PLUTONIUM: PROMISE or PERIL?

Address to
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Tonight I will again reach cautiously toward a nuclear 'third rail.' I last made this type of move when I took on ALARA and the Linear No Threshold (LNT) Theory. Note, please, that I am now putting on my "PERSONAL ME" hat. I want to make clear that my comments in no way reflect the positions, interests, or policies of the American Nuclear Society – of which I have been a part for the last 23 years.

First, let me admit that I am presenting this talk twice – first to the Savannah River Local Section, ably led by Amanda Bryson and then to the, Piedmont-Carolinas Local Section also capably led by Tom Doering. As an engineer, I am mindful of the efficiencies of using it two times in two days, but I am sure, or at least I hope, that the members of these two active and vital groups will understand and appreciate my motives – one of which is to discuss and help increase understanding of this important topic.

With this in mind I ask you to think about the element plutonium. Does plutonium hold promise for our future energy needs? Or is plutonium a peril to the human race? It is time to review what I see as misinformation regarding this crucial element.

As your 2005 ANS Glenn T. Seaborg Congressional Fellow I found the following in the Congressional Record:

> *"A new source of power, which burns a distillate of kerosene called gasoline, has been produced by a Boston engineer. Instead of burning the fuel under a boiler, it is exploded inside the cylinder of an engine. This so-called internal combustion engine… begins a new era in the history of civilization… Never in history has society been confronted with a power so full of potential danger and at the same time so full of promise for the future of man and for the peace of the world.*
>
> *"The dangers are obvious. Stores of gasoline in the hands of people interested primarily in profit would constitute a fire and explosive hazard of the first rank. Horseless carriages propelled by gasoline engines might attain speeds of 14 or even 20 miles per hour. The menace to our people of vehicles of this type hurtling through our streets and along our roads and poisoning the atmosphere would call for prompt legislative action …"*

Sound like the current scaremongering regarding another "source of power" – plutonium? By the way, that was 1875. I guess that people, being as they are, sense that "where there's fire, there's smoke." Today's version? "Where there's uranium, there's worry about plutonium."

WHAT IS IT?
Plutonium is a metal, much like uranium, found in nature, but in trace amounts. Today most of what exists comes from the conversion of uranium into plutonium in nuclear reactors. In the words of Seaborg, *"On Sunday, February 23, 1941, a series of experiments was performed in Gilman Hall of the University of California at Berkeley that established conclusively that a new element, number 94, had been created through deuteron bombardment of uranium, the heaviest element found in nature."* No mystery here for you ANS members. The view of some, however, particularly in the popular media, is that plutonium is somehow "different." This probably comes from the versatility of nuclear materials, plutonium being no exception. First use was as a weapon, then as a fuel to make electricity, and then it found applications - applications not generally known - in space exploration, medicine, agriculture, and other industries. Yes, it is a fact that plutonium always emerges as a byproduct from generating electricity with uranium. Some label plutonium as "waste." Engineers and scientists declare that plutonium is a fuel.

The use of plutonium is not a proposal; it is a current-day reality. Here are just three examples:

1) *Electricity Production*. When you load uranium into a nuclear power plant, some of it is "fissioned" to produce heat, boil water, and make electricity. Some of it is converted to plutonium, and some of that is itself "fissioned" to produce heat, boil water and make electricity. By the time nuclear fuel is discharged from the reactor, most of the energy produced is coming from plutonium, not uranium, because of this conversion process. Today, 20% of our electricity comes from nuclear energy. Nearly one-half of that comes from plutonium.
2) *Space Exploration*. More than 20 NASA missions have used plutonium-238 as a fuel, including Pioneer, Viking, Voyager, Ulysses, Galileo, Cassini and Pathfinder. Even data-gathering packages left on the moon by the Apollo missions are powered by plutonium.
3) *Nuclear Medicine*. Miss Boszet, my great grandmother's neighbor, had her life extended by a heart pacemaker powered by plutonium-238.

PERIL: THE BOMB
Conventional wisdom says that the way to avoid the bomb peril is not producing anymore plutonium, because that would lead to the proliferation of nuclear weapons. Conventional wisdom – and false.

Pu239 is not the only nuclear weapons material out there. Two other good ones being U235 and U233. There is nothing special about plutonium. The bomb dropped on Hiroshima did not contain ounce of plutonium. It was solely a uranium metal bomb. In other words, you don't need plutonium to make a bomb.

Are proliferation and terrorism made more likely by commercial nuclear power plants? No. A nation's use of nuclear power plant electricity for military use, such as powering a cyberattack hub, is a threat with an order of magnitude more likely than using commercial LWR plutonium for a nuclear weapon. The whole premise of the first sentence is absurd because, even if the proliferator had the technology and funding to separate the plutonium from the irradiated fuel, using the relatively high-burnup of commercial nuclear fuel is not an effective path to making a weapon. The nuclear *Non-Proliferation Treaty* is a bargain: non-weapons states agree to forgo the development of weapons; in exchange, weapons states are required to help with the development of peaceful applications of nuclear energy.

History has proved that the only effective way to control nuclear weapons is to promote peaceful uses of the technology. Even if we magically eliminated plutonium, there's still uranium. Uranium is ubiquitous, found throughout our Earth's surface, and can be extracted even from seawater.

Why do we pick on plutonium? jWe in this community casually throw around the terms "weapons-grade" and "reactor-grade" – and they do indicate important differences in the ability to support a fission explosion. We should, however, define more clearly when it is that reactor-grade plutonium no longer needs as many controls. A shipment of MOX fuel to a light water reactor, for example, with at best 10% concentration of reactor-grade plutonium, does not need to be treated as a nuclear weapon. We should have controls, yes. But with a realistic graded approach.

Another example can be found with uranium: depleted, natural, enriched, and highly enriched uranium (greater than 20%) – all are treated differently, as they should be. It is time for the same sort of understanding for plutonium and its isotopic mix and the matrix in which it is contained. Materials containing plutonium exist in a system that includes safeguards and security. Safeguards are the features that enable the detection of theft or diversion. Security is the means to thwart an enemy's intentions. Therefore, theft or diversion of plutonium is detected and security ensures the materials are recovered before they can be misused to make a nuclear detonation device.

That's the short version on the bomb, but the myths surrounding it are so pervasive, we need to delve just a little deeper into the details of history.

NPT: AESOP's CAMEL

Plutonium is a bit like Aesop's Camel, big and scary at first, until you learn the facts. Then, as Aesop put it, we "assume such boldness as to put a bridle in his mouth, and to let a child drive him." This illustrates the story of the longstanding myth of the connection between commercial nuclear energy and the bomb. The specter of the bomb has apparently scared too many of us into accepting the much-repeated assertion that spent fuel from commercial power reactors can be used to make nuclear weapons.

In 1944 the development of the bomb was well under way. Seaborg warned the bomb makers that uranium will be fairly simple, but they are going to have to make some special provisions to use plutonium. In his words:

> *"We suspected, however, that, like uranium-235, the odd-neutron isotope 239 of the new element could be readily fissioned with slow neutrons. Plutonium-239 is the desired isotope, but too much plutonium-240 and the bomb will have a low yield or a "fizzle."*

Emilio Segre proved by experiment that, because of plutonium-240, the gun-type assembly used for uranium cannot be made to work with plutonium. Thus, the "Thin Man" program was cancelled. For a reliable weapon, plutonium required an implosion-type assembly. The "Fat Man" efforts began; this part of the story is often ignored. This is why DOE is proposing to irradiate surplus weapons plutonium material in commercial nuclear reactors: to create an isotopic mixture of plutonium less suitable for nuclear weapons while generating electricity in the process.

In 1962, at the height of the Cold War, bomb design was reworked and refined over two decades. Bomb makers learned that a practical bomb needed fairly pure plutonium-239, around 93%. Much beyond about 7% plutonium-240 and the bomb will be impractical because it is too hard to keep the plutonium from getting so hot that it melts the explosive surrounding it. To validate their calculations, U.S. designers obtained, from a British weapons-plutonium production reactor, some used fuel that had been in the core long enough that the plutonium-240 was approaching reactor-grade concentration. They were testing future commercial fuel. The U.S. used this material in a test device. While the details of both the makeup of the bomb and the results of the test are classified, the bomb was a relative dud and apparently yielded no surprises, confirming the accuracy of the calculations. As far as we know, nobody else, before or since, has ever tried to produce an explosion using "reactor-grade" plutonium. Bomb designers found commercial-grade plutonium unacceptable, especially since plutonium from power reactors contains about 25% plutonium-240, triple the established cutoff for a practical weapon. The 1962 test is often misrepresented to have shown that reactor-grade plutonium is good weapons material.

In 1968, the world is working towards ratification of the *Non-Proliferation Treaty*. The NPT is an international agreement between weapons states and non-weapons states that calls for a simple exchange: non-weapons states agree to forgo the development of nuclear weapons; <u>in</u> <u>exchange</u>, weapons states agree to <u>actively</u> <u>enable</u> the <u>expansion</u> of commercial nuclear energy in non-weapons states. Regardless of how many reactors a country has, it cannot make a nuclear weapon without access to either enrichment or reprocessing (PUREX) facilities. The problem is the NPT does have a flaw, in that it legitimizes the possession of facilities for enriching uranium and separating plutonium, as long as weapons-grade material (plutonium or uranium) is not produced. The current difficulties with Iran are partly traceable to that. Commercial nuclear power does have two proliferation pathways associated with it: (1) possession of a complete, indigenous fuel cycle implies the ability easily to acquire the expertise to make bombs, given the right materials; (2) possession of facilities for enriching uranium and separating plutonium means access to the right materials, if desired. For plutonium, some research reactors have been subverted to irradiate U238 to make weapons-grade plutonium-239. These were problems that the

Global Nuclear Energy Partnership was beginning to address, before the program was stopped.

Moving to 1990, the Cold War is coming to an end and the world is getting ready to sign the *Strategic Arms Reduction Treaty*. An anti-nuclear organization decides this is the perfect time to fan the flames of discord, and gets Carson Mark, a Los Alamos weapons designer, to write an article about the assertion that commercial spent fuel may be used to make weapons. They do not really get what they want. The title of the article sounds good to them, but Mark clearly concludes in the body of his article that plutonium derived from commercial spent fuel is <u>unusable</u> in nuclear weapons. Undaunted, a famous academic cleverly edits the Mark article in 1993 to give the appearance of a conclusion that is the exact opposite of what was intended by the original author, and adds his name as a "co-author." It is this 1993 fabrication that is cited over and over again, up to the present day, to support the <u>false</u> assertion that the plutonium in current commercial spent fuel is good weapons material.

I close this section with information from ANS's 1995 special panel report titled "Protection and Management of Plutonium," to answer the question of how to deal with 'all' types of plutonium – military and civilian. In the preface, Glenn T. Seaborg states:

> "[Since 1945], *plutonium has, happily, moved to the sphere of peaceful nuclear uses. In today's commercial nuclear power reactors that are already furnishing some 20% of all the world's electrical energy, plutonium that is formed in the nuclear fuel assemblies supplies almost half of the energy produced.*"

ENERGY AND THE ENVIRONMENT

In short, plutonium presents two faces: one as an environmentally hazardous, nuclear explosive material, and the other as a unique energy resource. These contrasting features have given rise to conflicting views on how to deal with plutonium, ranging from land disposal to its preservation for use in nuclear fuel. Plutonium is valuable, not so much for its intrinsic energy, but because it is fissile and therefore serves as a catalyst, if you will, that permits the exploitation of vast amounts of U238. Because of this duality, some view plutonium as waste, while others, and I would say that is most of us in this room, see it as the key to a major energy resource. And I mean MAJOR! Recycling, in fast reactors will transform our current stash of "nuclear waste" into an already-mined energy source that is good for thousands of years – our current, profligate once-through cycle has used less than 1% of its energy.

Nothing could be more earth-friendly than plutonium fuel. To begin with, nuclear energy, the most concentrated energy resource, requires the smallest amount of land, the smallest amount of fuel, and produces the smallest amount of waste. Plutonium means nuclear fuel can also be recycled. If we did recycle, this could reduce almost to zero the amount of transuranics that society would have to dispose of in a geologic repository.

In high-level "waste" – used nuclear fuel – plutonium does contribute to long-term toxicity and heat load, about 90%. And here is where the controversy comes into play. Waste versus fuel. This is the whole point. As you know, high-level waste is really slightly used uranium fuel. At this point in the world market, either the Australians or the Canadians dig the rock out of the ground, and now, with the once-through fuel cycle, it is put back into the ground. Here is where the myths proliferate. What about the plutonium contained in the used fuel? It is now considered a white elephant, with a "half-life" of 24,000 years. "We are committing dozens of untold generations to ecocide," a person opposed to a geologic repository might say.

The truth is a little less spectacular. "Half-life" is a measure of how radioactive a substance is. The longer the half-life, the less radioactive it is. Let me repeat that. **The longer the half-life, the less radioactive it is.** Something that is not radioactive at all has an infinite half-life. With a half-life of 24,000 years, plutonium is hardly radioactive at all. And when it does release radiation, it does so as an alpha particle that literally can be stopped by a piece of paper. Most of the short-term danger in spent fuel comes from various forms of cesium and strontium, with half-lives around 30 years. The proof? An abandoned uranium mine in Oklo, Gabon contains the remnants of a two-billion-year old natural nuclear reactor. Constant exposure of unusually high-grade uranium ore to groundwater created a reactor that produced plutonium and all of the other byproducts that currently constitute high-level nuclear waste. Completely uncontained, in two billion years Mother Nature's waste products from Mother Nature's reactor did not move more than ten meters from the source.

What about the "fact" that plutonium is "the most toxic substance known to man." Well, it isn't! Not even close! Seaborg states again, in the ANS report:

> *"When I think back to the remarkable rate of discovery and the rapid accumulation of knowledge in those early days, I am troubled by how slowly much of this knowledge finds its way into the public consciousness and how much misinformation and misunderstanding arises and persists. Even though not a single death in the public or even among the thousands of individuals in the United States who have worked with plutonium is attributable to it, there is a persistent belief that plutonium is among the most toxic, if not the most toxic, substances known."*

A good toxicologist, such as Dr. Elisabeth Whelan in her book titled "Toxic Terror," tells you:

> *"The nuclear power industry had been beset by numerous economic and regulatory problems. Its future hinges on how these difficulties are resolved… but given the omnipresence of natural background radiation… the impact of nuclear power on the total level of radiation in the general environment will be negligible… there is no scientific basis supporting the restriction or elimination of nuclear power…"*

Again, from the ANS 1995 special panel report "Protection and Management of Plutonium,"

> *"Although plutonium has been processed in ton quantities, the average intakes by workers seem to have been consistently low. With one possible exception, epidemiological studies have not been able to demonstrate adverse health effects in humans. Animal experiments, coupled to human studies of the effects of other radiations, mainly gamma rays, have been used to estimate the like risks [as compared to alpha particles] and thus to set exposure standards."*

The radioactivity of plutonium causes anxiety about its storage and disposal, but plutonium is not unique. It is forgotten in popular culture that very much larger amounts of toxic elements such as arsenic, cadmium, and lead are stored and disposed of with much less concern, regulation, fear and press coverage. Plutonium is a valuable resource and for that reason should not be treated as a waste for disposal back into earth's environment. When it has been released into the environment, during atmospheric weapons testing of yesterday, it has been of little environmental importance and has given only insignificant doses to humans. It is both fissile and toxic, however, so it must be stored and handled with appropriate care. That is why glove-boxes are generally used when fabricating plutonium fuels while uranium fuel fabrication facilities do not require such precautions.

ECONOMICS

And that brings us to economics. When it comes to popular myths and the battle with the "doom and gloom" crowd, this is the ultimate trap. Let's return to basics. Supply-and-demand economics always works. As you run out, the price goes up, and less costly alternatives are sought. This applies to the role of plutonium and the recycle of nuclear fuel. Where uranium is abundant and cheap, it is more economical to use once and dispose than to recycle. When the demand exceeds the capacity of the infrastructure, the price goes up, and recycle becomes the economical choice. The only real question is timing. Plus, we are notoriously bad at the long-term view of economics. At a national meeting of the American Nuclear Society on the 50th anniversary of nuclear fission, the head of the French Atomic Energy Commission was asked, "How do you explain the fact that France is now 75% nuclear?" He replied simply, "No coal, no oil, no gas, no choice."

POPULAR CULTURE

Now let's talk a little more about the role of popular culture in the energy dilemma, with plutonium as a springboard. In the 1970s, the great energy debate began, spurred by the Arab oil embargo. Unfortunately, facts were tossed aside, myths swallowed wholesale, and the so-called "plutonium economy" was rejected. In 1976, the National Council of Churches declared, "If we continue to pursue nuclear fission… we will bequeath to our descendants stockpiles of deadly nuclear wastes… cancer and probably genetic defects caused by exposure to plutonium contamination may have reached epidemic proportions."

Today, examples abound of the nonsense we still bequeath to our children about nuclear energy and plutonium. Consider just three examples, two from television, and one from the movie theater. From television, there is a children's cartoon called *Captain Planet*. This animated series is not designed to be funny, but to educate about the environment.

Unfortunately, what it does is spread junk science and myths, especially when it comes to nuclear energy. The evil “Dr. Nukem” seeks to contaminate the earth with plutonium waste, while Captain Planet and the Planeteers come to the rescue. Set against this is another animated series, *The Simpsons*, a much better feature that, yes, makes fun of nuclear energy, with glowing green cylinders of “plutonium” stuck to the back of the reactor operator’s beer-stained t-shirt on his way home from sleeping at the controls, but it makes fun of everything, and is funny. The spirit of this one is right, so I tend to overlook the three-eyed fish.

Somewhere in between, is another children’s cartoon series, also made into at least three movies, called *Teenage Mutant Ninja Turtles*. This one is a little adventure, and attempts to be mildly funny. The basic story line involves four turtles and a rat that become human-like, human-size, martial artist superheroes after being exposed to green ooze that they find glowing in large vials that litter the New York City sewer, where they live. The green ooze is clearly identified as deadly “plutonium waste.” Don’t forget the recent Spiderman movie where our human was turned into a superhero by a radioactive spider bite.

THE POLITICAL WILL

From the very discovery of fission in 1938 in Europe, the development of nuclear energy has been inherently international in character. Proliferation has shown us all that national monopoly of key elements of the technology is unachievable and indeed never existed. This is where our Society plays an important role with the IAEA safeguards system in establishment of common guidelines, perfection of detecting and monitoring, and the development of positive, peaceful international cooperative programs.

Now, perhaps, we can begin to talk more about the benefits of plutonium, particularly in the broader context of nuclear energy. But first, we must overcome one more hurdle – the political will. We may want to “do the right thing,” but only leadership can bring us the political will to actually do anything. It is up to us to communicate, to connect with our neighbors, to stand up for what is right. If not us, then who?

ANS supports the possibilities of various forms of international participation in fuel cycle projects. I see merit in the possibility of international staffing of the national fuel cycle facilities for peaceful purpose and so did the recent Blue Ribbon Commission in their report released last month.

WHAT NOW?

Today’s electricity is good news for nuclear energy and the use of plutonium. We’ve talked about this already, but it doesn’t hurt to remind ourselves of the benefits of an energy resource that can be recycled, requiring little land, little fuel, producing little waste, and all without burning anything and so eliminating air and water pollution altogether.

The end of the Cold War has brought the welcome disassembly of thousands of nuclear weapons. Perhaps now we will “dispose” of the excess material by using it in a nuclear power plant to produce electricity, and again “beating our swords into plowshares.” This option has been proposed as the most economical and secure way to seal the peace and this seems to be the direction we are heading with local sections supporting this effort.

If America is to become a true participant in the global village, we must recognize and support the widespread use of nuclear technology for peaceful purposes, including the use of plutonium as an energy resource of the first rank. This will require that we help put fear aside as a ritual of modern society, and start acting like adults who live in a community. Let's use plutonium to make electricity, let's recycle nuclear fuel, and let's stop perpetuating the misguided beliefs of anti-nuke academics and activists.

Remember the words of Madame Curie, *"Nothing is to be feared, only to be understood. Now is the time to understand more, so that we may fear less."* Let's get on with the wise use of the natural resources we have been given, and move forward to a better world.

The absurdity of applying the proliferation argument to commercial nuclear energy is perhaps best illustrated by Sir Fred Hoyle in his book, *Energy or Extinction? The Case for Nuclear Energy*. The following passage is pertinent:

> *"There are some people who simply do not want to know about nuclear energy. The association in their minds with nuclear bombs is strong, and they tend to think the two are really the same thing. Logically this attitude is not very sensible, any more than it would be sensible to say that because eating a piece of chocolate and exploding a hand grenade are both manifestations of chemical energy the two are the same. Both TNT and chocolate are made up from atoms of hydrogen, carbon, nitrogen, and oxygen. If one wanted to go to the trouble, the chocolate could be made into TNT."*

To my knowledge, the U.S. military does not have any plans to ever guard chocolate factories.

I begin to close this address with another quote from Glenn T. Seaborg:

> *"These and related misunderstandings have led some to propose that plutonium should be treated as a dangerous waste and buried, but this suggestion is rarely if ever accompanied by the explanation that burial does not get rid of it and that plutonium can be eliminated, should this ever prove to be desirable, only by burning or transformation to another element through irradiation with neutrons. Plutonium should be used with great care and under strict international safeguards, but it is a unique energy source to be used, not a waste material to be buried."*

So what is our future? Part of it can be found again in that ANS special report titled: "Protection and Management of Plutonium," printed in 1995, which is available for purchase via the ANS website.

> *"Currently proven reserves of reasonable priced uranium are insufficient to support a long-term, major contribution of nuclear energy to meeting world energy demand. Additional reserves will undoubtedly be discovered, but there is no law of nature that assures that the rate of discovery will match increased demand at prices that will allow continued reliance on power reactors that utilize only about one percent of the*

available energy in uranium... the recent U.S. decision [circa 1994] to stop all development work on reprocessing and the breeder resulted in severe limitations on a promising approach to a proliferation-resistant fuel cycle and the termination of important work on liquid metal reactor technology. This decision should be reversed."

Here is what I suggest that we ANS members in the nuclear science and technology community should address:

1) For the fissile isotope of uranium, enrichment has an international cutoff of concern at 20%. About any isotopic mixture of uranium can be made to go critical, Fermi proved this in 1942 with 0.7% uranium-235 content. It comes down to attractiveness (fissile content, gamma dose, and thermal generation). Reactor-grade plutonium should have a similar attractiveness level based on isotopics mixture related to burnup, so that high-burnup LWR fuels can get credit for degrading the plutonium.

2) Transport of fully assembled MOX fuel needs a more graded security approach to eliminate unnecessary expense, so this nation can get on with the conversion of the weapons stockpiles to the spent fuels standard via reactor irradiation.

3) For the long term, the current thermal-reactor fuel cycle is clearly unsustainable, since it utilizes less than 1% of the uranium's energy. But we know how to use plutonium in fast reactors to get more than 100 times as much energy from a given amount of uranium. Moreover, those fast reactors can operate well with fuel derived from thermal-reactor "waste." This is revolutionary! The world's supply of uranium has become a vast source of cheap and plentiful energy – one that will outlast civilization! So let's get off the technical side lines and finish the job – demonstrate the practicality of a fast-reactor fuel cycle that safely recycles, sequesters, and utilizes what is now an ever-increasing inventory of plutonium in spent fuel.

4) And we – you and I – need to work tirelessly to debunk the plutonium myths. I will do that every day and if you want to join the myth-buster team then go to the ANS website where you will find what you need to help you do that.

It is my hope that our Society can work nationally and internationally to make this happen. Please take these four recommendations and these insights about plutonium to make you more questioning of our current technical framework for handling plutonium. We must be bold advocates.

If not now, when?

If not us, who?