Ted Rockwell

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In 1954, he became Technical Director, responsible to Admiral Rickover for helping to develop criteria, procedures and facilities for safe operation of nuclear-powered naval vessels and the world's first commercial central station nuclear power plant. In 1960 he was awarded an honorary ScD degree for his contributions toward the development of atomic power. In 1964 he left with two colleagues to set up the respected engineering firm MPR Associates, Inc.

He was the only non-medical member of the Advisory Group on the National Artificial Heart Program (1966) and a member of the Advisory Council, Princeton University Department of Chemical Engineering (1966-72). From 1965 to 1968, he was a Research Associate with the Johns Hopkins School of Advanced International Studies (in connection with nuclear proliferation research). He was Chairman of the Atomic Industrial Forum's Reactor Safety Task Force (1966-72) and Consultant to the Joint Congressional Committee on Atomic Energy (1967).

He is a Fellow of the American Nuclear Society and recipient of its first Lifetime Contribution Award, now known as the Rockwell Award. He has Distinguished Service Medals from both the Navy and the U.S. Atomic Energy Commission, and is a member of the National Academy of Engineering. He was Technical Director of Admiral Hyman Rickover's program to build the nuclear Navy and the first commercial atomic power station. He has several patents, including one listed in "a selection of [27] landmark US atomic energy patents from all the patents issued to date." His works have been published in German, Dutch, Russian, Chinese, Japanese and Korean. He is the first Sigma Xi Distinguished Lecturer sponsored by the National Academy of Engineering.

He has written numerous books and technical papers, including the widely-used text, Reactor Shielding Design Manual; The Rickover Effect: How One Man Made a Difference; and Creating the New World: Stories & Images from the Dawn of the Atomic Age. He co-authored The Shippingport Pressurized Water Reactor, and Arms Control Agreements: Designs for Verification.

THE REALISM PROJECT
RECONCILING NUCLEAR POWER AND RADIATION POLICIES WITH THE REAL WORLD

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Background

Let's get real. It is crazy to fear that one's health and life are threatened by entities known to be harmless, whether those entities are goblins under the bed or trivial levels of radiation from non-existent radiological catastrophes. The nuclear community is in that paranoid state, and no advice from public relations experts can cure it.

Some people claim that overstating risk is a prudent thing to do, but in practice it may do harm.

Let us recall what we have said and done to create this situation. Then let us look at what the real world tells us about those risks. And then we will consider what might be done to return to reason.

The Current Nuclear Worldview

I will discuss the American program; other nations have followed more or less similar paths. As first priority, we declared that no plants would be built unless the Government indemnified the companies involved, and assumed responsibility for the "highly radioactive waste" which developed, to be deposited in a multi-billion dollar government facility of unprecedented cost and complexity which, decades later, is still not within sight of completion. In fact, neither of these provisions has cost the Government a cent, but we don't get any credit for that—they are generally perceived as huge subsidies from the taxpayers.

The rationale given for these requirements has created a heavy burden for this technology. We were once told that the potential for a nuclear accident whose catastrophic consequences would exceed the resources of the world's insurance industry was sufficiently probable that no corporation could be expected to bear the risk. One might excuse such excessive caution in the earliest days of nuclear power, but 40 years later, after 12,000 reactor-years of reliable operating experience with more than 440 commercial power reactors, plus several hundred naval propulsion systems and many research reactors, we should not find that argument persuasive.

Similarly, it was argued that because radioactive materials have the unique characteristic of becoming continuously *less toxic* day by day, they pose an unprecedented hazard compared with mercury, selenium, cadmium, lead, and other common materials whose toxicity remains undiminished forever. The nuclear community based its future on this notion, and spent billions of dollars providing extreme safety features and theoretical analyses of incredible scenarios of every conceivable failure of materials, machines and operators. It carried out research on basic geology, biological effects of trivial levels of radiation, and came up with The China Syndrome, The Guillotine Break, The Hydrogen Explosion and other inventions.

When questioned about safety, we seldom challenge the nature of the casualties envisioned – the unrealistic "hypotheses" and invalid assumptions. Instead, we brag about the extraordinary measures we have taken to prevent them: triple barriers of exotic materials for our "garbage cans"; specially trained paramilitary forces guarding these commercial facilities; and Yucca Mountain, one of the most technologically sophisticated projects of the modern world. This doesn't reassure people. It only causes them to think, "Wow! This stuff must be really dangerous!" They reasonably expect that advocates will state their case in the best truthful light. Since people know that no protection system is perfect, they are left to fear that the uncontested catastrophe is held back only by superhuman efforts, subject to human failures, of which there have been many.

If someone described to you the terrible things that a hungry tiger can do to an unprotected village, and asked what you are doing to protect the people of Connecticut from this great danger, you wouldn't start installing alarms and electrified fences. You'd say that tigers are not a realistic risk to Connecticut people. If there is no hazard, then there is no risk. We have solid scientific evidence that nuclear plants and their fuel do not pose any greater risk to the population of America than do tigers. It's an historical fact that some people have been seriously injured by tigers, but none by nuclear power plants.

Have we just been lucky so far? Are we due, any day now, for the catastrophe that so many people have predicted? The answer is NO. Accidents and equipment failures are possible, of course (though they have been remarkably few), but it is physically impossible for any realistically conceivable "catastrophic failure" in a western-design light water commercial reactor or its fuel to cause more than a few, if any, deaths. The disinclination of the nuclear community to state this simple fact and to act accordingly has led to a state of fear that sullies nuclear power today.

Not only are there generic public words and actions, but all of the rules, regulations and procedures were built around these unrealistic hypotheses and invalid assumptions. The maximum permissible radiation from water "contaminated" by Yucca Mountain 10,000 years from now was set at 4 millirem (0.04 milliSieverts) *per year!* In a natural radiation background that varies from 20 times that, to more than 20,000 times that level. (Now even this requirement has been judged to be insufficiently conservative. The court can be blamed for such an egregious error, but the court is simply reflecting the flawed statements in the authorizing legislation and the National Academy of Sciences assessment which has simply followed the misleading dogma accepted by our nuclear institutions.) Radiation exposure from a postulated attack on a spent fuel cask is calculated by the U.S. DOE to include the assumption that no one moves or takes remedial action ***for one year*** after the attack. No one makes us do these silly things. We do it to ourselves. Surely we can, and must, figure out how to undo it.

Let me stress that these problems were created by the industry and its advocates—not its declared adversaries. But anti-nuclear activists are quick to use this ammunition, making it difficult for nuclear advocates to argue that the plants are safe. For example, Frank von Hippel and others at Princeton wrote a paper and circulated it around Congress, claiming that an attack on a spent fuel pool could release enough radioactivity to kill tens of thousands of people. This was then applied to the Indian Point reactor, where the "predicted" death toll was 518,000. Congress asked the U.S. National Research Council to evaluate this claim. The U.S. Nuclear Regulatory Commission testified that the claim was invalid because it was based on unrealistic premises. The authors replied that they had invented no new premises, but had used the same analyses as the Commission itself had used in the past. Both statements were demonstrably true. The Research Council's report has been classified, so we don't know how the issue was resolved, but it shows the problem the nuclear community has created for itself. Publicly, it remains an unanswered challenge to the adequacy of our safety systems. When asked how one could conclude these plants are safe in view of this situation, the industry's spokesman replied that the scenario that led to the postulated catastrophe was "highly improbable"--that is, we don't expect that sort of thing to happen very often. That is NOT a reassuring response.

Report from the Real World

For several decades, nuclear scientists and engineers have been finding that the real world does not match their computer simulations. (Note that computer simulations do not produce data. They are merely guesses, dressed in numerical form. Data come from measuring physical characteristics of materials and processes in the real world.) Scientists heated up some spent fuel to the melting point and found that most of the fission products stayed bound in the refractory fuel ceramic and were not released. Tests involving large-scale release of fission products showed that the radioactivity that is released tends to quickly settle to the ground (which never happens in diffusion models that don't incorporate gravity). It does not stay in respirable form, but tends to clump. It also dissolves in the ever-present water and steam, and plates out on any colder metal structure. Because radiation detectors can sense the presence of single atoms, they are able to measure harmless traces of radioactivity at great distances from the source. But they found that medically significant amounts do not travel far.

In addition, they checked analytical premises used in calculating radiological risk and found:

1. The use of unrealistically pessimistic convective flow assumptions in spent fuel pools led to unrealistic overheating of fuel elements, and thus to unwarranted conclusions as to zirconium cladding ignition.

2. Assumptions on personnel action are not merely conservative, they are ridiculous: e.g., radiation exposure calculations assume no cleanup or other remedial action for months.

3. It is assumed that the radioactivity remains highly concentrated in a narrow plume, then assumed that this concentrated plume exposes a large, dispersed population—a physical impossibility.

Replacing some of the most egregious of these premises with more realistic ones leads to the conclusion that realistic premises and physical and chemical laws alone would preclude any realistic series of events from leading to a serious public health hazard, i.e., producing radiation doses that are significant to human health and safety.

These conclusions were confirmed by analyzing the releases from deliberate destruction of some small experimental reactors for that purpose, and from large-scale reactor accidents, including Windscale, SL-1, Chalk River, and of course Three Mile Island. They found that actual releases were orders of magnitude lower than those "predicted" by the computer models.

This work was reported in a paper entitled "Realistic Estimates of the Consequences of Nuclear Accidents" (Levenson and Rahn, 1981), in a special issue of *Nuclear Technology* that reviewed the available scientific evidence and experimental results. 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. **There were no serious challenges to these findings.**

Another special issue of *Nuclear Technology,* in 1988, updated the experimental evidence, including the information gleaned from the TMI containment during defueling and cleanup (e.g. C.V. McIsaac, *Nuclear Technology*, Vol. 87, pp. 224-233). Since that time, numerous experiments have examined the timing, magnitude and controlling processes for fission product releases from the fuel, the primary system and containment.

After 9/11/01, in light of apocalyptic public 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 the three comments received. Then on 30 March 2005, an unprecedented unanimous joint report of the French Academies of Science and of Medicine repudiated the LNT premise and the arguments supporting it (http://cnts.wpi.edu/rsh/docs/FrenchAcads-EN-final.pdf).

Nearly all serious nuclear critics now agree that the individual radiation doses from even the worst realistic casualty are expected to be small. Yet, those critics argue that multiplying those doses by the large number of people exposed yields a large "collective dose" that constitutes a public health hazard. But this procedure has been roundly denounced by virtually all the advisory, regulatory and professional organizations in the field—even those that recommend use of LNT-to-zero for regulatory purposes. To quote Sir Roger Clarke, then Chair of the ICRP, (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".

An enormous body of scientific data on radiation effects demonstrates that radiation, like nearly every other assault on living organisms, can be deadly at high levels, but harmless and usually beneficial at low levels. This is true for chemicals, "nutrients," bacteria, sunshine, exercise, whiskey, wine, and virtually everything else. But advisory and regulatory bodies keep insisting that it is prudent to assume that radiation is linearly harmful all the way to zero, although their reports concede that there is no evidence that low-dose radiation is harmful, and that "the rates of cancer in most populations exposed to low-level radiation have not been found to be detectably increased, and in most cases the rates have appeared to be decreased." (NCRP-136, p. 6).

The result of all this is that the case has been well made and documented that the ultimate realistic casualty to a nuclear reactor or its fuel would not only be highly unlikely, but if it happened, it would be highly unlikely to cause any immediate radiation deaths in the public. This must be compared to the accidents that regularly occur in connection with coal, oil, gas, and many other large industrial operations and other conditions in a modern society that we accept without shutting down or requiring billions of dollars expended to assure that no one is ever harmed.

Yet everything associated with nuclear plant construction, design, operation, and the very choice between nuclear power and its competitors, is based on the unwarranted premise that it involves risk to the public health of unprecedented magnitude. The extent and magnitude of the harm this causes is extraordinary. For example:

Overstating Risk is NOT "Prudent;" it is Simply Wrong and Does Harm

1. It converts minor emergency situations (e.g. dirty bomb) into a life-threatening panic.
2. Minimizing collective dose restricts needed plant safety inspection and maintenance.
3. Mass evacuation diverts attention from those few who might actually need protection.
4. Improbable and low-risk scenarios divert attention from most-probable conditions.
5. Constraining nuclear power makes global warming more difficult to combat.
6. It has made a tractable waste problem into a major, expensive technological challenge.
7. Without nuclear power, high energy prices result, and reducing energy use becomes an urgent prime requirement, damaging U.S. and world economies.
8. By overstating radiation risks, more dangerous, less economic alternatives are used:

- coal-fired plants cause respiratory and environmental harm and kill miners;
- patients refuse life-saving nuclear medical procedures;
- research is constrained by limited availability of radioisotopes;
- food poisoning kills people who do not get irradiated food;
- enormous expenditures are wasted that could have been used beneficially.

How long will we allow real people, with names and families, to suffer from the non-use of radiation where it is needed, in order to protect hypothetical people from casualties that never happen?

Enter: The Reality Project

The Reality Project was established within the ANS by Larry Foulke, when he was President. Its purpose is to work toward reconciling the differences between the physical realities just discussed and the procedures, policies and practices of radiation protection as they affect the design, construction and operation of nuclear power plants and their associated operations and facilities. The Project was given wide circulation within ANS and was met with general agreement. It is and was often misperceived as a public relations project, but that is not its intent and it could not succeed as such.

What is needed is for the leaders of the nuclear community, starting with the ANS, and particularly involving the top nuclear officials in the companies which will build and operate nuclear plants, to conclude that this is an important and urgent matter, requiring action on their part. To arrive at that conclusion, they will have to assign a senior person in their organization, a trusted person with the requisite technical understanding, to become fully conversant with the issues and the relevant background, and then to acquaint management with this information so that the company can decide what action it should take in its own affairs, and what matters it should push with NEI, DOE, NRC, EPA, ANS, HPS, WNA, the various code committees, and the Congress. In addition to review of the underlying assumptions and dogmas of the nuclear safety regimes that are in place, the first tasks should be to identify the documents, policies, regulations and practices that are affected, the impact of changes to design and operation, and the benefits of changes that are realistic and consistent with the physical data. This action will develop an awareness of the enormous costs that are now (invisibly) embedded in existing policies and regulations. As these various examples are discovered, a strategy must be developed as to how best to go about revising them.

Once the nuclear community is in reasonable accord on these issues, we can start working on the revision process. This would include discrepancies of the following sort:

- Analytical procedure requirements set by DOE or NRC that contain premises inconsistent with measured properties of materials or processes;
- Extreme and unrealistic scenario presumptions as to personnel action or inaction;
- Requirements to use collective dose to "predict" health effects or to judge the quality of a radiation protection program;
- Emergency procedures such as massive evacuation of people where realistic analysis shows this would be more harmful than helpful;
- Design or operating requirements for extreme radiation reduction that have no public health benefits, for example, involving radiation levels commensurate with variations in natural background radiation and with medical radiation exposures that cause no harm.

This would form the basis of a program to revise selected significant existing studies and reports.

It would be used to initiate revisions to applicable standards and policies, and to undertake rulemakings. It would be the basis for decisions by appropriate organizations to develop Position Papers, public information materials, educational materials, including new textbooks on nuclear science and engineering, radiation biology and health effects, radiation protection and radioactive waste management.

After all this has become clear and under way, a public information program to explain it to the public will be both necessary and appropriate. There will presumably be objections from critics that we are trying to "weaken radiation protection." At that time, if will be refreshing and empowering to have a story that is consistent with rational actions and the laws of nature. **It's time to get real.**

Nuclear energy: *Not* a Faustian bargain, but a near-perfect providential gift

BY THEODORE ROCKWELL

A nuclear veteran encourages those in the industry to get serious and put nuclear energy in the positive light it deserves.

THE 33RD ANNUAL World Nuclear Association (WNA) Symposium, held September 3–5, 2008, in London, attracted a record-breaking 800 participants to the gleaming, modern Queen Elizabeth II Conference Center, with its huge picture windows facing its neighbor, the venerable Westminster Abbey.

On September 4, WNA Chairman Andrew White, president and chief executive officer of GE-Hitachi Nuclear Energy, and WNA Director General John Ritch, former ambassador to the International Atomic Energy Agency, bestowed awards on three people chosen to represent the educators, the innovators, and the pioneers of the international nuclear enterprise. The awardees were, respectively, Alan Waltar, of Pacific Northwest National Laboratory and former head of the Nuclear Engineering Department at Texas A&M University; Jacques Bouchard, of the Commissariat à l'Énergie Atomique, and head of the Generation IV International Forum; and me, Theodore Rockwell, of Radiation, Science & Health and MPR Associates. (See page 50, this issue.)

Mingling with the crowd of international nuclear professionals for three days gave me a chance to escape from the U.S.-centered bubble for a moment and get a wider view of the nuclear world. In the WNA and the associated World Nuclear University, John Ritch has built up two new substantive organizations and gotten important people involved, from inside and outside the corporate world. This creates arenas in which basic nuclear issues can be addressed, transcending the national institutions and technical "islands" in which many of these issues are bogged down. We have not yet taken full advantage of this situation.

Other countries now seem to be more urgently intent than the United States on building nuclear plants, which is good, especially when they speak with greater governmental authority. But they seem even more obsessed than the United States is with making nuclear "safer and safer." What's wrong with that? Can a plant be "too safe"? How do we know what's "safe enough"?

First, let me note that in the real world, no member of the public has ever been killed or seriously injured—or even exposed to a serious health threat—by a nuclear power plant or its fuel or waste.[1] So, what excuse is there for deciding that all sorts of extreme safety provisions must be applied to nuclear facilities that would never be considered for non-nuclear facilities, even those where lethal accidents have occurred and continue to occur?

That important policy decision is seldom acknowledged, and yet it is crucial to the future of nuclear. What became apparent from discussions in London is that the nuclear community seems bent on making its product ever more esoteric—kind of a fantasyland, where 200 years of mundane engineering experience and judgment seem out of place. In the 1970s, New Age gurus from Baba Ram Dass to Margaret Mead told young people that their elders had not experienced the coming age, did not understand it, and therefore could not advise them on how to live in it. Experience in the dying age was declared inapplicable to the New World.

At the same time, nuclear gurus were applying the same philosophy to the Nuclear Age. Alvin Weinberg, longtime senior spokesman from Oak Ridge, did not invent this idea, but in 1971 he approvingly characterized nuclear energy as a "Faustian bargain"—a miraculous gift, but with the devil to pay if we slip up.[2] I was in Oak Ridge not long before he died, and when he heard I was there, he asked me to come to his house. He urged me to carry that message onward. "You people in Admiral Rickover's group understand the absolute necessity for unprecedented excellence. To keep nuclear technology from slipping inexorably into mediocrity, we need to keep the Faustian threat alive." I told him I agreed fully with the

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[1] The Chernobyl incident in 1986 is only peripherally relevant to this question. It did not kill or seriously injure anyone *outside the plant*, with the possible exception of the 10 or 12 children with thyroid nodules, whose deaths could have been prevented. But more relevant is the fact that the type of accident that occurred there is not physically possible in the types of reactors being considered for the large-scale construction of new nuclear plants.

[2] Discussed in detail in Weinberg, Alvin M., *The First Nuclear Era: The Life and Times of a Technological Fixer*, published by Springer, 1994. Weinberg first discussed this analogy with his laboratory people in 1970, then "went public" in 1971, a date that he usually used in referencing it.

importance of maintaining the highest quality control, but that is justified on its merits and does not need support from a demonstrably false threat of a public catastrophe. Despite my respect for Weinberg's technical wisdom and leadership in the development of reactor technology, I firmly believe that applying the Faustian myth to nuclear technology has done great harm to the field.

I am not talking about public communication skills. If we learn to portray nuclear energy as acceptably risk free, but make no changes in our current policies and practices, we will surely be seen as hypocritical—advocating policies we don't follow, and thus presumably don't believe. Many nuclear advocates apparently believe that a severe nuclear accident could cause unprecedented public health problems, and they justify promoting nuclear power by convincing themselves that they have made such a casualty tolerably improbable. Unfortunately, when we say we have reduced the probability of an unspeakably devastating accident from 10_4 to 10_6, that doesn't satisfy most people. They know that improbable things happen, and they want to know how bad it could be. This is a legitimate request, but we brush it off because we've been told that it scares people to talk about casualty consequences.

The fact is, just since the Three Mile Island (TMI) incident in 1979, we have spent a billion dollars to build the case that a catastrophic nuclear accident is not merely improbable, but is physically impossible. We are protected from catastrophic consequences not by clever safety gadgets and procedures, but by the inescapable laws of nature and the known properties of the materials and processes involved.

Realistic consequences

In 1980–1981, after TMI, the Electric Power Research Institute (EPRI) reported on its studies that demonstrated that after the worst realistic accident, few if any public fatalities would occur. Each of the many steps that would have to occur to cause serious public consequences had previously been too pessimistically estimated: cooling the fuel, the release of fission products from overheated fuel, and the many processes that remove fission products from the containment atmosphere. The tornado of steam, water droplets, and air dissolve fission products or plate them out on the colder containment structure. Meteorological factors and population density immediately outside the plant have also been unrealistically selected. When each of these and other relevant factors are overestimated, the final product becomes exaggerated by many orders of magnitude. A "conservative" estimate becomes simply wrong. A tolerable situation is described as a catastrophe.

The heavily documented EPRI reports of 1981 were published in all the IAEA languages and presented all over the world by leading nuclear experts such as Chauncey Starr, Milton Levenson, Ian Wall, and Frank Rahn. The conclusions were never repudiated, or even seriously challenged. They were simply ignored, as practices (such as mass evacuation drills and the distribution of billions of iodine pills) continued unabated.

In 2002, after the attack on the World Trade Center's twin towers, I gathered 18 other members of the National Academy of Engineering who were nuclear leaders, and we published an updated report, including analyses of the Windscale, TMI, and Chernobyl data and the large-scale tests of molten fuel at Karlsruhe (*Science*, Sept. 20, 2002, p. 1997, and Jan. 10, 2003, p. 201). This report confirmed, and additionally documented, the conclusion of the EPRI reports that "few if any members of the public" would die from the worst realistic accident.

Fear is a powerful motivator, and by claiming that nuclear power technology is uniquely dangerous to the public safety, we create a great flow of money for research, prevention, and remediation. But we seriously distort policymaking and the specifics of how we design and operate nuclear facilities. What is the basis for believing that this technology is so dangerous? It results from an old weakness of scientists (which, incidentally, helps justify the existence of engineers). Scientists have learned to make "conservative" estimates of risk by multiplying together the various factors involved and making sure that each element of the calculation is a little on the safe side. The great physicist Werner Heisenberg did this when he calculated in his head the critical mass of an atomic bomb. He got such a large number that he concluded that the construction of an A-bomb was a practical impossibility, and therefore the Nazis never initiated a serious program to build one. This

We are protected from catastrophic consequences not by clever safety gadgets and procedures, but by the inescapable laws of nature and the known properties of the materials and processes involved.

common type of error does not give an answer that is conservative; it is simply wrong.

Edward Teller, also a brilliant physicist, made a similar error. In 1960, he made that kind of "conservative" calculation in his head, and concluded that an accident during the refueling of a submarine could create a lethal radiation zone extending several miles. He wrote an article for *Parade* magazine describing the situation and recommending that refueling be done at sea. The proposed article came to the Atomic Energy Commission (AEC) and was referred to Admiral Rickover for security clearance. Since refueling at sea would be difficult and even dangerous, Rickover asked me if Teller's calculation was realistic. It's not a difficult calculation, and I assured him that the radiological consequences of such an accident would be tolerable. He invited Teller to meet on a submarine with all 13 members of the AEC's Reactor Safeguards Committee, and Teller made his presentation to them. They saw no flaw in it, and Rickover threw me into the lion's den. I presented my calculation, which showed a tolerable one-time emergency radiation dose (25 rad) at 100 meters. Teller said, "I didn't see where you went wrong, but you used engineering units. Please do it again in physics units." Straining a bit, I got through it, reaching the same answer. So Teller said, "Well, let me show you what I calculate, and tell me if you see any error."

He started down the same path I had used, calculating the radiation dose from a cloud of radioactivity. "But it's not a whole sphere, Edward," I objected. "The bottom half of the sphere is underground—no radioactivity. We have to divide your radiation dose by two."

"We're just trying to get a conservative answer," he protested. But I pressed on. There was another factor, about the same magnitude, and then another. These finally brought his number down very close to mine. "Do you all agree with this?" he asked the committee members. They did, and after further discussion he did, too, and he withdrew his article and his recommendation. His "conservative" calculation was drastically wrong. The world might be very different today if Heisenberg had discussed his calculation with an engineer.

More safety features, more safety?

The Europeans at the WNA Symposium were talking proudly of how their latest reactor design, with its core catcher and superior leak-tight containment, is safer than the current plants' designs. This is wrong in concept. Adding provisions to solve a nonproblem merely provides additional potential paths to failure. One of the few serious failures in a full-scale commercial American nuclear power plant was caused by a core catcher—the only plant to have one. It vibrated, broke loose, and partially blocked cooling flow to the core, leading to some fuel meltdown. Although no radioactivity was released outside plant boundaries, the incident led to a book, *The Day We Almost Lost Detroit,* much cited by nuclear critics. (One of the problems in designing a core catcher is keeping the core molten until it can be moved to the basement for handling. Doesn't that tell you something?) Instead of an unneeded add-on, why aren't we promoting features that provide improved performance, such as an annular fuel design?

Safety is not an independent variable. We cannot add 50 percent more safety at will, and it's deceitful to imply otherwise. Safety results from the interaction among a variety of factors such as materials, design, selection and training of personnel, attitude of management, safety culture, and regulators. Probabilistic risk analysis is an important tool. Used properly, it can help reduce the probability of a serious incident, and that's important. But nothing can replace the knowledge that when all else fails, the consequences of the worst realistic incident are tolerable. The nuclear industry has demonstrated decades of nearly flawless performance and safety worldwide. Nuclear plants do not need more safety features. They need to be simpler and less expensive to build and to operate so that we can maintain that excellent record. We need to build thousands of them, as quickly as possible.

We say that nuclear plants should take their place as equals alongside windmills, switchgrass, and chicken manure. That nuclear mustn't take too much of the market. That a balanced portfolio is the goal. Articles on powering the 21st century nearly always picture windmills. That's nonsense! If your first car is a Jaguar, should your second one be an oxcart?

Nuclear energy is a near-perfect energy source. Its alleged problems are distortions of advantages. (For example, is the longevity of nuclear waste really a problem compared with non-nuclear poisons whose half-lives are infinite? Compared with the toxic waste from making solar collectors that never goes away?)

Probabilistic risk analysis is an important tool. But nothing can replace the knowledge that when all else fails, the consequences of the worst realistic incident are tolerable.

The unique feature of nuclear energy that makes it orders of magnitude superior to all of its competitors is that chemical processes such as combustion require *tens of millions of times more material* as fuel (and logically produce tens of millions of times more waste) to generate a given amount of electricity than does nuclear fission. This derives from the simple fact that a chemical reaction releases a few electron volts of energy, whereas a nuclear fission releases 200 *million* electron volts. This basic fact of nature cannot be changed by more research. And, of course, the

various types of solar power are even more dilute. Even windmills and solar panels require more steel and concrete per kilowatt-hour than nuclear plants. So when you picture a "clean-coal plant" trying to permanently dispose of millions of tons of toxic metals, radioactivity, and gaseous carbon dioxide, ask whether there is any reason to believe that this can be done more reliably, more cheaply, or with less damage to the earth than by just building another nuclear plant. Let's save the coal as feedstock for medicines, plastics, and other complex chemicals. Let's save petroleum products for feedstock and airplane fuel. Uranium has few other major uses.

All ANS members should read and digest the society's recent Position Statement #82, *Nuclear Power: A Leading Strategy to Reduce Oil Imports*. It states, "As an example, if one-third of our vehicles were plug-in hybrids, a practical goal by 2020, we could reduce our use of oil for motor transportation by about 25 percent from today's levels, sharply reducing our needs for oil imports."

Once the full potential of nuclear power is recognized, we have to ask: Why should we base the future of humankind on restricting energy? That's perverse! The worldwide demand for energy is increasing exponentially. Each year, 130 million bicycles are made, but since 2004 the city of Shanghai has been threatening to ban its 10 million bikes from crowded highways to make way for the burgeoning number of automobiles now flooding the roads. India's new $2500 car is expected to open huge new markets previously thought to be out of reach. These new car owners will demand driveways, houses, and gasoline. Then they'll consider air conditioning, toasters, and computers. That demand will be met, if not by nuclear power then by coal, natural gas, or, if necessary, by burning yak dung and denuding the world's forests. (Did you know that burning wood puts more noxious pollutants into the air than coal-burning power plants? And that some Tibetans have more lead in their blood than inner-city dwellers because they hover over smoky yak-dung fires, and yaks eat plants that concentrate lead? That was a cover story in *Science,* years ago.)

This growing demand for energy will be met, despite proclamations to the contrary by think tanks and politicians. Further efforts to reduce waste and improve efficiency are desirable and will have some effect on reducing demand, but they cannot meet much of the basic need. Energy that cannot be instantly available in large quantities, whether or not the sun is out or the wind blows just right, requires a reliable backup source.

The dictionary definition for *energy* is the thermodynamic one: the capacity to do work, to take action. There is a great deal of action needed and work to be done in the world: rebuilding and extending highways, bridges, electric power lines, rail systems, housing, hospitals, schools, libraries, and factories. Curtailing energy use would be like fighting urban sprawl by outlawing hammers: It defies common sense.

The cry for reducing energy comes from the premise that generating electricity adds to the carbon dioxide in the air and thus may cause serious ecological damage to the planet. But nuclear power does not add significantly to the carbon burden, nor does it add significantly to all the other pollutants that derive from burning hydrocarbons—particulates, SO_2, and NO_X. And so we should move as fast as we can to power the world with the atom. We've seen and heard all the reasons why this can't be done very fast. But if we had all done what the French did, as an immediate response to the OPEC oil crisis of 1973, we wouldn't be having this discussion. If 80 percent of the world's electricity were now nuclear-generated, how different would the world be today? Would we have invaded Iraq? Would the 9/11 attack have occurred? Would gasoline cost $4 a gallon?

We can't turn back the clock 35 years, but it isn't going to get any easier to do what we should have done then. We need to get serious. NN

Required reading . . .

The Perspective "Nuclear energy: *Not* a Faustian bargain, but a near-perfect providential gift," by Ted Rockwell (*NN,* Nov. 2008, p. 34), should be required reading for every member of Congress. Ted hit all of the pertinent points and stressed many of the issues we have been trying to get across to the public for many years.

Thanks to Mr. Rockwell for writing it, and to *Nuclear News* for publishing it.

James E. Owens
La Canada, Calif.

. . . and right on target

Ted Rockwell's Perspective is right on target. With characteristic clarity, he forthrightly states the major problem with our industry today. (As always, the views that follow are my own and do not represent any official position of my utility, its leadership, or its owners.)

It was good to see Mr. Rockwell speak out because there are many of us with a lot of plant experience who have thought the same thing for a long time, but it seems that no one listens to us. Now we have someone who has validated what we have come to learn and know over these past years of operation. His thesis is nowhere more aptly demonstrated to me than in two particular areas: the extremely costly fixes being implemented in the name of fire protection in our plants, and nuclear plant security against hostile attack.

We continue to pursue the "hot short" during fires inside and outside the control room with massive design efforts and thousands of dollars spent to put isolation switches at various locations in the plant. At the same time, we have to have fire suppression, fire brigades, hot permits, etc.—none of which gets credit for helping to prevent or minimize the fire that has to happen before one has the "hot short." This is classic overkill and "voodoo" analysis in the category that Mr. Rockwell mentions. If you dare to challenge, then you hear about the Rocky Flats fire, the Windscale fire, the Browns Ferry fire—the only thing not used against you is the Chicago Fire! I wonder if Mrs. O'Leary's cow had a "hot short."

And then there is Homeland Security's seeming obsession with "protecting" our nuclear plants. My plant just completed its required hostile action drill, which involved several hundred people—state, federal, and local oficials, FBI personnel, plant workers, sheriffs, fire chiefs—over a five-hour period. There were simulated fires, explosions, bombs here, bombs there, and eight simulated intruders. After we were done, there was a two-hour critique. Then the report went in with those of all the other nuclear plants that do the same thing, and joint task forces will review all the input and modify guidance yet again, and on and on, *ad infinitum.*

No one seems to be asking, "Are we really protecting the right targets?" What about our city water plants, plants that make plastics and process chemicals, oil refineries, and even our borders? Utilities have spent millions of dollars and are being required to spend more and more every year for the exact reasons Mr. Rockwell mentions: emotional and irrational assessment of actual consequence. No one has ever explained to me why, if nuclear power plants are such favorable terrorist targets, the 9/11 attackers flew over *so many of them* on the way to the Twin Towers in New York City. I submit to Homeland Security and to the Nuclear Regulatory Commission: Enough is enough; finish up this hostile action project and then, no more.

We need to get back to basics and simplicity, as Mr. Rockwell states. The AP1000, for example, has less piping, less cabling, canned rotor/canned stator reactor coolant pumps, no shaft seals, and convection cooling of the containment. Why has Naval Reactors built up such an outstanding nuclear safety record? There are many reasons, but *simplicity to the maximum extent practical* has a lot to do with it.

I would like to congratulate Mr. Rockwell on his World Nuclear Association award (*NN,* Nov. 2008, p. 50) and for his courage in speaking out in his Perspective. I also wish him continued good health and thank him for all he has done over the years.

Dennis Mosebey
Emporia, Kan.

LETTERS TO THE EDITOR on any aspect of the contents of *Nuclear News*—or on related nuclear industry issues—are welcome. Letters (which should not exceed 700 words and may be subject to editing for length/clarity) should be addressed to:

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Letter should include the writer's full name, address, and daytime phone and fax numbers.

Nuclear Energy is Renewable and Sustainable

"Renewable" and "sustainable" energy means: energy sources that are available indefinitely – they cannot be depleted. Our fossil fuel energy supplies, coal, natural gas, and oil, are not sustainable. As we use them, they are not being renewed at a sufficient rate to be sustainable.

"**Biofuels**" such as wood, corn, switch-grass, and corn husks, are said to be **renewable** because they are replaced with new crops. The ultimate energy source in that case is the nuclear reactor we call the sun, and we expect its fuel to last indefinitely for all practical purposes. The same is true for other solar energy sources such as solar panels, wind, hydroelectric dams, ocean waves, etc.

Most nuclear power plants today produce electricity from the fission (splitting) of uranium atoms. Fission releases several million times as much energy from a given weight of fuel as combustion of fossil or other chemical fuels. There are **claims that uranium is, like fossil fuels, being depleted**, that it is not renewable and not sustainable. But that is **simply not true.**

Only 0.7% of natural uranium is "fissile" (the kind that fissions in water-cooled reactors). The rest of the uranium (99.3%) is non-fissile (not fuel). However, nuclear power plants convert some of the non-fissile uranium into fissile plutonium (by capturing a neutron) so that the energy available from uranium is thereby extended.

If we don't recycle the fuel, the significant amounts of fissile uranium and plutonium that are left in the fuel (roughly one-quarter to one-third of the initial fissile uranium), plus the non-fissile uranium (roughly 95% of the used fuel), would be discarded and wasted.

But even while we aren't recycling the fuel, **there's enough uranium in the world to operate for hundreds to thousands of years**. The oceans maintain a consistent uranium concentration of 3.3 parts per billion – this is about 4.5 billion tons of uranium. Uranium is constantly being incorporated in many marine organisms, e.g., corals; but the seawater concentration is replenished and maintained by the chemical equilibrium for dissolving uranium.

Seawater continually leaches uranium from ocean bottom sources, and is being resupplied by hydrothermal venting and cold seeps, and by land sources from rivers emptying into the sea, and direct discharge of ground waters into continental shelf areas, to maintain its equilibrium concentration. If we removed a billion tons of uranium from the oceans over thousands of years, basic chemistry would ensure that seawater concentration would be little, if any, reduced –the oceans would still contain nearly 4.5 billion tons of uranium. From the perspective of uranium recovery, this is a "renewable" energy source. It does not get depleted, nor more costly, as it is being extracted. Thus, **even in once-through mode, uranium is renewable.**

(It is interesting to note that **about 10% of American electricity is made each year from Russian nuclear warheads** that have been converted to civilian use. That weapons-grade uranium is then no longer available for use in weapons. A similar project, to convert the plutonium made for U.S. weapons into power reactor fuel, is just getting under way.)

We can recycle used fuel. And further, this process can be optimized to create more fuel (from the non-fuel uranium) than is being "burned" (from the fissile fuel uranium). We can operate this way for hundreds of thousands of years, creating more fuel each year than we consume. **Here's what is truly renewable: recycling fuel so that the fuel source is <u>not</u> reduced, but is instead <u>increased</u> from cycle-to-cycle, and year-to-year.**

Furthermore, **nuclear energy is also available from thorium.** Thorium is three to four times more abundant than uranium in the earth's crust. Like the non-fissile uranium, thorium can capture a neutron to produce new nuclear fuel (in this case, a different fissile uranium energy source). **This further provides a reliable, full-time, uninterruptible, energy source, which can be sustained for millions of years.**

It has always been assumed that nuclear fuel would eventually be recycled, and that we would build nuclear reactors to make full use of the earth's uranium and thorium energy resources. This has been demonstrated in operation. The first U.S. reactor that powered light bulbs in 1951 was "Experimental Breeder Reactor I" in Arco, Idaho. Shippingport, the first demonstration commercial nuclear plant (60 MWe net, started up in 1957), operated in light-water breeder reactor mode for its last five years. After five years of producing power, the reactor contained more fuel than it had started with. It created new fuel from thorium as it operated. Breeder reactors are not now economical, and with many decades of low-cost mined uranium available, and somewhat more costly extraction of uranium from seawater available, there is no urgency that requires us to meet any near-term deadline.

With renewable seawater supplies of uranium and large terrestrial sources of thorium, plus fuel recycling and breeder reactors, **more nuclear fuel will be created than we consume each year, for millions of years.**

That's even better than merely "renewable!"

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Some Relevant Engineering Considerations

If we don't get the engineering right, good politics or economics can't save us. As Admiral Rickover said, "Nature isn't as forgiving as Jesus"

Energy is defined as capacity to take action, to do work. Lots of action needed, quickly.

So we'll need more energy, not less. Don't choose between that and improving efficiency; do both.

Many scientists say the right energy solution will be some long-range research miracle, beyond present imagination.

Could be. So we ought to devote some resources to that. But urgent need is more energy.

Today's nuclear plants are ***much*** better than any non-nuclear plant we know how to build. We should build 100s of them quickly. (I've said for long time, not just for today.)

Today's nukes fully meet all requirements for any energy source: safe, reliable (predictable), affordable, renewable, gentle on earth. Nothing else does. (Yes, nuclear ***is*** renewable).

Technical facts & real-world experience strongly favor nukes Need good reason to choose otherwise. Early nuclear experience says can build fast. Yet we treat nuke as last-resort.

The alleged problems don't occur in real world. Waste? Rad buildup? Casualty? See handout information.

President says don't need Yucca Mtn; used fuel no hazard where it is. He's right. Used fuel will soon be recycled to make more fuel. Let's quit arguing about non-problems, and build.

Nuclear people should stop bad-mouthing nuclear. There's nothing to apologize for. Cite the nearly flawless half-century record, where nukes consistently outperform the competition.