The Paradox of Nuclear Waste

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I feel very honored to be here with you today at Waste Management 2006.

What a great tradition you are continuing! It is a real tribute to the organizers that this conference has become an institution that has been sustained throughout so many changes in the economic and political landscape.

Congratulations to Fred Sheil, the General Chair and to Michelle Rehmann and Gary Benda for the Technical Program. Thank you Washington Group International—a good Idaho-based company—for sponsoring this luncheon. I know that there are many others who also deserve kudos for another outstanding job here in Tucson.

I am also pleased that the American Nuclear Society has retained an affiliation with the conference, this year once again putting on another successful Teacher's Workshop. With the great opportunity that they have every year, these Tucson teachers must be more knowledgeable about nuclear science than their peers anywhere else in the country.

Now turning to the business of the hour, some of you who paid attention to the title of this talk are undoubtedly wondering what I smoking. How else could you explain how I came up with this paradox idea? Well, the truth is that I was at a bar on the beach where a bunch of happy people were celebrating when the idea came to me.

Fred's email request for a title for my talk had arrived that morning of January 19th. In the afternoon I had the privilege of watching the launch of an Atlas V rocket from the Kennedy Space Center. Zipping by the moon in only 9 hours, it was fastest object every created by humans.

The launch was the culmination of 17 years of effort by a dedicated team of scientists and engineers. In another 9 years they can flip a switch and begin humankind's first close encounter with the planet Pluto. After the rocket parts had fallen away, all that was left was the

Pluto/New Horizons Observatory coasting along at 27,000 miles per hour. This is NASA's most important science mission of the decade.

The NASA science team is confident that when they flip that switch to start recording and transmitting data, more than 200 watts of electricity will be available out there in the coldest and darkest region of the solar system, some 40 astronomical units from home. The power is provided by a radioisotope thermoelectric generator, a space technology that has been successfully used by NASA for 4 decades on some 25 missions.

That's why I was there. Our team at the Idaho National Laboratory had fueled the generator with plutonium-238, delivered it to the Cape, and watched over it until the launch. Having not done any of the actual work, I was there to help out with the celebration.

It was during the party that one of the Lockheed engineers, flushed with pride and relief that his rocket had performed as advertised, gave me half the first half of the idea. He said, "You guys just sent 24 pounds of plutonium on its way out of the solar system. That is the ultimate nuclear waste disposal."

But within 10 minutes, the Department of Energy program manager looked me in the eye and said, "Damn, that's 24 pounds of plutonium that I have to replace."

Having just read Alan Waltar's wonderful new book on radiation, I was reminded that one's man's waste is another man's treasure. And so I want to explore some of those contradictions with you today.

Most of us in the nuclear industry think about radioactive waste as ordinary stuff contaminated with activation products or fission products from nuclear operations. Fission products include most of the elements in the periodic table—everything between zinc and holmium, plus tritium and the transuranics, and of course all the radioactive decay daughters. In that context, just about every element we know of can become a part of a radioactive waste stream.

However, if we consider the medical, agricultural, industrial and other applications, about 2/3 of the elements in the periodic table include radioisotopes that have beneficial uses.

Most of you are aware of some of the medical applications, ranging from diagnostic tests to aggressive cancer therapies. Perhaps half of all patients who enter modern US hospitals are touched in some way by radiation technology, whether by diagnosis, treatment, or equipment sterilization.

The irony is that the medical industry has gradually dropped nuclear from its lexicon even as its practitioners take advantage of nuclear's benefits. Now we have "magnetic resonance imaging" instead of "nuclear magnetic resonance" and the term "medical physics" encompasses a broad range of radiation technologies.

Modern industry routinely uses radiation technologies for a variety of applications. Process control for thickness, density and levels typically employs non-destructive nuclear techniques. Radioisotopes are used in plant diagnostics. Gamma radiation is routinely used in polymer development of such products as heat shrink fabrics. The rubber in tires is often vulcanized by radiation rather than chemical processes that generate waste.

Radiation technology has long been used in agriculture. Among the best known applications is pest control, which has been successfully employed for decades to eradicate infestations of Mediterranean fruit flies, screw worm and gypsy moths. Worldwide, more than 2000 crop varieties have been developed through radiation accelerated mutations and testing. Food safety through irradiation is becoming more accepted and has the potential for becoming a very large industry.

In the realm of public safety and crime fighting, nuclear technology has found many applications. The use of radioisotopes in smoke detectors, exit signs and airport runway lighting has saved countless lives. Nuclear techniques have proven to be powerful forensic tools for fighting crime. And of course, we are all aware of the increasing role of high sensitivity sensors and diagnostics in fighting terrorism.

Our ambivalence about nuclear materials is reflected in the way that we talk about nuclear fuel that has experienced life in a reactor. For a long period, high level waste and spent nuclear fuel were synonymous. Recently the country has started to acknowledge the residual 95% energy in this fuel that is far from spent. The term de jour is "used fuel." In another decade or two, "feed material" may become a common name for spent fuel as we move away from an extractive industry to a greener recycle nuclear economy.

Let me use one more plutonium 238 illustration. The Government Accounting Office has estimated the cost of Pu-238 production to be about $5000/gm. In the simplest case, it takes $1000 to initiate the shipment of waste contaminated with 1 gram of Pu-238 to the Waste Isolation Pilot Plant in New Mexico.

But in 2003, NASA loaded up a couple $300M rockets with the solar-powered Mars rovers, Spirit and Opportunity. One of the nation's best kept secrets is that each of those rovers contains 8 little Pu-238 heaters to keep the axles and instruments warm through the Martian night--which I am told is colder than Idaho in February. Each of these heaters contains about 2 grams of plutonium oxide, which supplies about 1 watt of thermal power.

As successful as Spirit and Opportunity have been, they have only moved a few hundred yards from where they landed. They can only operate in summer, during the daytime, and within 15^{o} of the Martian equator.

In 2009 NASA expects to launch a radioisotope powered rover that can operate in more interesting regions of the planet, drill samples and explore vast distances. Most of the prioritized science missions for future solar system exploration will be enabled by radioisotope power systems. They will venture to the moons of Jupiter and to the sun, where powerful magnetic fields have trapped high-energy ionized particles that would destroy solar panels. They will power exploration on the surface of Venus, where the temperature exceeds 400 C and dense clouds block the sunlight. And if the President's vision for human exploration is realized, even larger nuclear power systems will be required those fragile astronauts alive and breathing.

Before getting back to terrestrial waste disposal, let's consider the economic benefits of radioisotope applications.

The last survey of the economic impact of radiation technologies in the US that I know about was in 1995. International Atomic Energy Agency data and a much more recent Japanese survey show the same trends.

- In 1995 combined radiation technology industries had a larger sales volume than any single Fortune 500 company.

- The nuclear electricity component was less than 20%.

- As an industry, radiation technologies ranked just behind banking and ahead of electronics.

- The economic impact of the industry was slightly larger than either the Mexican or South Korean economies.

In more than a decade since that compilation was made, a lot has changed including increased use of radiation technologies, 7 million metric tons of CO_2 emissions avoided by the use of nuclear power, and a 20% increase in nuclear electricity production without construction of a single new plant.

In spite of all these benefits, responsible management of radioactive waste is challenged at every step, and not just by activist groups. It has taken great tenacity by those of you involved in the waste industry to continue to make progress on keeping waste solutions open. It is neither easy nor pleasant to stand up to criticism and political pressure, but it is necessary for the future of our country.

Since 1980, the nuclear waste industry has reduced low level waste volumes by more than 90%. Modern nuclear fuel yields more than twice as much energy as 1970s vintage fuel resulting in lower waste volumes. In New Mexico, the world's first deep geologic repository has now operated successfully for several years.

High level waste is a perfect example of one of the contradictions that contributes to my paradox theme. When people hear that there is 44 thousand tons of spent fuel looking for a permanent home, they have an image of this mountain of highly sinister material. In fact, as we know, removed from its protective casks, all the spent fuel generated to date would fit on a single football field.

The Energy Policy Act of 2005, better known as EPACT, contained provisions to stimulate new nuclear plant construction. The response of the nuclear industry and the financial markets has been positive. Most officials are now saying that we will have new nuclear plants on line by 2015. By 2020 new plant orders at the rate of 2-3 per year not only seems feasible, but likely.

Earlier this month, the Administration announced a new initiative called the Global Nuclear Energy Partnership, or GNEP. Although it will take decades to fully implement, this initiative is a vision of an end-state in which nuclear technology a cornerstone of US energy and nonproliferation policy.

These bold federal actions could initiate nuclear expansion that will extend throughout this century. Such an expansion is needed if nuclear is to hold or increase its 20% share of electricity generation and be used for new industrial applications such as hydrogen generation.

Coupled with expansion in radiation technology applications, the expected growth in the power industry will challenge the waste industry. GNEP will bring with it the sanity of a closed fuel cycle and the power of reprocessing to waste management.

If anyone doubts that the US will find the resolve for a national resurgence of nuclear energy, consider the pressure from abroad.

In the past 2 years, we have seen a jump in commodity prices, particularly for steel and concrete, driven by the building boom that is an expression of China's rapid economic expansion. India, the second most populous nation, is expanding just as rapidly and has perhaps an even stronger technology base. Both countries are acutely aware of the pressure that realizing the rising expectations of their burgeoning populations will place on the global energy markets.

About a year ago, my friends looked at me tolerantly when I told them that within 3 years we would see $3/gal gasoline and $75/barrel oil. With last season's hurricanes, it turns out that I was too optimistic about how long it would be before we saw record gas prices. Oil prices are volatile, but still in the 60's.

In spite of the rosy outlook of some economists who predict a return to $30/barrel oil, the global pressure on oil will only increase. Most of our supply comes from a politically unstable triangle in the Middle East that is no larger than this State of Arizona. New oil field discoveries are smaller, more expensive to extract, deplete quicker, and produce heavier oil that requires more extensive refining.

The rapid rise in natural gas prices caught many developers unaware, leaving a number of new gas turbine projects underwater even before their completion. Efforts to significantly increase gas supply through liquefied natural gas imports are largely being thwarted by community opposition.

There are large reserves of fossil energy in North America. With reserves measured in centuries, coal already supplies the lion's share of our electricity, but needs improved technology to reduce its environmental impact. US oil shale has the potential to yield up to 2 trillion barrels of oil equivalent under favorable economic conditions. The oil sands of Canada are huge fossil fuel reserves, but are expensive to extract and convert to useful petroleum products.

Most of these indigenous reserves will require vast quantities of hydrogen to convert them to gasoline, jet fuel, and diesel products. If nuclear is to supply that hydrogen—and control of greenhouse gas emissions seems to be pushing in that direction—rapid nuclear expansion will be required throughout the 21st century.

Another impetus for the resurgence of nuclear energy in the US is the need to maintain some leadership and influence over the expansion of nuclear energy worldwide. Returning again to the example of Southeastern Asia, both China and India plan to have more than 200 GWe of nuclear plants installed by mid-century, or more than the world's currently installed nuclear capacity. Even so, nuclear will remain less than 10% of their total electrical generation.

India and China's plans are more ambitious than even our recent GNEP proposal. Both countries are proceeding at full speed to closed fuel cycles; both are constructing breeder reactors and expect them to be the dominant technology by mid-century. While we fret about perhaps building fast burner reactors to manage actinide waste, the developing countries realize that uranium resources will also be stressed like other commodities. They are planning ahead to reduce the global impact of their anticipated appetite for energy resources, including uranium.

Japan will continue its deliberate push toward a self sufficient nuclear economy, although with less urgency due to a shrinking population and a mature economy. South Korea plans to continue rapid nuclear growth in both capacity and technology, mirroring the development ambitions of China, albeit at reduced scale. France has returned to fast

reactor development after a 15 year hiatus and Russia remains focused on advanced technologies.

By some counts, 123 new nuclear plants are planned or under construction worldwide; the much heralded nuclear renaissance is happening. It is just a matter of whether the US will contribute or slip into the shadows.

I believe that the United States has only a brief window of opportunity to re-establish its international nuclear energy leadership. Such a move would be welcomed abroad, but other nations will not wait another decade for us to get over our hand wringing episode. I think that it is essential that we seize this opportunity in order to influence the international safety and nonproliferation regime to our standards. It is also important from an economic perspective to maintain at least parts of this key, high-tech industry in the US—particularly after the loss of so many manufacturing jobs has discouraged many American workers.

I believe that there are a number of conditions that must be satisfied in order to have a true nuclear resurgence in this country.

- The first condition is reestablishing trust. We have come a long way with the public, with 70% now favoring new plant construction. However, there are still major issues at the state level. The recent episode with the questions regarding the integrity of the Yucca Mountain analysis shows just how expensive the loss of public confidence can be.

- A major reason for the lack of trust in the state governments is waste. The legacy of cold war waste—long the subject of this conference—is still generating mistrust. The waste issues have to be resolved, solved and streamlined if we are to move aggressively ahead on a civilian program.

- A third condition is resolution of the federal and private domains. Failure by the government to take control of the spent nuclear fuel in 1998 has generated bad consequences for both sides. As we move into materials recycling, the federal/private boundary for materials and facilities ownership must be resolved satisfactorily. Successfully closing this deal will require an unfamiliar level of leadership.

- The Administration has been careful to cast its new initiative within a nonproliferation framework. The argument about whether we influence by leadership or by self denial has to be resolved. In my opinion, the latter approach, first expounded by President Carter, has been a consistently demonstrated failure. It is time for something new, and for this I give President Bush high marks.

- Whatever our program, it needs to be sustainable through administration changes. There are broad elements that should be unassailable, and we need to learn to speak with one voice on those. In open forums such as this one we can argue about the rest.

Since this is a waste conference, let's just concentrate on that aspect of this anticipated resurgence.

For 20 years we have been trying to deal with the Cold War's legacy—a problem that is concentrated in a few states: Washington, South Carolina, Idaho, Tennessee, Ohio and New Mexico. Colorado has largely resolved its problems, no doubt in part because Rocky Flats exported its worst waste legacy to my State of Idaho.

The bill for cleanup of the weapons complex will run into the hundreds of billions of dollars, even then with continued arguments and lawsuits about the definition of completion. This legacy continues to provide ample ammunition to those who oppose nuclear energy. More importantly, it puts key state governments in the unenviable position of trading off new nuclear development against progress on legacy remediation.

There will never be enough money in the federal budget to effect cleanup to a level that satisfies the very last person. The ultimate resolution will take creativity, statesmanship and most of all, tenacity. It won't be easy and it won't be quick.

Many of you are to be commended on moving this issue toward eventual resolution. The key for all of us is to recognize its importance to our nuclear future and keep on keeping on, as the saying goes.

While at times it seems that we are moving at a glacial pace on dealing with the Cold War legacy, there is at least one statistic that I

find remarkably reassuring. On average, one out every 10 light bulbs in the US today is powered by uranium downblended from former Soviet Union nuclear warheads that were targeted at US cities. That's real progress even if there is a long way to go.

There are other positive signs of progress. Accelerated cleanup contracts are now setting the trend. At sites such as Idaho and Savannah River where there are simultaneous cleanup and development activities, separate contracts are being written by the Department of Energy to be sure that each set of activities can be independently prioritized.

Another essential item for a nuclear resurgence is the continued safe operation of existing nuclear power plants. The US civilian nuclear industry has been one of the safest places to work. To my knowledge no death has been attributed to nuclear side of the business, a remarkable statistic for such a large undertaking.

Chernobyl notwithstanding, the worldwide safety record with disposal of radioactive sources has not been as good as the power production side. There have been severe injuries and even deaths due to loss of control of industrial sources and radioactive scrap. Safety in cleanup and waste management activities will be just as important as power plant safety in maintaining public confidence in the years ahead.

With all the recent Utah-based activities, there is evidence of a maturing of the waste industry, what with mergers, acquisitions, and now the NRC licensing of the Goshute temporary spent fuel storage facility. Industrial improvements tend to come naturally with the maturing process, because they simply make good economic sense.

One of my favorite examples is from the reprocessing industry in Europe. During the last 30 years, peak doses from reprocessing discharges at Sellefield have been reduced by a factor of 20. During the same period, liquid radioactive discharges at La Hague have been reduced by two orders of magnitude, worker exposures have been reduced by a factor of 20, and the average dose to the public is now less that 0.01 millisieverts/year.

Conferences such as Waste Management 2006 and the suite of ANS-run conferences on fuel cycle issues play an important role in technology exchange and in objectively defining the state of the industry. They provide an opportunity for peers around the world to

get to know each other, to collaborate, to argue and to form lasting bonds. They provide a forum for service providers and customers to hook up. [Actually, if we were at the High Level Waste meeting in Las Vegas, I would word that last one differently.]

For those of you who are committed to a future in the nuclear business, I encourage you to join a professional association if you have not already done so. If you employ such folks, I encourage you to support their activities and to involve your company. At the American Nuclear Society, we are just beginning to implement the latest revision of our strategic plan. Among other benefits of this plan, we will arm our 10,000+ members with the tools they need to engage effectively in the coming public debate over nuclear expansion.

It is important that we are all out there spreading the word about the benefits of our industry and putting its risks in proper perspective.

Once again I commend the organizers of this conference for providing such a forum. I wish you all a very successful week here in Tucson. Thank you very much.