrupt the electronic equipment. The third energy component is a longer-lasting magnetohydrodynamic (MHD) signal, about 1 microsecond up to many seconds in

> duration. This late time pulse, or geomagnetic signal, causes an effect that is damaging primarily to long-lines electronic equipment. (Wilson 7-8)
>
> There are two components to this third energy pulse, which experts call "blast" and "heave". The "blast results from a distortion of the earth's magnetic field lines by the expanding, fully conductive fireball. The "heave" comes from the heating and ionization of a patch of atmosphere directly below the bomb that rises, and being conductive, also distorts earth's magnetic field. Both of these are considered MHD signal and are termed "slow" because they depend on the dynamics of cloud or fireball expansion. As the fireball expands a localized magnetic effect builds up on the ground throughout the length of long transmission lines and then quickly collapses, producing the MHD "late-time" power surge, which can overload equipment connected to the power grid and telecommunications infrastructure. This late-time effect can add to the initial HEMP effect, and systems connected to long-lines power and communications systems may be further disrupted by the combined effects. Smaller isolated systems do not collect so much of this third energy component, and are usually disrupted only by the first energy component of HEMP. (Wilson 7-8)

The devastation caused by a high altitude electromagnetic pulse would cripple the world with radioactivity. This could be a strong deterrent from a nation state employing such a tactic against the United States. Nature is not so thoughtful. While coronal mass ejections can be predicted by the development of a dark spot on the sun, with the size of the ejection being proportional to the size of the sun spot, space-storms of this type, are not solar flares. They are mass-coronal ejections. Photon plasma is ejected from the sun, taking several days to reach the earth. The CME acts like a solar flare, shelling the earth's magnetic field with ionized hydrogen, x-rays and gamma rays. When this energy hits the magnetic field it is driven to the earth's poles and descends into the atmosphere (Slade 22) driving extra current into the electric grid (Hapgood 311). When it reacts with oxygen and nitrogen, light is emitted as the Aurora Borealis (Slade 21). The largest of these storms, designated as *x-class,* have massive potential for destruction. The ground itself can become electrified. The terrifying aspect of an x-class coronal mass ejection is that the majority of its intensity is driven to the earth's poles, which means that the majority of earth's fleet of nuclear power plants, located in North America, Europe and Asia are at risk for simultaneous black-out. A world in black out will melt down.

Human hands cannot shield the earth form the deleterious mixture of nuclear power and natural cataclysms. No mathematician can calculate the unpredictable. The Manhattan project pushed the world to the detonation of the Trinity shot, and with that first nuclear explosion, the world was forever changed. From vaporized islands, to nuclear fall-out, to cancers, reproductive anomalies, and the uptake of radionuclides into the terrestrial and oceanic food-chain, 67 test shots over the Marshall Islands demonstrated the devastation and irremediable poison of weaponized fission: The promise of abundant, safe and inexpensive energy never materialized. The promise was an ideal driven by the need for the uranium radionuclide's plutonium fission product—and the promise proved unkeepable. Uranium is too radioactive; uranium's fission products are too radioactive for human hands, and the unconditional requirement of uninterrupted electrical supply to prevent a criticality event—too fickle. The decades have worn, one into another, with no viable remediation strategy for the waste. The reason—waste cannot be remediated. With a 24,000 year half-life for plutonium, safety calculations cannot be made with any certainty. American Democracy is slightly over 200 years old; Christianity, only 2,000; recorded history, only 5,000. 12,000 years ago, the glacial period of our current ice age ended.

24,000 years ago, *Homo neanderthalensis*, the Neanderthals, became extinct, leaving Homo sapiens as the only species of intelligent hominids the on earth.

With our intelligence we have littered the planet with massive spent nuclear fuel pools, emitting lethal radiation in over-crowded conditions, with circulation requirements of electricity, water-supply, and neutron absorbent chemicals. The failure of any of these conditions for any calculable or incalculable reason, will release all of a pool's cesium into the atmosphere, causing 188 square miles to be contaminated, 28,000 cancer deaths and $59 billion in damage. As of 2003, 49,000 *tons* of SNF was stored at 131 sites with an additional 2,000-2,400 metric *tons* produced annually. The NRC has issued permits, and the nuclear industry has amassed unfathomable waste on the premise that a deep geological storage facility would be available to remediate the waste. The current chances for a deep geological storage facility look grim. The NAS has required geologic stability for 1,000,000 years. It is impossible to calculate any certainty 1,000,000 years into the future. Humanity could not even predict the mechanical failures at Three Mile Island or Chernobyl, nor could it predict the size of the tsunami that triggered three criticality events at Fukushima Daiichi. These irremediable crises span just over 70 years of human history.

How can the continued production and maintenance of SNF in pools be anything but a precedent to an unprecedented human cataclysm? The Department of Energy's outreach website explains nuclear fission for power production, providing a timeline of the industry. The timeline ends, as does most of the world's reactor construction projects in the 1990s, with the removal of the FCMs from Three Mile Island. One would think the timeline would press into the current decade, however the timeline terminates with the question, "How can we minimize the risk? What do we do with the waste?" (The History of Nuclear Energy 12). Nearly fifteen years into the future, these questions are no closer to an answer. The reactors at Fukushima Daiichi are still emitting radioisotopes into the atmosphere, and their condition is unstable. TEPCO has estimated it could take forty years to recover all of the fuel material, and there are doubts as to whether the decontamination effort can withstand that much time (Schneider 72). A detailed analysis of Chernobyl has demonstrated that nuclear fall-out, whether from thermonuclear explosions, spent fuel pool fires, or reactor core criticality events are deleterious to the food-chain. Cesium and strontium are taken into the roots of plants and food crops, causing direct human and animal contamination from ingestion, causing cancer, teratogenicity, mutagenesis and death. Vegetation suffers mutagenesis, reproductive loss, and death. Radioactive fields and forest floors decimate invertebrate and rodent variability and number necessary to supply nature's food-chain and life cycles. The flesh and bones of freshwater and oceanic biota contribute significantly to the total radiation dose in the food-chain. Fresh water lakes, rivers and streams become radioactive. Potable aquafers directly underlying SNFs and FCMs are penetrated by downward migration of radioisotopes. Humans *must* eat to live. Humans *must* have water. No human can survive 5 Sv of exposure to ionizing radiation, many cannot survive exposure to 1 Sv.

Realizing the irremediable devastation caused by one thermonuclear warhead, by one Chernobyl, by one Fukushima Daiichi, it remains to be said that the earth can handle as many simultaneous loss of coolant failures as nature can create. Humanity cannot. It is not good enough to lead by relegating probable human wide extinction phenomena to an appeal to lack of evidence. Policy cannot indefinitely ignore responsibility by requiring further study. Nor can leadership idle into cataclysm by relying on the largest known natural phenomena of the last 200 years. Permitting construction and continued operation of malefic machinery, based on 200 years of cataclysmic experience is a protocol for calamity. Of coronal mass ejections, Hapgood warns, that we need to prepare for a once-in-1000-year event, not just simulate infrastructure safeties by the measure of what we have seen in the past. The same is true for all natural phenomena. The future of humanity is too precious to operate with such insouciance. The engineering is not good enough. It never will be. Nature is too unpredictable, and nuclear power is too dangerous.

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