USING UNREALISTIC PREMISES
GIVES PREDICTIONS THAT ARE NOT MERELY CONSERVATIVE
THEY ARE SIMPLY WRONG

On November 1, 1982, the US Nuclear Regulatory Commission published "worst case" accident studies for each of the 130 nuclear power plants then operating, a-building or planned. If everything went wrong, how bad could it be? Sandia Lab, as NRC's contractor, dutifully tabulated the answers: up to **610,000 "early injuries, 100,000 "early fatalities," 25-mile "fatal radius," 70-mile "injury radius" and hundreds of billions of 1980 dollars lost in a single plant casualty.** To top it off, NUREG-0340 states that other circumstances (such as the casualty spreading to the spent fuel pool) might increase the early fatalities by a factor of 3 or 4.

We can hardly blame the media for giving this report prominent coverage. And we shouldn't be surprised that opponents of nuclear power still quote these figures today—they've never been effectively repudiated. The fact that these consequences were said to be highly improbable is little comfort. And new claims of this sort are published repeatedly. As recently as 2003, an NRC contractor report of a postulated casualty to a spent fuel pool claimed there would be radiation-induced cancer deaths 500 miles away. If there is any validity to such estimates, we should have long ago stopped operating nuclear power plants. If they are not valid, the public deserves to be shown why, and we should stop using such unrealistic premises in policy, engineering and operations.

The purpose of this paper is to show that **such consequences are not realistic—i.e. not relevant to the real world.** They are not merely improbable; they are in fact realistically impossible. The difference is important. No valid prediction can result from calculations based on events that are physically impossible.

For this paper we examine a realistic but highly improbable situation: **simultaneous destruction of systems outside containment, rupturing containment penetrations, melting the reactor core, and producing ground-level unfiltered releases within about one hour.** This is the worst realistic casualty, and if we found the consequences were intolerable, we would have to examine all the steps that might lead there and show that we had made them sufficiently improbable. But we have found that even this extraordinary situation could **yield few if any fatalities,** whereas casualties actually experienced with natural gas systems, oil, coal, dams and other means of generating electricity have repeatedly caused hundreds, and even thousands, of deaths.

We know a great deal about what is physically possible with nuclear reactors. We have demonstrated that **nuclear fuel retains most of its fission products,** even when molten. We have measured the limited distribution of the fission products that do escape, especially in a water environment. And we have seen how **most of what escapes clumps and drops out** and does not stay in the air to be carried far away. We know these things with the same physical and chemical certainty that we know a power reactor cannot explode like a bomb.

And we know that **trivial amounts of radiation do not cause cancer or other harm,** and that computer models that multiply trivial individual radiation doses by millions of people to get thousands of cancer deaths are not just improbable. They are not conservative. They are simply wrong. Hundreds of millions of medical patients have received low to moderate doses that refute this premise, along with hundreds of millions of people that have lived in high natural background areas. We've been told that it is merely

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prudence and good practice to presume that things are worse than they are. "Better safe than sorry." But good policy does not result from a distorted picture of reality. And **we will describe briefly what a high price we pay for assuming otherwise.**

There is another type of flaw in the computer models that 'predict' massive deaths. **Some of the premises that are not impossible in an unrealistic hypothetical sense are in fact impossible in a realistic sense.** For example, the famous charge, "Only an EPA analyst would assume that smokers begin smoking at birth." A more relevant example here is the DOE requirement that calculations of fatalities from a spent-fuel shipping cask casualty assume the event takes place is a high-density city environment and that *no one moves until one year after the explosion* and that *no steps are taken during that year to reduce any contaminant.* Neither of these premises is physically impossible, but most people would agree they are not realistic—i.e. not relevant to the real world. We identify such premises and replace them with technically justifiable conservative but realistic premises. We also show that the leading individuals and organizations that created and maintain the present radiation protection policy have affirmed clearly and publicly the judgments we make, but then recommend the regulations be based otherwise, "to be prudent."

Finally, the most basic reason to change **current radiation protection policy,** and the regulations that prescribe it and derive from it, is that **it is self-contradictory.** It defines as dangerous, radiation levels that it elsewhere claims are harmless. It requires tearing down a building if it becomes contaminated to even a small fraction of the radiation level of the National Capitol or New York's Grand Central Station or the base of the Statue of Liberty, all of which are built of naturally radioactive granite. It has regulated man-made radiation levels down below those encountered in natural backgrounds, and has then tried to obliterate this contradiction by calling Nature "the silent killer." A responsible professional should not long abide such unscientific policy.

So in this paper, we consider the consequences of some very improbable casualties. But we do not presume that anything happens which tests and experiments refute or the laws of nature prohibit. And having made such an analysis, **we find that nuclear power plants and their fuel are not capable of creating a significant public health hazard under any realistic conditions of operation or hostile attack.** We then suggest some actions to bring radiation protection policy, and engineering and operations, into line with these realities. The first step should be for the sponsoring government agency to show and assert clearly that past reports, with "predictions" of **thousands of deaths** from nuclear casualties, are **based on unrealistic premises** and therefore are **not applicable to the real world.**

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* Not yet written

GETTING REAL

Nuclear technology has been repeatedly characterized in widely circulated public statements as posing public hazards so extensive and unprecedented as to outweigh any possible benefits. The record of several hundred plants operating reliably for decades without any public harm is countered with the fear that a casualty, of a type not yet considered, might some day release radioactivity causing thousands of deaths and injuries over great distances. Underlying this fear is a feeling that nuclear radiation is somehow in a class by itself, not fully controllable by normal means.

In this situation, informed professionals have an obligation to state the laws of nature and the physical properties of materials that limit the consequences that could result from any casualty to a nuclear power plant or its fuel. **Nuclear materials and processes are not mysterious or unpredictable;** they are governed by the same kinds of familiar physical laws that are the basis of all science and engineering.

Apocalyptic descriptions of nuclear casualties are based on speculation, sometimes aided by computer models, of what might happen if certain premises obtain. Computer models do not produce real-world data. They produce guesses in numerical disguise. The large numbers of deaths they "predict" rest on false premises. **If the premises are wrong, then the calculated deaths based on them will not occur.**

But we don't have to speculate about those premises. We have a great deal of credible scientific data on each of them. Engineering analysis and tests show that **nothing could be done to an American-type nuclear power plant or its fuel that could lead to a serious public health hazard.** (See Annex 1.)

Let us look at the scientific evidence for this conclusion:

1. Studying various possible accident scenarios or terrorist acts enables us to design systems to minimize the possibility of fuel meltdown. We cannot foresee every possibility. But **for casualty evaluation, we need only to assume the worst realistic consequence** of any such scenario, which is melting of much of the fuel and compromise of the containment structure. If we can deal with that situation, no other realistic situation could have worse public health consequences.
2. Nuclear fuel is a zirconium-clad very high-melting ceramic. **Even when molten, it does not readily release much of its fission products.** This is known from theory, from laboratory studies, and from large-scale tests over a period of decades.
3. Harmful quantities of hot **fission products do not stay suspended in respirable form for long.** So they cannot affect people far away. The particles rapidly clump, fall out, or plate onto cold structures or dissolve in on-site water. We have good confirmation of our test data on this from the Three Mile Island incident.
4. **Few, if any, credible scientists claim there is any evidence** to show that low-dose radiation is harmful. They concede as much in official documents. But they argue that we should assume so anyway, "just to be prudent." (Annex 2.)
5. Even advocates of extreme scenarios concede that radiation doses to an individual from a nuclear casualty would be very small. But they argue that exposing millions of individuals to small doses will result in thousands of deaths. This is scientifically indefensible. Groups don't get cancer, only individuals do. **If no individual gets a harmful dose, then no individual is harmed.** (Annex 3.)
6. But **promoting unwarranted fear** of radiation and wildly overstating hazards from minor spills or the potential of a "dirty bomb" **is not prudence. It is fear-mongering.** The public is scared away from life-saving nuclear medical procedures, from irradiated food, from non-polluting nuclear power plants, and many other benefits. (Annex 4.)

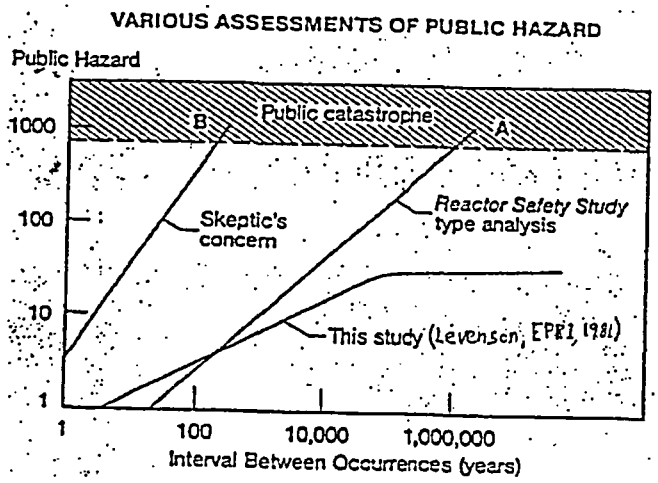
THE RELEASE AND DISPERSION OF RADIOACTIVITY FROM REACTOR FUEL

Experience with a dozen reactor and fuel casualties has confirmed theoretical studies showing that the release and dispersion of radioactivity from damaged or molten fuel is severely limited by the physical and chemical properties of the materials involved. After the Three Mile Island incident in 1979 made it widely known that the large amounts of radioactivity predicted by unrealistic computer models were not in fact released into the environment, a major multi-year program was carried out by the government and industry to determine the parameters of release and dispersion from damaged and molten reactor fuel.

The program confirmed in numeric detail how **radioactivity remains largely bound in the reactor fuel at very high temperatures**, and how the material that does escape into the air is largely absorbed in the surrounding water and steam, and how it is plated out onto the surrounding cooler structural surfaces even when containment is severely compromised. Moreover, it showed that radioactivity that begins to disperse in the classical meteorological plumes tends to clump and drop out, so that **very little remains in hazardous respirable form to travel miles from its source.**

This work was done at ORNL, ANL, INEL, Karlsruhe and other sites, sponsored by NRC, DOE, EPRI and others. An EPRI summary report of this work by Milton Levenson and Fred Rahn with 48 technical reference was published in *Nuclear Technology* (Vol 53, May 1981) with an editorial on page 97 and an article on pages 99-110. The paper was published in all the IAEA languages (10 or so). The author gave invited seminars in England, France, Japan, South Korea, China, Taiwan, and about 10 places in the US. **No one raised any serious challenge to the findings.**

The figure below shows the significance of this work. Casualties of increasing severity (in projected deaths) tend to be increasingly improbable. The straight line on the right extends to hundreds of deaths, but advocates argue that this is tolerably improbable (we don't assume airplanes will crash into the superbowl game). Critics reply that they are not convinced that such events are so improbable (left-hand straight line). The work of Levenson and others shows that Nature limits the consequences. (A 200-passenger airplane crashing into the ocean cannot kill more than 200 people, plus the crew, even under the most extreme accident scenario. **This changes the basic nature of the nuclear safety debate.** *[See Appendix 1, where this work will be updated and summarized, with references.]*



After 9/11, in light of apocalyptic prophesies of the consequences of postulated terrorist attacks on nuclear facilities, 19 members of the National Academy of Engineering knowledgeable in nuclear technology examined the subject anew.. They confirmed the earlier findings in the light of their own experience, and published their well-documented conclusions in a peer-reviewed Policy Forum in *Science*, 20 Sept 2002. In the 10 January 2003 issue they responded with further documentation to commentary received. (See Appendix 2.)

These papers transcended the need to justify various casualty scenarios by going directly to the worst realistic endpoint: they presumed the reactor core melted (for whatever reason) and presumed containment was significantly compromised. They concluded that even under these extreme premises, **the release and dispersion of radioactivity would not create a serious public hazard.** Mass evacuation would not be required, and still there would be few, if any, fatalities. They showed that the consequences of TMI, Chernobyl and other massive releases of radioactivity support this conclusion. (See Appendix 3 for authoritative summary of consequences of TMI and of Chernobyl. *This attachment, not yet written, will be based on TMI survey reports and UNSCEAR evaluation of Chernobyl consequences.*)

THE HEALTH EFFECTS OF LOW-DOSE RADIATION

The fact that low-dose radiation is harmless and often beneficial is not a new or minority opinion. It has been given multi-page coverage in *Fortune* (Jun 03), *Discover* (Dec 02), *American Spectator* (Jul/Aug 02), *Crisis* (Jun 02), *Wall St. Journal* (DATE?), and *Boston Globe* (Dec 12, 03). The proto-scientist Paracelsus said in 1540, "Nothing is poison but the dose makes it so." Within a few months after Roentgen's discovery of x-rays, articles began appearing in scientific journals on the use of x-rays to cure infection (See Appendix 1). It was recognized even then that the radiation was not strong enough to kill the bacteria directly, and that its effectiveness must result from stimulation of the immune system. This phenomenon—toxicity at high levels and stimulation of healing at low levels—is a nearly-universal biological process call *hormesis*. Calabrese and Baldwin report (*Nature* 421, 691, 2003) "thousands of studies demonstrating hormesis...we see it across the whole plant and animal kingdom... and at essentially every endpoint...hormesis is not an exception to the rule, it is the rule." Jocelyn Kaiser's four-page News Focus on hormesis (*Science* 302, 376, 2003) contained a full-page sidebar documenting the phenomenon's occurrence with ionizing radiation.

There is no lack of data on the effects of low-dose radiation. T.D. Luckey, Chairman Emeritus, Biochemistry, U. Missouri-Columbia, wrote two books, *Hormesis with Ionizing Radiation* (1980) and *Radiation Hormesis* (1991) with nearly 2000 references validating hormesis in plants, animals and humans. James Muckerheide, as Chair of the ANS B&M Division Committee on Health Effects of Low Dose Radiation, organized a series of sessions on Health Effects of Low-Dose Radiation at ANS annual meetings, 1994-2003 (See Appendix 2). The international public interest organization Radiation, Science, & Health has amassed and evaluated several thousand documents on the health effects of low-dose radiation (See http://cnts.wpi.edu/rsh/docs). Edward Calabrese and colleagues at the Northeast Regional Environmental Public Health Center, U Mass School of Public Health, publish a newsletter, *Biological Effects of Low-Level Exposures* and run an annual international conference on Non-Linear Dose-Response Relationships (See www.belleonline.com).

The nuclear medicine pioneer, **Rosalyn Yalow, Nobel Laureate** in Medicine, asserted:

> No reproducible evidence exists of harmful effects from increases in background radiation three to ten times the usual levels. There is no increase in leukemia or other cancers among American participants in nuclear testing, no increase in leukemia or thyroid cancer among medical patients receiving I-131 for diagnosis or treatment of hyperthyroidism, and no increase in lung cancer among non-smokers exposed to increased radon in the home.
>
> The association of radiation with the atomic bomb and with excessive regulatory and health physics ALARA practices has created a climate of fear about the dangers of radiation at any level. However there is no evidence that radiation exposures at the levels equivalent to medical usage are harmful.
>
> The unjustified excessive concern with radiation at any level, however, precludes beneficial uses of radiation and radioactivity in medicine, science and industry. (*Mayo Clinic Proc 69:436-440, 1994*)

Hugh F. Henry at Oak Ridge summarized the low dose data in the *Journal of the American Medical Association:*

> A significant and growing amount of experimental information indicates that the overall effects of chronic exposure (at low levels) are not harmful...The preponderance of data better supports the hypothesis that low chronic exposures result in an increased longevity... Increased vitality at low exposures to materials that are markedly toxic at high exposures is a well-recognized phenomenon. (*JAMA176, 27 May 1961)*

The "**Wingspread Conference**" August 1-3, 1997, concluded:

> In a surprise move, leading US and international scientific experts agreed in an historic accord that an increase in cancer has not been observed at radiation exposures below 10,000 millirem given to the whole body in a short time.

Prof. W.V. Mayneord, former member of UNSCEAR and ICRP, wrote:

> I have always felt that the argument, because at higher values of dose an observed effect is proportional to dose, at very low doses there is necessarily some effect of dose, however small, is nonsense (*Radiation and Health, p.140, 1964).*

In fact, **no credible scientific case has ever been made for the belief that low-dose radiation is harmful.** Long, formal reports by the National Council on Radiation Protection and Measurements (NCRP) discuss high-level radiation and other peripheral subjects in detail but they concede that science does not support the idea of deleterious health effects from low-dose irradiation.

For example, the report NCRP-121, states (p.45):

> Few experimental studies, and essentially *no human data*, can be said to prove, or *even provide direct support for the concept*...It is *conceptually possible, but with a vanishingly small probability,* that any of these effects *could* result from the passage of a single charged particle...It is a result of this type of reasoning that a linear non-threshold dose response relationship *cannot be excluded.* (emphasis added)

And NCRP-136 goes further, to concede (p. 6):

> It is important to note that the rates of cancer in most populations exposed to low-level radiation have not been found to be detectably increased, and that in most cases the rates have appeared to be decreased.

The French Academy of Medicine quotes and concurs with the above statement from NCRP-136, and states publicly 4 Dec 01:

> The hypothesis of the risks of cancer induced by low doses and dose-rates is founded on the extrapolation of data of highly-exposed human groups, applying the risk as being constantly proportional to the received dose without being limited by a threshold, the linear no-threshold (LNT) assumption. This hypothesis conflicts with itself and has many scientific objections (10); and it is contradicted by experimental data (11) and epidemiology. ..[the Academy] denounces utilization of the linear no-threshold (LNT) relation to estimate the effect of low doses...

Even some prominent environmentalists concur; e.g. Gaia proponent **Prof.James Lovelock, FRS,** in his forward to Bruno Comby's *Environmentalists for Nuclear Energy:*

> Life began nearly four billions years ago under conditions of radioactivity far more intense than those that trouble the minds of certain present-day environmentalists....We need to keep in mind the thought that these fierce energies flooded the very womb of life.

The two relevant professional societies, the **American Nuclear Society** and the **Health Physics Society,** have also supported this stance in carefully considered Position Statements:

> It is the position of the American Nuclear Society that there is insufficient scientific evidence to support the use of the Linear No Threshold Hypothesis in the projection of the health effects of low-level radiation. (*PS-41, June 2001*)

> In accordance with the current knowledge of radiation health risks, the Health Physics Society recommends against quantitative estimation of health risks below 5 rem in one year. (*Public Statement on Radiation Risk in Perspective, Jan 1996*)

Both societies agree in these statements that:

> Below 10 rem...risks of health effects are either too small to be observed or are non-existent.

The Situation is Clearly Ripe for Reform

Prof. Gunnar Walinder, former Chair, Swedish Radiobiology Society and UNSCEAR member, wrote in his book *Has Radiation Protection Become a Health Hazard?*:

> Not only do the current models of radiation carcinogenesis disagree with modern oncology, but most important they have contributed to a number of misconceptions about radiation risks. What concerns me most is whether the radiological doctrines have sometimes caused greater health and environmental problems that those we seek to avoid.

Walinder called this situation "the greatest scientific scandal of the century" and **Lauriston Taylor** called such practices "deeply immoral uses of our scientific heritage."

Philip Abelson, Editor Emeritus of *Science,* wrote:

> The current mode of extrapolating high-dose to low-dose effects is erroneous for both chemicals and radiation. Safe levels of exposure exist. The public has been needlessly frightened and deceived, and hundreds of billions of dollars wasted. A hard-headed, rapid examination of phenomena occurring at low exposures should have a high priority. (*Editorial in* Science *265, 9 Sept 1996.*)

Marvin Goldman, past HPS President, wrote:

> It is time to scientifically challenge the old tenet that cancer risk is always proportional to dose, no matter how small...It is time to update our thinking and policies. (*Science 271*, Mar 1996)

The NRC Advisory Committee on Nuclear Waste report to the Chairman, NRC:

Some studies in the U.S. as well as in China, Sweden, Poland and Canada have arrived at conclusions that do not support the LNT model. Other research concludes that it is likely that at least a threshold or perhaps beneficial risk decrements (hormesis) exists at lower doses. We conclude that a reexamination of the regulatory model is appropriate. (July 10, 1996)

Appendix 3 discusses Radiation Levels in Perspective. [*This appendix, not yet written, will briefly compare some of the radiation levels being regulated (e.g 4 mrem/year leakage from Yucca Mountain) with leaching into the water and the air from natural ground sources; radon in homes, radium in water, radiation from spent fuel shipping casks, build up of radioactivity in nuclear industry vs. natural decay of earth, etc. and include a graphic presentation of Zbigniew Jawowoski's data from UNSCEAR 2000.*]

The Harmful Fallacy of Collective Dose

Use of Cumulative Radiation Dose as a Measure of Good Practice or of Casualty Magnitude

Radiation protection policy uses as a prime measure of the severity of a casualty, or the efficacy of "good plant operation," the total collective radiation dose in person-rem, multiplying trivial individual radiation doses by large numbers of people to "predict" many induced cancer deaths. That process has been repeatedly condemned as scientifically indefensible. Yet current policy presumes that, in the absence of more data, this is the prudent course. That contention is wrong on both counts: there is no lack of applicable credible data and the data show persuasively that low-dose radiation is not harmful. And use of this unwarranted practice continues to have serious detrimental effects.

NCRP-121 specifically warns that collective dose should not be used to predict death or injury from low-dose radiation:

> "The summation of trivial average risks over very large populations or time periods...has produced a distorted image of risk, completely out of perspective with risks accepted every day, both voluntarily and involuntarily." (p.58)

And again:

> "...it is recommended that regulatory limits not be set in terms of collective dose...When the uncertainty in the number of individuals ...is large... collective dose should not be used as a surrogate for risk, even at relatively high levels of individual radiation dose." (p. 62)

Roger Clarke, Chairman of the **International Commission on Radiological Protection** wrote (1 Oct 98 at *http://hps.org/documents/controllable.pdf*) :

> "If the risk of harm to the health of the most exposed individual is trivial, then the total risk is trivial—irrespective of how many people are exposed".

And the **Health Physics Society**, in its March 1993 Position Statement, emphasized in bold-faced type:

> "We strongly recommend that dose limits be applied only (sic) to individual members of the public, not (sic) to the collective dose to population groups."

The French Academy of Medicine quoted and concurred with the above statement from NCRP-136, and stated in a press release 4 Dec 01:

> [the Academy] associates with many international institutions to denounce improper utilization of the concept of the collective dose to this end. These procedures are without any scientific validity, even if they appear be convenient to administrative ends.

Zbigniew Jaworowski, MD, PhD, the noted member and former chair of UNSCEAR, wrote in "Radiation Risk and Ethics" (*Physics Today*, Sept 1999, 24-29) that use of collective dose:

> "was introduced in the early 1960s...the concept is still widely used, although both the concept and the concern [about harmful hereditary effects] ought to have faded into oblivion by now...Individual doses cannot be additive over generations, simply because humans are mortal and the dose dies when an individual does. Similarly, individual doses cannot be added for individuals of the same generation because we do not contaminate one another with a dose that we have absorbed...
>
> If harm to the individual is trivial, then the total harm to members of his or her society over all past or future time must also be trivial—regardless of how many people are or will have been exposed...

THE PRICE WE PAY FOR EXCESSIVE RADIATION PROTECTION

Reports recommending the use of the LNT and ALARA down to zero radiation dose generally concede that science does not support this usage and admit that most populations exposed to low-dose radiation (LDR) show no deleterious effects and usually show beneficial effects. But they argue that the practice, even if not necessary, is justified as conservative, i.e. protective of the public health. However, the record is clear that the continued insistence that any amount of radiation is harmful has been severely damaging to the public welfare in many ways. Some of these are listed below.

Zbigniew Jaworowski, UNSCEAR member and former chair, opens his article "Radiation Risk and Ethics" (*Physics Today*, Sept 1999, pp.24-29) as follows:

> The psychosomatic disorders observed in the 15 million people in Belarus, Ukraine and Russia who were affected by the April 1986 Chernobyl accident are probably the accident's most important effect on public health. These disorders could not be attributed to the ionizing radiation, but were assumed to be linked to the popular belief that any amount of man-made radiation—even miniscule, close to zero doses—can cause harm, an assumption that gained wide currency when it was accepted in the 1150s, arbitrarily, as the basis for regulations on radiation and nuclear safety....
>
> In the regions of the former Soviet Union that were highly contamionated by the fallout from the Chernobyl accident, the increased radiation dose rate for the local inhabitants is far less than the dose rate in areas of high natural radiation. In those places, the entire man-made contribution to radiation dose amounts to a mere 0.2% of the natural component.

Not only were **depression, alcoholism, absenteeism and suicide** at record heights, but an estimated additional **100,000 induced abortions** were performed in the year following the accident by people downwind, presumably in unwarranted fear of bearing a "nuclear mutant." This is one direct result of characterizing harmless levels of radiation as deadly. The actual rate of birth defects did not increase.

The whole sorry, multi-billion-dollar saga of Yucca Mountain is caused by the quixotic quest for zero radiation in a naturally radioactive world. The trivial radiation levels we are committed to prevent taking place hundreds of thousands of years in the future are dwarfed by the leakage of natural radioactivity into the air and water by unstoppable natural processes that we've lived with safely since the dawn of time.

Terrorism gave new impetus to anti-nuclear activists. Their postulated potential of tens of thousands of deaths dictates unworkable mass evacuations, and the lack of a threshold of harmfulness means that evacuated lands might remain "uninhabitable" forever. This, in turn, makes continued operation of plants like Indian Point appear to present unacceptable public risk, thus accomplishing the terrorist goals without any terrorist action required. Similar arguments apply to potential terrorist attacks on nuclear fuel, in storage or being shipped. Even the ineffective "dirty bomb" has been so characterized. The resulting fear generated threatens to turn even an insignificant event into a life-threatening panic, and to keep us tied up trying futilely to forestall the imagined consequences.

The requirement to reduce even harmless levels of radiation even lower creates incentives to minimize collective dose at power plants, even at the cost of skimping on necessary inspection and maintenance in radiation zones (e.g. corrosion or leakage at reactor heads). It has burdened nuclear medicine facilities to the point where some hospitals no longer provide these life-saving procedures. It has scared people away from mammograms and other techniques involving radiation. Researchers are urged to use less effective colorimetric procedures to avoid the paperwork and constraints associated with radioisotopes. Life-saving smoke detectors and tritium exit signs are denounced as radiation hazards.

Ground water and soil, which EPA was set up to protect, are called "silent killers" when they contain trivial amounts of natural radium, uranium or radon. Tank-piercing depleted uranium ordnance, less radioactive than the natural element, is decried as a health hazard. Irradiated food, which could prevent thousands of food poisoning deaths, is too scary for many.

[This annex has yet to be written. It will briefly describe the very large number of applications of nuclear technology and radiation. It will make clear that the applications other than power plants exceed ten-fold or more the more visible power plant work. These are all being restrained by the current excessive radiation protection requirements.]

Unwarranted fear of radiation has been consistently used to block public acceptance of nuclear technologies and increases their cost. As a result, coal-fired power plants are built instead of nuclear. This exacerbates global warming, respiratory problems, acid rain, mercury contamination, mountain-tops pushed into valleys, black-lung syndrome, mine casualties, etc.

If natural gas is used instead of coal, this drives gas prices up, depletes this valuable resource, causes repeated fires and explosions, and still contributes to global warming.

Use of nuclear power, via electricity or hydrogen, for transportation would decrease or eliminate our dangerous dependence on foreign oil.

Avoidance of nuclear power requires us to buy industrial and medical isotopes abroad. Since many of the most useful isotopes are short-lived, this constrains our options for diagnosis, treatment, research and industrial uses.

Thus, overstating the consequences of a hypothetical nuclear casualty is not harmless conservatism but has serious harmful effects without providing any public health benefits.

{And many more examples could be given.]