ANS WINTER MEETING

The revival of nuclear energy—Going forward together

WILLIAM MAGWOOD remembers back to 1998, when the Department of Energy's budget for nuclear energy R&D was $0. He was asked at the time by international visitors what that meant, what the message was that the United States was sending the world about the future of the industry. "The answer," he said, "was that, quite frankly, we just had not done a very good job in planning for the future, i.e., the reactor program and some other things."

There also were those several high-ranking government officials, Magwood said, who pulled him aside and said, "Why are you worrying about this? Nuclear power isn't going anywhere. Deregulation is going to make it impossible to ever build another nuclear power plant." It was a gloomy time, indeed, for the industry, he said.

Fast forward to 2004, when Magwood, in assessing the technology's future prospects during the opening plenary of the American Nuclear Society's Winter Meeting in Washington, D.C., told the audience, "You're a much happier crowd these days."

Much has changed during the six years since the dark days of 1998. "Looking back," said Magwood, director of the DOE's Office of Nuclear Energy, Science and Technology, "I think it's easy to say that we passed the crossroad five or six years ago and we came out on the positive side of it."

Magwood

As general chair of the ANS meeting, titled *Leadership Toward a Progressive, Integrated Nuclear Community—Going Forward Together,* Magwood's message was that "the revival of nuclear energy in the United States and all over the world is already happening right now."

As examples, he pointed to the ongoing push to build new reactors in the United States, the increase in the number of college students enrolled in nuclear engineering programs, and the burgeoning international cooperation to develop new designs for next-generation plants.

Participation in the Winter Meeting might be another measure of that revival. More than 1300 participants signed up for the meeting, held November 14–18, 2004, "one of the larger gatherings we've had with the ANS," Magwood said. There were also 74 exhibitors and about 120 nuclear engineering students who attended.

The meeting's opening plenary was divided into two parts. The first part featured presentations on nuclear's prospects around the world—and in outer space. The second part consisted of a panel discussion on November's election results and the path forward to an energy policy in the United States.

Major themes of the meeting:

- *Climate change issue must be addressed*
- *Energy policy should combine supply and efficiency*
- *Nuclear regulation must change with industry*
- *Prominent environmentalist supports nuclear power*
- *The outlook for nuclear power in space*
- *Nuclear's role in hydrogen production*
- *Planning for nuclear's next 100 years*
- *Innovations in nuclear engineering education*

World view

Donald Johnston, secretary-general of the Organization for Economic Cooperation and Development (OECD), stressed that a critical challenge for the 21st century is climate change. "The central issue is, of course, sources of energy and their attendant greenhouse gas emissions, especially CO_2," he said. "I do not have to remind this group that nuclear energy does not emit greenhouse gases."

Climate change must be addressed "quickly, seriously, and objectively by the developed and the developing world," he said. He then summarized a report from a group of NGOs (nongovernmental organizations), independent citizen organizations that are increasingly active in policymaking at the United Nations. The report alleged that global warming will hit poor countries the hardest, and these countries will experience more flooding, declining food production, more disease, and the deterioration or extinction of entire

Johnston

ecosystems upon which many of the world's poorest people depend. He further warned, "None of us will be spared."

What can be done? Johnston said that while many people, especially those in the Green movement, look to renewable energy sources such as wind and solar power as the answer to climate change, data from the International Energy Agency show that the world's renewable energy consumption represented only 14 percent of total demand in 2002, and will represent only 14 percent of total demand in 2030, according to IEA projections. Meanwhile, the IEA's projections say there will be a 60 percent increase in the world's energy demand between 2002 and 2030. "On those projections, we can hardly look to renewable energy as a means of effectively addressing greenhouse gas emissions," he said.

The world is shrinking every day . . . and leadership by nuclear regulators should contribute to a progressive, more integrated nuclear regulatory community.

Johnston commented that while there is the prospect of developing nuclear fusion as a power source, "no matter how promising, it is many years away—too far to impact the immediacy of the problem at hand."

That leaves nuclear power (fission) to combat global warming. It remains "the only reliable and proven source of energy which can bridge the next 50 to 100 years, while new technologies, such as fusion, hydrogen, renewables, whatever, are further developed," he said.

The bottom line, he added, "is that a massive increase in the installation of nuclear energy capacity . . . should lie in our future—our immediate future. It appears to me that the fear generated by some NGOs in the public mind has succeeded in building a wall of political resistance in many countries which must be broken down." He suggested the hiring of credible spokespersons from outside the industry to make known the facts about the operational safety of nuclear facilities, guarantees against proliferation, and nuclear waste disposal.

Ignoring nuclear power in the world's energy plans is becoming increasingly difficult, said William Magwood, who stepped in to make a presentation for the DOE when the scheduled speaker from that agency couldn't make it. Using electric power sources in the United States as an example, he said that about 1 percent of U.S. energy comes from non-hydro renewables. "If we meet our aggressive goals and quadruple that over the next decade, it will be 4 percent of U.S. requirements," he said. "That is not the way to create an energy policy."

Nuclear power has to be part of "the energy mix," he said, and that is why the President, Vice President, and Secretary of Energy went public in saying that nuclear power was important and should be expanded in the future. "We've really been moving down the chain in a lot of activities to try to make that happen," he said, pointing to the DOE's issuing of two grants ($4 million to NuStart Energy and $9 million to Dominion) to assist with building new nuclear power plants. "The fact that we're able to work with the industry at this point to move forward, that a new power plant can occur, is really a credit to the industry," he said. "As you recall, it wasn't that long ago that the industry was very ambivalent about it."

Magwood added that the DOE has been working with three utilities and the Nuclear Regulatory Commission to exercise that agency's Early Site Permit (ESP) process. If the task of securing ESPs is successful, he said, "I believe that sometime in 2006 there will be three sites in the United States that [will be] permitted for construction of nuclear power. This will be a major accomplishment."

He said it was important, too, to look beyond the short term (Generation III) to next-generation plants (Generation IV). "I was at a meeting in Paris recently where we heard top-level plans for nuclear generation from representatives from several countries," he said. "The most remarkable thing about that meeting was that the U.S. participant, the European participant, and the Japanese participant were saying almost exactly the same thing. I think this is due largely to the fact that we've been communicating with these international communities on these issues more aggressively and with more detail than ever before."

Many countries involved within the Generation IV context have discussed the possibility of working together to develop one technology instead of four or five technologies. "And considering the fact that this project will probably cost about $2 billion or so once it's done, it seems to me it would make more sense to spend $2 billion internationally than to spend $8 billion [total on four technologies] one country at a time," he said.

In that regard, it is important that the United States recognize the work being done today in other countries, "particularly Germany with the EBR process and Japan with their demonstrator," he said. "China is making tremendous progress with their hydrogen reactor technologies. It's important that we work with our international partners to bring as much of that as we can," because international cooperation will change the face of nuclear development. "We can change the market now for nuclear energy away from what we've done in the past—one plant at a time, one country at a time," he said.

Another area that should remain in focus is nuclear technology education, he said. "In 1998, there were 60 students in nuclear engineering [in U.S. institutions], and we've increased that to 1400, but we can't stop there." He said the DOE has been active in forming partnerships with universities to increase nuclear programs.

The regulatory side

Offering his views from the regulatory side of the aisle was Nils Diaz, NRC chairman. "For the utilization of nuclear technology to advance to a new level of performance in the 21st century, nuclear regulation needs to be better, more predictable, more usable, more consistent across borders, and more risk-informed," he said.

The world is shrinking every day, Diaz observed, and leadership by nuclear regulators should contribute to a progressive, more integrated nuclear regulatory community. "In fact," he said, "nuclear regulation needs to be better managed to better serve individual countries as well as international needs. Nuclear regulation is a complex techno-legal construct that requires constant examination and management, even apart from sociopolitical issues."

Diaz claimed that there are "more striking differences" in the global regulation of nuclear power than in the technology and operation of the plants themselves. "I value the distinct contribution that each nuclear regulator makes to safety within each country's framework," he said. "However, I believe that more convergence on the regulatory framework and its tools would enhance predictability and decision-making."

While a country's licensing and regulatory authorities should remain strong and fully responsible for making regulatory decisions within that country's boundaries, there are parts of regulations that Diaz believes are amenable to "internationalization," he said. "I believe that safety will be better served when certified designs can be accepted across borders as a commodity, fully respecting property rights and the licensing responsibility of

Diaz

regulatory authorities. Therefore, I am convinced that regulators should seek to develop the tools needed to certify new reactor designs, as well as to certify the related research programs used to validate these designs, using bilateral or multilateral agreements. The bottom line is that safety and regulatory decisions would be facilitated globally."

Diaz remarked that regulatory activities need to keep pace with changes in the industry and that regulations need to be maintained in step with technology developments.

Nuclear's role in space

Technology development was a theme of Theron Bradley's talk about nuclear's role in space applications. Bradley, former chief engineer at NASA, said that the agency has been looking at nuclear as a power source to support instruments such as lasers and radar that cannot be easily supported by solar power. Nuclear is also needed to provide habitability for future generations of explorers, when people follow robots into space. "These are things that for a variety of technical reasons, can't be done by solar power in the outer planets where there isn't much solar energy, or by batteries that aren't able to function at -200 °C," he said.

NASA is continuing to work with the DOE to produce radioisotope thermoelectric generators (RTGs) to provide power for space applications. In all, the agency has launched 28 spacecraft equipped with RTGs, all fueled by plutonium-238 dioxide fuel. Bradley said that four of the 28 were used only to provide heat, such as on the Mars Rover. "The others also provided thermoelectric power and were used for Apollo, Viking, Pioneer, and Voyager—all the big-name programs of the past, the latest ones being Galileo and the Cassini probe," which has photographed and sent back pictures of Saturn.

At the beginning of flight, the current RTGs typically provide 250 watts—"That's not megawatts, not even kilowatts," he emphasized. They each also weigh about 57 kilograms, which in the spacecraft business is a lot. "It's a lot in terms of the total mass of the spacecraft," he said, "and it's a lot compared to instruments. However, it's not a lot compared to the weight of the chemical fuel currently needed for propulsion."

Bradley said that NASA is on a path "that will make practical use of nuclear energy in new and exciting ways, and it is necessary in order for NASA to complete its mission." The agency is focused on delivering a robust, reliable technical product that will form the basis for long-term exploration of the solar system. "This isn't a dream," he said. "We're going to go do it."

View from the Hill

Issues are seen often as only black or white. For example, Democrats are sometimes seen as being only for energy efficiency, and Republicans, only for energy supply.

The fact is, according to Tom Kuhn, president of the Edison Electric Institute, that both parties are made up of members who favor a combination of efficiency and supply. "And any kind of new legislation should be and has to be bipartisan and should combine elements of both," he said, with reference to a national energy policy that has been promoted by the Bush administration since 2001 but has stalled on Capitol Hill since then. "If we're going to move forward on competitive electricity wholesale markets, we need to move forward in viability," which means a mixture of generating options, including nuclear, fossil fuels, and renewables.

Kuhn

Kuhn noted that the need for an energy policy is greater than ever. Since 2000, the price of natural gas had climbed from between $2 and $3/million Btu to more than $8 before leveling off. In addition, he said, "We've seen oil prices soar up to $50 for a barrel of oil, and gasoline is over $2 a gallon. Coal prices have changed dramatically in the last year. I think the one stable factor in the energy business is nuclear energy."

[T]he future's electric power will come from three sources: nuclear, renewables, and clean coal, because oil and natural gas will have priced themselves out of the market.

The general public is beginning to see the benefits of nuclear, too, he said. That has been reflected through opinion polls that have shown a dramatic increase in the numbers now accepting nuclear. "More and more, as we have climate changes, people will say, 'Wow, how are we going to [reduce CO_2 emissions] without nuclear?'" he said.

Capitol Hill has been debating energy legislation for three years, but an energy bill is, of course, still pending. When the new Congress convenes in January, the energy bill will rightly emphasize energy efficiency, said Kuhn. It should also include provisions for increased investment in the nation's transmission infrastructure, because the past four years have brought major blackouts, he said.

Bob Simon, staff director for Sen. Jeff Bingaman (D., N.M.), said that there are four "legs" to an energy policy. First, he agreed with Kuhn that a bipartisan agreement would rely on many options for providing power. "I think everybody, regardless of where they are in the political spectrum, would agree that one of the things we need to do in any forward-moving energy policy is to secure an adequate supply of energy going into the future," he said. "So, obviously, a good energy policy has to increase energy supplies from a broad range of sources."

Second, he also agreed with Kuhn that the policy needs to increase the efficiency—and, further, the effectiveness—of the ways in which energy is delivered and used.

The third leg, again in unison with Kuhn, has to do with "the first two things, while at the same time keeping an eye on the environmental aspects of energy," because energy policy and environmental policy are inseparable and are linked in many ways, Simon observed. "In fact, one of the principal themes that I see in developing an energy policy in the next few years has been developing for some time," he said. "I think we will increasingly become involved in a climate change policy . . . We're either finding lower carbon paths to producing energy or more efficient ways of using energy that we produce, regardless of its source."

Finally, "the fourth leg of the table of energy policy" relates to having "an aggressive, coherent, realistic science and technology policy going forward," he said. That means that most of the problems with the energy policy to be debated by Congress and with similar energy initiatives of the past have been their lack of reliance on technology. To illustrate, he said, a private business identifies a problem and fixes it, but the government likes to muddle around, never solving the problem. So, what the government should do, he said, is play up the "scientific frontiers" aspect of the energy policy in order to draw the attention of undergraduate and graduate students, because it is their young and fertile minds that will come up with the solutions that are currently missing. "The task of attracting [students] into energy-related areas is a current problem and something that has to be part of any current energy policy," he said. "If we are going to have the energy technologies we need years from now, then we need recently graduated students right now and in the future who will be key agents in the

nuclear industry."

Simon said that the energy bill as proposed by the Bush administration "is more affected by uniting all the critics than in uniting all the proponents."

The fact about the energy bill is that while the nation has had an election and George Bush was reelected President, it doesn't change realities, according to Pete Lyons, public policy advisor to Sen. Pete Domenici (R., N.M.). The realities are that the future's electric power will come from three sources: nuclear, renewables, and clean coal, because oil and natural gas will have priced themselves out of the market.

Relying on those three sources will depend on the avoidance of "politicizing" them. "It's going to take a sustained, bipartisan effort to try to advance to the point where all three of those sustainable energy sources are really making strong contributions to the energy portfolio in this country," he said. "The more we avoid politicization of any of those three energy sources, the better we will all be."

Lyons

Lyons said he hoped the energy bill would be a priority for both parties in both houses. "From Senator Domenici's perspective . . . he had five key points on nuclear energy, and I don't see those points changing as we look at an energy bill in the next Congress," he said.

His first priority is renewal of the Price-Anderson Act, because "there has to be a predictable liability framework for nuclear energy to advance," Lyons said.

The second priority is the construction of new commercial reactors, "and that isn't going to change," he said. Domenici regards it as "absolutely essential that we demonstrate, perhaps to ourselves, perhaps to utilities, perhaps to the public, that nuclear energy can move ahead now, can move ahead safely, and can move through the licensing process with new commercial and economically viable systems," Lyons said.

The third priority is advanced reactors. "There has to be a future 'looking ahead' with advanced reactor concepts in order to maintain and rejuvenate the infrastructure and the educational system in this country," he said.

Domenici's fourth and fifth priorities, Lyons said, are the advanced fuel cycle initiative and work force development, which tie in together. He noted that Domenici strongly supports the high-level waste repository planned for Yucca Mountain, but that he recognizes that better waste solutions are needed, which is where the advanced fuel cycle initiative comes in.

Regarding what will happen with Yucca Mountain, and specifically the federal court's overturning of the Environmental Protection Agency's (EPA) regulations for groundwater protection, Lyons said he could not see a solution around that roadblock. The issue involves the unanimous ruling on July 9 by the U.S. Court of Appeals for the District of Columbia Circuit, which vacated the 10 000-year compliance period established by the EPA for regulating the proposed repository. The court ruled that the compliance period violated the Energy Policy Act, under which the EPA's radiation-protection standard for Yucca Mountain must follow National Academy of Sciences (NAS) recommendations. The EPA's current regulations apply only for Yucca Mountain's first 10 000 years of compliance. The repository's peak radiation dose, however, would occur after that period, and a requirement stretching out to 1 million years would be technically feasible, according to an NAS declaration in 1995. NAS added that the 10 000-year period could be acceptable if the EPA showed that compliance was consistent with "management of risks from long-lived hazardous nonradioactive materials." In that regard, the court allowed that Congress could enact legislation empowering the EPA to deviate from NAS's recommendations.

Lyons said that perhaps Congress would see fit to have a series of hearings during the new session on the Yucca Mountain/EPA matter, or that perhaps the EPA would consider issuing a revised regulation. "I just don't know at this point," he said. "Again, that's high on our list of critical issues for [2005], and I simply can't tell you how it will be resolved. But it has to be resolved sometime."

On the contrary, don't look for the House or Senate to handle the Yucca Mountain/EPA issue at all, according to Sue Sheridan, an aide to Rep. John Dingell (D., Mich.). Sheridan said the issue was "too hot to handle" for Capitol Hill, and that it is "going to have to be resolved outside of Congress."

President's Special Session

ANS President Jim Tulenko chose the topic "Energy and the Environment: Golden Opportunities for the Next 50 Years" for his President's Special Session. Much of the discussion was about how to open up nuclear power to those opportunities. One of the concerns Tulenko raised was the growing energy demand in the developing world that would soon dominate the security of supply and environmental issues with which the industrialized world is now grappling. China, he noted, recently overtook Japan as the second largest importer of oil and in four years is expected to surpass the United States. China already uses much more coal than the United States, and its energy consumption—and the environmental damage it brings—will continue to accelerate.

Tulenko left comments concerning the political scene to the first speaker, Sen. Pete Domenici (R., N.M.), a powerful nuclear ally on Capitol Hill. Domenici, first elected in 1972, said he would discuss where we have been and where we are going with nuclear power, adding that his new book, *A Brighter Tomorrow: Fulfilling the Promise of Nuclear Energy*, gives a much fuller explanation. He has been waiting for some time now to see if the United States would come to its senses and move ahead again with an energy source that is clearly clean and, taken in total, much safer than any other form of energy for producing electricity. The United States, he said, finds itself becoming more and more dependent on imports of natural gas as well as oil. The country faces a clear dilemma, as there is no relationship more certain than the availability of electricity and material wealth—"they go together like day and night."

Domenici also noted that people everywhere are clamoring about global warming. The United States has been rather immune to some of this, he said, in part because many Americans have not believed there is a problem—and some still don't. Most developed countries are looking at ways to reduce emissions, he observed, and France, which releases very little greenhouse gas from electricity production, is telling everyone to sign up for nuclear. He noted, however, that even if other Western countries followed the French example, the billions of people in developing countries who want to improve their lives will need a lot of electricity and have few choices other than fossil fuels.

Domenici

Some people want renewables to fill the energy gap, he noted, adding that, fortunately, others besides those who favor nuclear energy—including some enlightened environmentalists—know that renewables can solve only a little bit of the problem. In the meantime, the nuclear option continues to gain support. Domenici previewed the views of James Lovelock, a world-renowned environmentalist, who has said that nuclear power is the only green solution to the world's power needs. The senator added that the former Bishop of Birmingham, Hugh Montefiori, wrote in the last few weeks, "As a theologian I believe that we have a duty to play our full part in safeguarding the future of our planet. It is because of that commitment that I have come to the conclusion that the solution is to make more use of nuclear energy." This led to the bishop's being kicked off the board of Friends of the Earth.

Continued

Looking at congressional issues, Domenici said that an energy bill will be passed, but its cornerstone is not going to be energy independence. Like many others in Congress, he does not believe that Americans would accept the sacrifices that would be necessary to reach independence soon. And so the legislation will concentrate on moving toward diversity of sources, with a special emphasis on how we produce electricity, and upgrading national grid connections, particularly to avoid more blackouts. At the same time, he said, we must have feedstock that will keep the air clean and prevent global warming.

As for Yucca Mountain, Domenici explained the current funding problem, which was worse than usual because of an error made by the White House, leaving a gap of some $577 million. (The senator succeeded in resolving this issue a couple of weeks later.) Another Yucca Mountain problem, he said, relates to environmental standards. "Beyond any comprehension," the senator said, a court recently ruled that the Environmental Protection Agency was wrong when it set a 10 000-year standard for protection instead of matching the peak dose, which the National Academy of Sciences suggested might occur in a few hundred thousand years. The issue can be resolved, he said, through congressional hearings and new legislation or a new EPA standard, but he could not say when.

Past ANS President Larry Foulke (2003–2004) asked if construction tax credits would be included in the new bill. Domenici replied that he thinks Congress will move toward that solution. There will be a big "hoo-hah" about it, he said, but, as renewables also need it, he thinks it will happen.

An environmentalist for nuclear

The next presentation was a video interview of James Lovelock, conducted by Sue Lyon, president of the British Nuclear Energy Society and director for science and research at British Nuclear Fuels plc (BNFL). Lyon noted that Lovelock is one of the ideological leaders on the environment and has a "fantastic" standing in the international community. At the heart of his beliefs is the Gaia theory, which views the earth as a self-regulating entity and claims that anything that affects the earth and its long-term future is very important to humankind. Lovelock wondered how so many environmentalists can think that global warming is the most important issue facing mankind and yet deny the opportunity to use nuclear energy.

Lovelock explained that when the Intergovernmental Panel on Climate Change (IPCC) published its first report in 1990, no one was really sure that global warming was real. To determine with some certainty that global warming does exist, the panel set up a test—based on a rise in temperature beyond half a degree Celsius—that it thought would provide the necessary level of confidence. What surprised the panel was how soon it was reached: in 1999. Should anyone, Lovelock said, doubt how bad things are, just look at the unprecedented heat wave in Europe last summer (2003). It was, he noted, five standard deviations beyond anything that had happened before. For Lovelock, it was almost unequivocally a consequence of global warming. "I regard that as the first real warning of much worse to come."

Lovelock wondered how so many environmentalists can think that global warming is the most important issue facing mankind and yet deny the opportunity to use nuclear energy.

Among climatologists, said Lovelock, the consensus is that if nothing is done, at some time during this century, a threshold will be passed, in terms of a rise in temperature and carbon dioxide concentrations, at which point climate change will become irreversible. This means that the world will continue warming, and the consequences will be with us for a thousand years. It will be an utterly changed world that will not be able to support the current population. We have to think of our descendants, he said: Are we going to leave them an utterly impoverished world because we were too slow, too selfish, or too indolent to do anything about it? We seem to forget, Lovelock stressed, that we live on a self-regulating planet, and the comfortable climate we enjoy is managed by the rest of life.

Lovelock said he disagreed with the Greens right from the beginning. They have presented a "false story based on humanism," he said, while his concern is for the earth. "If we do not take care of the earth, the earth will be unable to take care of us. If we damage it, we damage ourselves. The Greens do not seem to understand this. . . . They have sucked themselves into a rather false and bad position of using fear of cancer to get support. . . . We all breathed in the dust of weapons testing in the 1960s. If the Greens had been even a fraction right, we should all be dying of much more cancer than we are. We are not. If anything, the rate has dropped."

"Nuclear waste really irritates me," said Lovelock. Wastes from nuclear energy, he said, are one of its major benefits, as there is so little of it. If the invisible mountains of carbon dioxide being released are considered, he said, to fret about a few cubic meters of high-level waste is "absurd, it's ridiculous," and it is not a problem at all.

The next speaker was Gail Marcus, a past President of ANS (2001–2002), who currently is the deputy director general of the Paris-based OECD Nuclear Energy Agency, which has done a study on "externalities" called *Nuclear Electricity Generation: What are the External Costs?* One of the main reasons for doing the study was to examine claims by opponents that nuclear power would be much more expensive if all the external costs were included. The study actually shows the opposite, said Marcus, who, along with Tulenko, thinks the report needs to be better known.

Marcus

Marcus defined an externality as a cost or benefit that is not included in the market price of goods or services. It can be negative, such as health damages from pollution, or positive, such as contributing to security of supply. If externalities are not accounted for, she said, consumers get a wrong price signal, as society, not consumers, bears the costs of the damages caused. Market mechanisms then fail to promote the cheapest option for society as a whole, she added.

Part of the problem is that in most cases it is difficult to attach a dollar value to costs or benefits. For items such as decommissioning and waste management, there are many uncertainties. In the case of the impact of severe accidents, there will be some costs not covered by existing forms of liability insurance, she said. External benefits, such as security of supply, can be even more difficult, if not impossible, to quantify.

"I know there are many here who will quarrel [with the assumptions]," said Marcus. " I will point out that we were trying to do a bounding calculation to see whether external costs are as large as some people

claim." In fact, the results demonstrated that external costs for nuclear power are very low, she said—only 5 to 6 percent of the total—and the authors think that this is a good bounding estimate. Marcus then presented the external costs of other sources. Nuclear and the renewables are all found to be much lower than the fossil fuels. Looking at total production costs, however, the picture changes, she observed, with wind power nearing the total cost of coal and oil (although these figures were from 1999, before the large increases in fossil fuel prices of recent years).

In conclusion, she said that internalizing external costs of all electricity generation alternatives would only enhance the competitiveness of nuclear energy.

Telling a new nuclear story

The final speaker, Alain Bucaille, from Areva, described the new approach for handling nuclear public relations adopted in France some four years ago. A new approach was deemed necessary because the national consensus in support of nuclear power that had existed since the 1970s began eroding after 1990, dropping 1 percent every year. By a happy coincidence, however, this downward trend began to reverse itself in 2000, just when the project began.

Bucaille

Under the new approach, industry was to be active, not passive, in its public relations, realizing the need to market nuclear power, not just to argue the case. Marketing requires a strong message—in this case, that nuclear energy is not an option, but a requirement. It also focuses on the undecided: "We no longer speak to opponents," Bucaille said. The approach requires greater understanding of public opinion, communicating directly to business as well as the public ("If the people in charge of the economy are not interested in nuclear energy, then forget it," Bucaille said), and provoking debate instead of simply reacting to it.

The first move was to use an advanced consumer survey technique to characterize opinions. It involves fairly extensive questioning of members of the public over one to three separate interviews. This technique, he said, was developed by consumer product groups to assess their trademarks. As far as he knew, only seven or eight companies (selling cars, food, and luxury goods) have used it. It is expensive and demanding. You do not really find out things that are not already known, he said, but you increase your knowledge of the problem considerably. It is based on a belief that to communicate is not only a matter of packaging and educating, but also a matter of marketing.

The survey identified the reasons for the change in public opinion that began around 2000. They are: the expansion of nuclear power outside Europe (35 percent); events in Israel/Iraq/Chechnya (65 percent); the advantages of nuclear energy (65 percent); oil spillages (70 percent); and the greenhouse effect (85 percent). This change in attitude was demonstrated over the proposal made by Electricité de France to order a new reactor, the advanced European Pressurized water Reactor (EPR). Following the national energy debate during 2003, public support for the idea rose from below 50 percent to over 80 percent.

Under the new approach [in France], industry was to be active, not passive, in its public relations, realizing the need to market nuclear power, not just to argue the case.

The biggest challenge, Bucaille said, is to win the debate on waste. The survey showed that:

- 70 percent of people are frightened about *waste.*
- Only 6 percent base their fears on *real facts.*
- 94 percent are frightened by what they *imagine to be true.*

It was clear, Bucaille said, that people's imagination is so strong that they will take it for reality. The team developed the idea of analyzing how imagination worked on this issue. They concluded that the opposition to waste was not really about waste; it was linked to other "phenomena," such as the person's relationship with nature, with history, and with modernity. Using these results, a storyline was developed to answer their real concerns. It was designed to "strike a chord" with people's reason and with their sensitivity—both the right and left sides of the brain. An approach that is merely factual and educational is not enough, he said.

Part of the storyline is the following:

- Many of the problems associated with waste have already been solved, and we have been making continuous progress for the last 20 years.
- The treatment process (recycling plus vitrification) means that the most "frightening" types of radioactivity can be contained quite safely. A great deal of progress has been made in the last 25 years.
- Once the decision to treat used fuel has been made, the main question is what to do with the resulting glass.
- Even if vitrified waste were immersed in water, it would be exceptionally resistant to all kinds of leaching (99.9 percent 10 000 years from now with permanent high flows of water); this is all the more true in an impermeable environment where infinitesimal amounts of water circulate.
- This resistance is all the more important in that the level of radioactivity of today's waste will be divided by a factor of one thousand, 10 000 years from now.

Finally, Bucaille noted that while he does not expect other countries to adopt a French energy mix, if 12 other major countries adopted it, we would reduce carbon dioxide emissions by 20 percent.

Emergency preparedness, response

The session on emergency preparedness and response covered the efforts of industry, the Nuclear Regulatory Commission, and the Department of Energy to deal with the security issues created in the aftermath of the terrorist attacks of September 11, 2001. The session was sponsored by the ANS Environmental Sciences Division and chaired by Kent Welter, of the NRC's Office of Nuclear Regulatory Research.

The first speaker was Jim Fairobent, director of the Office of Emergency Management in the DOE's National Nuclear Security Administration. Fairobent explained that for the DOE, "Comprehensive Emergency Management," the title of his presentation, addressed all the elements of emergency management: hazards, emergency planning, emergency preparedness, readiness assurance, emergency response, and recovery.

For the DOE, hazards include everything that could affect its sites, from natural phenomena, to the release of hazardous material, to terrorist events. Emergency preparedness refers to demonstrating readiness to respond to emergencies; this includes evaluations, corrective action programs, lessons-learned programs, and documenting what would have to be done in an emergency. The last item, recovery, begins as the emergency response fades out.

Emergency management, said Fairobent, comes in when the safety and protection systems, which aim at controlling hazards and preventing accidents, fail. It has the goal of mitigating consequences, reducing impacts, and protecting public health and safety. The DOE's emergency management program was developed in the wake of the Three Mile Island-2 accident. The department started by considering nuclear emer-

gencies, using NRC guidance. It expanded to include chemicals in the 1990s, taking lessons from the accident at Bhopal, India, and other accidents. The department is now extending its program to hazardous biological agents/toxins, as the national labs are using these more and more.

The DOE's Base Emergency Management Program (BEMP) starts with general requirements and adds measures that the DOE needs to standardize across its complex (e.g., notification protocols, basic training, and drill requirements). Because not all sites are equal, the DOE has set up an approach called "Commensurate with Hazards," which allows individual sites and facilities to tailor emergency management programs to their specific needs (e.g., earthquakes in southern California, tornados in the Midwest). The approach requires an analysis of the hazards present and their potential impact on workers, the public, and the environment. The analysis should address a spectrum of initiating events for emergencies.

The Hazardous Material Emergency Management Program builds on the BEMP to address the specific planning needs for hazardous materials and utilizes protective action criteria. While industry is familiar with the Environmental Protection Agency's (EPA) radiation protective action guides, there is nothing comparable for chemical materials. The EPA is developing Acute Exposure Guideline Levels for chemicals, but they are not yet available for all the thousands out there. In 1995, the DOE put together an internal group to develop a methodology for calculating interim values, which it calls Temporary Emergency Exposure Limits. These now exist for more than 1700 chemicals. Work is also in progress to develop criteria for biological agents and toxins.

Protective action strategies

The next speaker, Dave Leaver, of Polestar Applied Technology, is involved in a project to assess the effectiveness of off-site emergency response protective action strategies for nuclear power plants. The project is sponsored by the nuclear industry under Nuclear Energy Institute and Electric Power Research Institute leadership. The main objectives are, first, to provide an updated technical basis for emergency planning, including the development of a risk-informed framework; and second, to develop a methodology that would help identify and evaluate protective action strategies that could significantly reduce public risk from a range of accidents.

To start, the team considered typical plants in order to develop a generic methodology for evaluating protective action strategies. The first task was to update source terms—which can also be referred to as "release categories"—associated with accident sequences. Besides the traditional events, such as loss-of-coolant accidents, station blackout transients, and containment bypass, they are also determining source terms for other situations, such as shutdown events, spent fuel pool events, external events (e.g., earthquakes), and terrorist-initiated events.

In determining source terms, the project is following the lead of NRC Chairman Nils Diaz, who is promoting his concept of "realistic conservatism," which in this case means using realistic, not worst-case, scenarios. In the same vein, the aim is eventually to develop off-site emergency response plans that are "recognizable, usable, and practical." The project also intends to develop a set of release categories for emergency planning in a way that should discourage the misuse of the results. Leaver said that an exercise that involves calculating disastrous results for highly unrealistic events helps no one, wastes resources, and could create unnecessary public fear.

"[W]hen an incident occurs, we are all on the same side. The NRC stops being a regulator and starts being a facilitator, a coordinator, a helper."

The second task is to develop a risk-informed framework. This includes devising a "risk metric" that would measure the effectiveness of off-site emergency responses. This would be similar in concept to core damage frequency and large early release frequency metrics, which are used to set acceptable/unacceptable reactor risks based on NRC safety goals. The risk metric being considered for emergency response is near-site "individual early fatality risk" (IEFR).

A third task is to develop a consequence modeling procedure that takes into account the conditions (e.g., weather and road) at the time of an accident. It is then possible to evaluate the effectiveness of different protective action strategies, such as evacuation versus sheltering and strategies that combine the two.

Leaver said that a good strategy should be simple but effective in reducing the IEFR and overall dose. It also should be easily implemented by the off-site response organization and its effectiveness in reducing risk easily understood by the public. Examples of protective action strategies that are being considered are the following:

- Evacuation from near site areas (e.g., 1 or 2 miles) by walking.
- Evacuation to a shelter within the emergency planning zone, as opposed to a shelter that is outside.
- Providing more specific guidance as to when to shelter and when to evacuate.
- Real-time plume monitoring using the latest technology.
- Use of plume marking.
- Real-time optimization of protective actions.

Two speakers came from the NRC's Office of Nuclear Security and Incident Response. Susan Frant, the deputy director of the Incident Response Directorate, described the NRC's role in incident response, noting that the licensee's role tends to be clearer: to mitigate whatever is happening and make recommendations to state and local officials who have the authority to take action.

The NRC is among the radiological resources available during an emergency to help assess what is going on and figure out what to do. As part of the federal family, the NRC is also able to coordinate activities with other federal agencies, including the Department of Homeland Security. While "the licensee is the firefighter," said Frant, "when an incident occurs, we are all on the same side. The NRC stops being a regulator and starts being a facilitator, a coordinator, a helper." The NRC can ensure that the resources needed are available, and that state and local authorities are taking action to protect public health and safety, she added.

Frant described some of the work of the 24/7 operations center, which gets called around 17 to 30 times a year. These are almost always unusual events (UE), such as a fire or transformer explosion. A UE will usually be exited within a couple of hours—"end of story." During that time, the licensee keeps the center informed. The center notifies other people in the agency, because, since 9/11, the question is always asked: Could this be a trigger for a much bigger event?

According to Frant, there have been only a few plant alerts, the next level up from a UE. The only recent example of an event at the next level—a site area emergency—was at a fuel facility in 2003; the last one that occurred at a power plant was in 1979. The next level up from that is a general emergency. In a real emergency, the NRC response would be led by the chairman, as he or she alone has the statutory authority to tell licensees what to do.

Frant also discussed the improvement initiative work that she is heading up for the chairman. While the NRC thinks that what it is doing is effective and sound, she noted,

after 25 years, it is time to take a good look at it. The questions being asked include: Do we have the right resources? Do we qualify our incident responders correctly? Is our staff adequate to provide the required support for the National Response Plan and for our licensees in the post 9/11 threat environment? She is also taking a good look at the emergency planning documents and at ways to use modern communication technology in this area.

Information on further work of the NRC was provided by Kathryn Brock, a senior emergency preparedness specialist. Previously, all emergency preparedness work had been done in the Office of Nuclear Reactor Regulation. That effort was turned into the Emergency Preparedness Directorate (EPD) formed in summer 2004.

The EPD is responsible for developing emergency preparedness policies, regulations, and guidelines. It is also the contact point for the regional offices and provides coordination with state, local, and federal agencies. EPD has about 27 people divided into five teams.

1. The Communications group, which wants to let people—inside and outside the NRC—know what the EPD is doing. This is the group in which Brock is involved. External communications are vital, not only with other agencies, but also with the media, which has changed dramatically in recent years. CNN, she notes, can be anywhere at any time, and the NRC has to respond using 21st-century technologies to get good information out quickly. A new Web page is aimed at providing information for all types of stakeholders.
2. The Inspection group is the main link with the regions. It prepares guidance and helps with inspections and emergency exercises. The group follows events called in by licensees, assessing the problem and determining if action is needed.
3. The Licensing group is busy now assessing early site permit applications, looking at all the EP aspects.
4. The Security interface group did the vulnerability studies called for after 9/11. It just finished a pilot program with licensees on force-on-force exercises.
5. The Regulatory Improvement group is involved in improving regulations through rulemakings, preparing regulatory guides, and other measures. For example, it has come to the group's attention that some licensees had taken sheltering out of their range of protective actions, in part because the NRC has been so focused on evacuation. A two-year study is under way to see how to enhance sheltering as a protective action. Sandia has already done a study on evacuations that showed that they work well. It found, for example, that emergency workers do not just take off with everyone else and not return; they come back and do their jobs.

Advanced technologies

Two presentations described how advanced technologies are being used to develop fast and effective emergency response.

Even before the events of 9/11, California's San Onofre Nuclear Generating Station was upgrading its security capability. Ky Nguyen described work undertaken on force-on-force (FOF) exercises, which he called "war games in a security arena." These exercises use a Multiple Integrated Laser Engagement System—MILES—which features third-generation eye-safe laser gear. The advantage of the third-generation system is that it provides a high-quality casualty assessment, which was lacking in earlier generations. This means that if a player is shot, his weapon is disabled; this avoids "dead" players continuing to shoot. If a vehicle is hit, the results depend on the angle and the amount of energy it receives: It could be totally blown away, immobilized, or affected in some other way.

Early FOF exercises involved site-penetration games. Now, the aim is to penetrate the control room. The NRC stopped FOF exercises immediately following 9/11, but resumed them with a pilot program in 2003. The new exercises are to be much more ambitious, where "the bad guys have more capability and more intelligence." He mentioned a contractor that offers a "ninja" team for very advanced exercises.

[In an emergency,] external communications are vital, not only with other agencies, but also with the media, which has changed dramatically in recent years.

A safety evaluation of the MILES gear was carried out by NRC staff in 2003. It covered three areas: EMI-RFI electronic emissions, laser light emissions, and smoke emissions (the MILES-converted rifles actually fire blanks, which use "smokeless" gun powder that does, however, produce some smoke). The NRC study concluded that the equipment will not affect safety-related instrumentation in the plant, nor does it present a hazard to people. The smoke, however, could affect smoke detectors and requires operators to analyze this for their plant. Nguyen described the work being done at his plant.

Yong Li, an NRC geophysicist, described development work he has been doing using Geographic Information System software as an emergency response system for nuclear facilities. Such a system can provide a lot of help to authorities in emergencies: calculating damage distributions, determining how to allocate emergency resources, finding the best evacuation path, and more.

A system should be able to cover a wide range of events, including plant accidents, external events (e.g., hurricanes and earthquakes), and terrorist attacks. It should have access to databases providing information about the area (for example, maps, population distributions, and local activities), about facilities (details of nuclear plants, schools, shelters, hospitals, police, and fire equipment), and other information, as well as access to real-time data (over the Internet) from, for example, weather, radiation and other environmental monitoring stations, satellites, camera images, traffic monitors, and others. The software should have the capability to integrate the information and analyze it quickly. He used data primarily extracted from the Federal Emergency Management Agency's HAZUS-MH (multihazard software program).

As an example, for an accident with releases outside the plant, his system can connect to weather monitoring stations and satellites to track the plume, show the affected area, and determine which population should be evacuated and to where. For a terrorist situation, his system can use topographic data to identify locations where the plant can be viewed directly to predict where a terrorist may launch a weapon.

During the discussion it was noted how expensive his system is. Li agreed, explaining that his work was to investigate how powerful this tool was, particularly given all the information already out there. The NRC is now looking at what level of information is really needed for an emergency system.

Alternative source term use

The Nuclear Regulatory Commission amended its regulations in 1999 to allow power reactor licensees to use an alternative source term (AST) for radioactive release to reflect the known chemical behavior of radionuclides that would be released from a damaged core. AST use can lower costs and regulatory burdens and allow less complexity in plant systems, but a paper by the NRC's Stephen F. LaVie showed that licensees sometimes misinterpret the amended rule and related guidance, prompting the NRC to ask for more information and delaying approval of AST use. (LaVie

was not able to attend the session, "Alternative Source Term Applications to Improve Power Reactor Safety Analysis"; the paper was presented by Michelle Hart, also of the NRC.)

Among other things, LaVie noted that although Regulatory Guide 1.183 states that 10 percent of total leaked iodine should be assumed to escape as an airborne release, some applicants have assumed 10 percent release only of elemental iodine, excluding cesium iodide, which is generally presumed not to become airborne. LaVie maintained, however, that leakage into a building sump with an acidic pH would increase conversion of cesium iodide to elemental iodine. His presentation cited research showing that 2 to 20 percent of the iodine in a liquid pool would be converted to a volatile form, probably elemental iodine, when the pool evaporates to dryness.

The other side of the situation was represented by William R. Ziegler of Progress Energy, who spoke on his company's experience in seeking to switch to AST use at its five power reactors. Among other things, Ziegler said that the NRC is reluctant to allow flexibility in the interpretation of Regulatory Guide 1.183. He said that conversion to AST has been completed at Brunswick-1 and -2, Crystal River-3, and Harris, but noted the recent disapproval by the NRC of AST use for loss-of-coolant accident scenarios at Robinson-2 (*NN*, Nov. 2004, p. 12). Ziegler said that the effort for Robinson-2 was complicated by the age of the plant, not because of hardware condition but because of the piecemeal licensing that was done in the early days of power reactor regulation. And so, much of the AST-related work involved redoing old documentation to achieve consistency. He also noted that some of the AST submittals were later found to have been modeled improperly.

While AST adoption has overall benefits for the licensee, some extra expenditure may be required in the short term. Christie Taylor, of Duke Power Company, reported that AST use at the three-unit Oconee plant would require that the control room air intakes be moved from the roof of the auxiliary building to the roof of the turbine building, with two intakes for each unit; these changes are necessary to support relaxations on containment closure during fuel movement. Also, the high-pressure injection/low-pressure injection relief valve discharge will be rerouted into the reactor building emergency sump, and the existing active Caustic Addition System will be replaced with a passive system that requires no operator action and is not susceptible to single active failures.

John Duffy, of PSEG Nuclear LLC, reported that his company has submitted five AST-related applications to the NRC for its three reactors at the Salem/Hope Creek site, with three of them approved by the NRC thus far and the others still pending. Through AST use, said Duffy, PSEG is able to operate Hope Creek with a higher allowable leak rate for its main steam isolation valves (MSIV) and has eliminated the MSIV sealing system and the filtration, recirculation, and ventilation systems' recirculation filters. Duffy added that the two Salem units now have revised requirements for fuel decay time prior to the commencement of irradiated fuel movement.

Project Prometheus

The possibility of a larger role for nuclear energy in forthcoming missions to outer space has lately been discussed with somewhat more vigor, but the speakers at the special session on Project Prometheus—the joint effort of the Department of Energy and the National Aeronautics and Space Administration (NASA) to maximize the nuclear energy options for spacecraft—still recognized that the more ambitious prospects would encounter considerable public wariness, if not outright opposition. The issue here is not what the nuclear energy systems would do in outer space, but what they would do (and how they would be secured) between here and there.

The . . . Cassini-Huygens mission . . . is powered by an RTG, and the fact that this mission has thus far gone without a hitch may help brighten the image of nuclear energy in space.

The session, "Project Prometheus Overview: Nuclear Science and Technology in Space," was chaired by Milton Klein, retired vice president of the Electric Power Research Institute and onetime manager of the Space Nuclear Systems Division set up jointly by NASA and the Atomic Energy Commission in the 1950s.

Klein

In his opening remarks, he said that the strong performance of radioisotope thermoelectric generators (RTG), which generate electricity from the radioactive decay of otherwise passive materials, may be boosting interest in the long-dormant concept of critical assembly reactors with much higher energy output, perhaps for the actual propulsion of spacecraft. RTGs mainly provide power for onboard operations, experiments, and communications to and from Earth; Klein said that some RTGs are still operating as designed more than 30 years after activation, far from Earth and any possibility of repair. As for reactors, Klein recalled the work done until the early 1970s on the nuclear thermal rocket. These tests released fission products to the atmosphere, but, he asserted, the effluent could be scrubbed to prevent such releases, and there are no extreme technical barriers to the development of a space propulsion reactor that could produce 250 000 pounds of thrust.

Because most of the interesting destinations for planetary science are far from the sun, the capabilities of solar energy drop accordingly, thanks to the inverse square law. The current Cassini-Huygens mission—exploring Saturn, its rings, and its moons—is powered by an RTG, and the fact that this mission has thus far gone without a hitch may help brighten the image of nuclear energy in space. The RTG choice had been criticized as a potential environmental threat, both during the launch and in the orbital trajectory that brought the spacecraft near Earth for a gravitic assist toward Saturn.

Matt Forsbacka, of NASA, surveyed Project Prometheus and the mission that would be its debut, if ultimately approved: the Jupiter Icy Moons Orbiter (JIMO), which would spend four to six years in close proximity to the Jovian moons Callisto, Europa, and Ganymede, where substantial amounts of water ice are known to exist on their surfaces. The instrument packages would study the moons' oceans (seeking liquid water), astrobiology (seeking volatiles and organic chemicals), and Jovian system interactions (the tidal relationship of the planet and its moons). JIMO would be aimed for launch in the 2012–2015 time frame and would employ a nuclear reactor to power ion propulsion.

Forsbacka

As space science becomes more ambitious, the payloads will have to increase. Forsbacka said that reactors with capacities in the hundreds of kilowatts could carry science payloads of more than 500 kilograms. JIMO would set the stage for more ex-

tensive missions to Saturn and its moons, Neptune and its moons, the Kuiper Belt, and the near reaches of interstellar space. It is also expected that Earth's moon will be used as a staging area for eventual missions sending humans to Mars. Forsbacka added that NASA will comply with the National Environmental Policy Act with respect to the launching of reactors into space.

Initial design work on the JIMO reactor began in April 2004, according to Michael J. Wollman, of the Knolls Atomic Power Laboratory. Reporting on the Naval Reactor Program's involvement in Prometheus, Wollman said that the goal is a device with peak power in the range of 135 to 200 kWe, running for 12 to 15 years at full power, with an operating temperature between 950 and 1350 K. The reactor would be designed so that if there were a problem upon launch of the spacecraft, the reactor would be subcritical upon impact with the Earth. Reporting on development of reactors other than the one for JIMO, Jack Wheeler, of the DOE, said that technology development is sought for surface power systems (for habitation on the moon and Mars), nuclear thermal propulsion, and multi-megawatt nuclear electric propulsion (which might shorten the duration of cargo missions to Mars). He said that work may take place during fiscal year 2005 on fuel performance, technology adaptation, materials and shielding, and component and control technology.

Victoria Friedensen, of NASA, addressed the job of selling all of this to the public. She noted that although NASA has generally enjoyed widespread public support, the *Columbia* shuttle disaster in 2003 has forced the agency to address concerns about what else could go wrong. She said that the concerns generally have three components: Trust (Why should I trust you?), Liability (Who pays if something goes wrong?), and Consent (Why wasn't I asked for permission?). NASA is seeking to satisfy the concerns not just through outreach, but also through engagement with the public, fostering technological literacy.

On the specific issue of whether a reactor launch would be controversial, Friedensen mentioned Presidential Directive/National Security Council Memo #25, which states that there must be presidential-level approval (which could mean the head of the Office of Science and Technology Policy) before an RTG or reactor could be launched, and it would follow analyses and evaluations by an interagency group (including NASA, the NRC, and others). A member of the audience noted that the public might have more faith in this process if it involved agencies that may be seen by the public as more impartial, such as the National Science Foundation or the National Academies of Science and Engineering. Friedensen admitted that this could be true.

Decommissioning work

The Department of Energy's West Valley Demonstration Project is a former nuclear fuel reprocessing facility and the first project in the nation to complete, in September 2002, a high-level waste vitrification program. The site came into being through the West Valley Demonstration Project Act of 1980, which made the DOE responsible for solidifying the HLW, disposing of waste created by the solidification, and decommissioning the facilities used in the process.

A sense of ownership in the deactivation work at West Valley has been created . . . because project operators and supervisors have been involved in the job plans.

West Valley's land and facilities are not owned by the DOE, but are the property of the New York State Energy Research and Development Authority (NYSERDA) and represent only 200 acres of the larger Western New York Service Center. This area is approximately 3300 acres and is also owned by NYSERDA. After the DOE completes its responsibilities under the act, it is required to return the premises to New York state. Until that time, the act requires the state to pay 10 percent of the project costs and the DOE to pay the remaining 90 percent.

Much remains to be done to deactivate the site before it can meet all the conditions of the act, according to the DOE. In accordance, the agency is striving to accomplish the majority of the work by 2008.

Rowell

The deactivation activities are being performed for the DOE by West Valley Nuclear Services. During the session, "Decommissioning: General Topics," the company's Laurene Rowell, project manager of facility characterization at West Valley, explained one part of the project—specifically, the first-ever dismantlement of a vitrification cell in the United States.

During the HLW vitrification program, more than 2 271 000 liters (600 000 gallons) of liquid radioactive waste were solidified, said Rowell. The project has now turned its focus to dismantling the vitrification cell, whereby the cell's equipment will be moved and the low-level waste will be shipped off site for disposal.

The cell contains eight major vessels weighing from 9 to 47 metric tons (10 to 52 tons), nearly 300 000 curies of radioactivity, contamination levels in the millions of disintegrations per minute, and 708 m^3 (25 000 ft^3) of wastes to be removed. The project is also being completed in the short time frame of about 15 months, she said.

A sense of ownership in the deactivation work at West Valley has been created, Rowell said, because project operators and supervisors have been involved in the job plans. These workers offer the many levels of experience necessary to complete the task ahead of schedule, and about 65 percent of them actually operated the vitrification system during its processing phase. "This experience has greatly assisted the dismantlement project by allowing the operators to identify and segregate the equipment into appropriate waste types," she said. The operators' knowledge has also reduced the amount of time the engineering staff spends in the field.

Through May 2004, the project team has removed all debris from the floor of the vitrification cell. A Mega-Tech™ shear, a hydraulic tool capable of cutting up to 13-cm (5-in.) pipe, has been successfully deployed and helped remove 160 components used for processing. The Brokk® 330, a remote excavator with a shear and saw-end arm, was modified for in-cell use and has been used successfully during the project. Ninety-four waste boxes have been removed from the facility as of the end of May (out of approximately 161 waste boxes) and 22 have been shipped off site for disposal, Rowell said. The cell's dismantlement was scheduled to be completed by the end of December 2004.

At another DOE facility—the F-Canyon Complex, one of two chemical separations facilities at the DOE's Savannah River Site, in Aiken, S.C.—deactivation work is also under way.

F-Canyon, which began operations in 1954, is a six-story, 835-ft-long, 122-ft-wide nuclear facility. It used nitric acid dissolution and the PUREX chemical solvent extraction process to extract Pu-239 and U-238 from spent nuclear fuel.

The F-Canyon's suspension plan was issued in February 2002 and approved by the DOE in November 2003. The suspension activities include the reduction of hazards by removing radioactive materials and reducing chemical inventory. It also includes early planning for total deactivation, according to George Zachmann, deputy facil-

ity manager at the F-Canyon nuclear separation facility.


Zachmann

F-Canyon's separation area, called the FB-Line, is operated for the DOE by Westinghouse Savannah River Company. The line's mission includes conversion of Pu solutions into Pu metal, along with characterization, stabilization, and packaging and storage of both metal and oxide forms of Pu.

In March 2002, chemical separation activities concluded at F-Canyon and deactivation activities began. The FB-Line will conclude its mission in early 2005, Zachmann said, and the goal is to reduce the facility's operating staff by 93 percent and budget by 94 percent. At the completion of deactivation, F-Canyon will be in "a cold, dark, and dry state" (called post-deactivation) for an undetermined amount of time until decommissioning begins, he said.

The project, which will involve about 12 000 separate activities, has a budget of $579 million and is scheduled to be completed by November 2006. Zachmann said work is currently tracking "significantly ahead of schedule and under budget."

To work on the F-Canyon's deactivation, a "Design Lab" was created to identify improvements in the work force, the work process, and efficiency, explained Steve Howell, deputy facility manager at Savannah River. Those persons elected to participate in the lab came from the Operations, Maintenance, Radiological Control, and Engineering departments and are first-line managers, group managers, professionals, and exempt and nonexempt workers.


Howell

The lab helped create multiskilled deactivation teams and developed more performance-based management and evaluations to assist in meeting objectives. The lab also improved the method of doing the work involved with the deactivation of the F-Canyon. For example, one major change was the improvement of the process used to develop and approve work packages.

In that regard, F-Canyon had been using a software program from Passport Software, Inc., to develop, document, and record maintenance work packages. "For an operational facility that needs to maintain a chronological history of all maintenance activities and materials, this was and still is excellent software," said Howell.

But for deactivation activities such as those in which F-Canyon is involved, the existing software was much more detailed than necessary. As a result, the lab turned to the DOE's Automated Hazards Analysis (AHA) software program, which was in its development stages and was to be ready to use at about the time deactivation was to begin.

AHA is a software program used to identify hazards and hazard controls. It combines software information with employee knowledge to produce a single action plan. "Every activity performed during the deactivation process requires an analysis for hazards and mitigation for each hazard identified, to ensure a safe accomplishment of each deactivation milestone," Howell said. "The AHA software turned out to be an excellent software tool to combine the hazards analysis, mitigation of the hazards, and development of work instructions to perform deactivation work."

For maintenance activities associated with systems and equipment that are to remain in place throughout deactivation of both the F-Canyon and the FB-Line facilities (and will continue to remain when both facilities are in post-deactivation), the Passport system is still used in order to maintain consistency of the maintenance history for the lifetime of that equipment, he said.

In sum, Howell said the deactivation activities at the F-Canyon facility have been improved greatly because of the changes in the organizational structure; the methods used for developing and approving work packages; the processes now in place to identify, analyze, and mitigate hazards; and the multiskilled work teams that have been put in place. So far, these changes have been "extremely cost-effective and efficient, while at the same time helping to maintain a safe as possible work environment for all deactivation employees," he said.

Hydrogen production

The prevailing view these days in the nuclear community is that the surest niche for fission reactors in the future is in a joint role of electricity generation and large-scale production of hydrogen, to serve as a substitute for petrochemical fuels in the transportation sector. For this reason, there was a session on hydrogen production and storage at the Winter Meeting, although this session did not bear directly on the nuclear fields of study. The focus was on basic chemistry, aimed at what is expected to be the operating temperature range of the advanced reactors that have been proposed as hydrogen producers.

Charles Forsberg, senior scientist at Oak Ridge National Laboratory, proposed a system in which the hydrogen produced by steady-state operation of a high-temperature power reactor would be stored underground at the plant site, but would then be used in an accompanying fuel cell power plant to provide peak-demand electricity. Among the potential advantages he pointed out are the ability of a fuel cell to go from shut down to full power almost instantly in response to peak demand; the hydrogen separation process's parallel production of oxygen, which would be fed into the fuel cell instead of air and would improve efficiency; and the elimination of the cost of transporting the hydrogen elsewhere for other uses. The use of fuel cells as peaking plants, he said, would provide the electricity grid with abundant "spinning reserve"; it was the lack of this reserve, he added, that led to the extreme severity of the the August 2003 blackout in the northeast United States and southern Canada.

The prevailing view . . . in the nuclear community is that the surest niche for fission reactors in the future is in a joint role of electricity generation and large-scale production of hydrogen.

Chemical processes for hydrogen production have been studied for several decades, and there are still dozens being pursued, in the hope that one or more will eventually provide the ideal shortcut. These days it is generally agreed that it would be preferable for large-scale production to extract hydrogen from water, rather than natural gas; beyond that, the differences in processes mainly have to do with the required operating temperature, amount of throughput possible, and system support issues like volatility and corrosion. Michael Simpson, of Argonne National Laboratory, reported on an Aspen Plus computer simulation of the Reverse Deacon Cycle, which combines water with magnesium chloride in a three-step cycle that yields hydrogen and oxygen and returns all the other material to magnesium chloride. Simpson said that the simulation found the process to be about 10 percent more efficient than the best-case electrolysis process. The process can also work at temperatures in the range

of 550 °C, well below the 900 °C range often mentioned for hydrogen production. Simpson said that could broaden the choice of reactor, because it would not require only a high-temperature gas-cooled reactor. Liquid metal–cooled fast reactors might also work in this cycle—but not the light-water reactors in wide use today.

[A]t present, industrial infrastructure sufficient to support a large-scale return to power reactor construction in the United States may not exist domestically or worldwide.

Ideally, the chemical formulae for the various hydrogen production cycles show water and other substances going in, and hydrogen, oxygen, and the same other substances coming out. This appears to be very neat, and even suggests a sort of perpetual motion, but not all of the chemical reactions will always go to completion, and sometimes competing reactions can occur under the same conditions. Michele Lewis, also of Argonne, reported on progress with a low-temperature (550 °C or so) copper-chlorine cycle. She said that one of the aims of the work is to reduce the excess water required to make the cycle work. Both Argonne cycles, and sulfur cycles cited in a paper presented by Maximilian Goransek, of Savannah River National Laboratory, would require designing systems that can handle the products of their intermediate steps—in these cases hydrochloric acid and sulfuric acid.

Planning for a century

Technical Program Chair Mark Reinhart, of the Nuclear Regulatory Commission, chose as the topic for his special session "Taking the Lead on Critical Issues—The 100-Year Integrated Plan." In his opening remarks, he said that for nuclear energy to endure in the next century, there would have to be a well-thought-out, integrated approach to policies, programs, design, regulation, utilization, economics, and communication throughout all sectors of the community. He even asked for the attendees to get involved, saying that he wanted to recruit a task force called Nuclear Technology Quest 2100, and giving them an e-mail address to reach him: <parsec248@adelphia.net>.

One example of a plan that could cover several decades, if not a whole century, is the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) development proposal assembled by the International Atomic Energy Agency (IAEA). Mikhail Khorochev, of the IAEA, presented a wealth of detail on potential INPRO projects, which would be carried out by nuclear programs in the member nations most interested in them and coordinated by the IAEA. Case studies have been started on four concepts to assess their prospects for wider application: CAREM-X, an integral pressurized water reactor, by Argentina; an advanced heavy-water reactor, by India; the BN-800 breeder reactor, by Russia; and the DUPIC fuel cycle, by South Korea. The INPRO effort is generally separate from the multinational Generation IV reactor development project.

Whether anyone would be able to turn these projects into working devices on a wide scale may be in doubt, according to Amy Roddey, of American Tank and Fabricating. She said that at present, industrial infrastructure sufficient to support a large-scale return to power reactor construction in the United States may not exist domestically or worldwide. Drawing on her own company's experience in qualifying for an "N" stamp and other certifications for nuclear-grade manufacturing, she argued that the process is essentially punitive and tends to drive away companies that might otherwise become nuclear suppliers. By her statistics, there are now fewer than half as many "N" stamp-holders as there were at the industry's peak in the 1970s. Reinhart responded by saying, "Amy is telling us what we don't want to hear, but what we need to hear."

Legacy materials management

During the session on environmental aspects of legacy materials management, Jody Waugh, of S. M. Stoller Corporation, reported on experience with engineered covers of disposal cells that were established and sealed as part of the effort to isolate uranium mill tailings. He said that early cover designs, prescriptive in nature, did not adequately consider long-term changes in ecological settings. For instance, layers of crushed rock placed on top of the covers—which might be expected to deter vegetation—often encourage it, by collecting moisture. Because so many tailing sites are in arid regions in the western United States, any accumulated water can encourage plant growth. Waugh said that one of the plants found growing on the cover at a site near Grand Junction, Colo., has roots that can extend downward for 40 feet—and covers are usually only about six feet thick.

Waugh said that alternative cover designs are now being developed to mimic natural soil-water balance and make use of plants native to the area, to help deter the arrival of more aggressive exotic plants. She said that the cover at Monticello, Utah, relies on the water storage capacity of a thick soil "sponge" layer above a sand-and-gravel capillary barrier to retain precipitation while plants are dormant; native sagebrush removes precipitation during the growing season. Waugh noted that even in cases where older covers appear to have been permeated, the covers were over-designed, so none of the legacy material has leached out of its confinement.

Educational innovations

A popular computer game played by young people is called "Doom." In it, the player's perspective—or point-of-view—is first person, and the objective is to travel through virtual reality (VR) dungeons using a gun in hand to blast away monsters or Nazis or whatever it is that Doom players like to kill. The point is that Doom and other games like it are immensely popular with the younger crowd, and in trying to connect with that segment of society, there is logic in creating training tools that play like computer games.

Enter the Department of Nuclear, Plasma, and Radiological Engineering at the University of Illinois, which has created a VR laboratory and nuclear plant control room. Instead of a gun in hand, however, the user is equipped with a VR detector that is used to measure radiation fields. The VR program "looks like the video game the students have been playing the previous 18 years of their lives," commented Rizwan Uddin, a nuclear engineering professor at Illinois, during the session on "Innovations in Nuclear Engineering Education, Training, and Distance Learning."


Uddin

Supported by a grant from the Department of Energy's Nuclear Engineering Education Research program, the university is working on developing tools to facilitate the modeling and simulation of VR nuclear plants. The first step is developing tools "from scratch," Uddin said. With the second step, Illinois researchers are using existing CAD software to develop 3-D models of components and their assembly, he said. For example, models of meters, gauges, and levers can be assembled on a control panel; control panels and furniture can be assembled into a control room; and rooms can be assembled to form a building.

The KODADA-1 nuclear power plant can be accessed from a computer located anywhere in the world, provided there is an Internet hookup.

Models can be divided into four categories: static, dynamic, interactive, and interactive/simulators. Static models are the simplest, with no moving parts, and a user can walk or fly through these static virtual models. Dynamic models have moving parts, with predetermined motion that cannot be altered by the user. Interactive models allow the user to move components, such as a chair, by "grabbing" them. Interactive/simulator models are the most detailed and allow the user to interact with the environment and then observe the result or consequence of an action. A simple example, Uddin said, would be a worker with a Geiger counter in a radiation field. As the worker walks around the radiation field, the counter displays the exposure/dose, based on a precalculated radiation field or as determined in real time. Another example is that of a control room in which the operator can press buttons and turn knobs, and the meters and dials, based on precalculated responses or real-time simulations, then display the reactor response.

Hajek

Several models have been developed, Uddin said, including the VR lab for radiation-related experiments, a model of the GUS (graphite uranium subcritical [assembly]) facility at the University of Illinois, and a research reactor.

A similar VR program is being created through international cooperation, explained Brian Hajek, a nuclear engineering professor at Ohio State University. Working with researchers from South Korea, Hajek has helped develop the VR KODADA-1 nuclear power plant—K standing for Korea, O for Ohio State, and DADA for the Korean company (Dadaworlds.com, Inc.) that helped establish it. Project development started in May 2003 and is expected to be complete at the end of 2005. The Korean government provided about $315 000 in financing for the project.

One of the most important aspects of the project was the ability to tap into the same technology used to create computer games, Hajek said. This allows KODADA-1 to have a "rendering capacity" of 15 frames per second, meaning that the visual imaging of the plant is of computer-game quality.

Like the University of Illinois' model, users can perform in different scenarios at KODADA-1. For example, in some scenarios, external exposure rates are provided for routine work done by operators and for workers in high-radiation jobs such as steam generator maintenance and refuelings.

KODADA-1 can be accessed from any personal computer (Pentium 3000 MHz or greater) anywhere in the world as long as there is an online hookup, Hajek said. Connection time on the Internet is 20–30 seconds for initial loading and 3 seconds for subsequent visits. The main server is located in Korea, but there is no difference in access times from either the United States or Korea, he said.

Development work is continuing on KODADA-1 through additional modeling of equipment in the reactor building. By mid-year, work will start on optimizing the Internet connection.

Other research work in South Korea involves development and application of simulation and modeling technologies for nuclear plants, according to Myeong-See Lee, of the Korean Electric Power Institute. The focus of KEPRI's research breaks down into five categories: First, developing a real-time simulation environment for training simulators. Second, using a best estimate code for process modeling. Third, expand-

A VR control panel is used for training at the University of Illinois.

ing the scope of the simulation beyond the plant's DBA (design basis accident). Fourth, creating a new classroom training system that integrates VR with simulation technology. Fifth, establishing an integrated system for validation of human-system interface design.

Distance learning

The ability to conduct reactor experiments over the Internet is being investigated by the University of Tennessee (UT) and North Carolina State University's PULSTAR reactor facility. Developments in both hardware and software during the past few years, coupled with cameras controlled by a remote user, allow nuclear engineering students at UT to use the PULSTAR for a variety of tasks, according to Larry Miller, nuclear engineering professor at UT.

Equipment for performing the remote experiments has been purchased and is being tested, he said. The UT students are able to view the PULSTAR, its personnel, and data on a large LCD screen and on a touch-sensitive "SMART Board™," which is an interactive, 16-ft^2 whiteboard that connects to a computer and digital projector to show a computer image. A user can then take control of computer applications directly from the display, write notes in digital ink, and save work to share later. Likewise, operators, faculty, and administrators at the PULSTAR have similar interactive whiteboard capability to assist in communicating back to the students at UT.

Miller explained that the implementation of remote access to university reactors involves some general tasks, including assessing the data acquisition capabilities at the university reactor; selecting and purchasing the hardware and software for video and audio communication and for control of experimental facilities; selecting experiments for remote participation; and resolving any licensing, safety, and economic issues.

UT is also involved in using distance learning technologies to offer an M.S. degree in nuclear engineering, explained Wes Hines, a nuclear engineering professor at the school. The courses in the program are offered over the Internet by using the Centra Symposium™ software suite. With this delivery method, instructors can reach both distance and local students at the same time "using a SMART Board as the computer interface," he said.

Hines

Hines added that the distance-learning system at UT has the ability to deliver instruction "from a distance," meaning that the instructor doesn't have to be physically located in a classroom to teach a class. As long as the instructor has access to a high-speed Internet connection—whether at home, at a hotel on a business trip, or sitting at a beachside cafe equipped with wireless technology—he or she can communicate both with distance students and students in the classroom.

In this "from a distance" scenario, a SMART Board would be used in the classroom as the computer interface and the distance students would attend as usual. The distance students would have the same access as the local students and could communicate through audio streaming with the instructor. Hines said the instructor would then teach the class using pre-loaded PowerPoint® slides, Windows® applications, and the SMART board. "A special laptop with a touch-sensitive screen is necessary so that the instructor can draw diagrams, graphs, or other items necessary to explain complex engineering principles," he said. These special computers are called tablet PCs.

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Steve Binney, a nuclear engineering professor at Oregon State University (OSU), discussed that school's newly developed distance learning program in nuclear engineering (NE) and radiation health physics (RHP).

Binney

Historically, OSU offered a nuclear engineering undergraduate distance learning program for Trojan nuclear plant employees in the early 1980s in response to augmented post–Three Mile Island-2 accident requirements for plant operators. "When the need for B.S. degrees for operators disappeared, so did the distance program," Binney said.

OSU jumped back into the program in September 2002 when it was awarded a grant from the DOE's Innovations in Nuclear Infrastructure and Education initiative. To resurrect the program, according to Binney, two key decisions were made. First, only graduate-level NE and RHP degrees would be offered, and second, all distance courses would be taught concurrently with their on-campus counterparts.

OSU purchased a distance-learning system from a vendor (Tandberg) and installed it in the school's main Radiation Center classroom. The system consists of a presentation module, an LCD desktop touch panel, room cameras, a compression/decompression module, a streaming encoder, DVD/VCR players, a document camera, a multimedia projector, and a SMART Sympodium™ interactive graphics tablet. The system can double as a videoconferencing center.

With this equipment, the user can show PowerPoint or other computer-based material, play or record on DVDs or video cassettes, use the document camera, and show the instructor or the on-campus class on camera. The distance students see whatever is projected on the screen at the same time the on-campus students are seeing it.

Communication with the distance audience is done through Web streaming. The distant student has the option of viewing the presentation live, although because of conflicting work commitments, most students view archived lectures at their convenience at a password-protected Web site, Binney said.

Communication with the distant students is primarily through one-way audio and video, although, he said, if a group of students were at the same site, communication could be done with two-way audio and video. Under consideration is the installation of a phone line in the Tandberg system to allow two-way audio during the lectures. The awkward part of this, Binney explained, is that there is about a 20-second delay in the signal received at the distant site.

The distance program began in fall 2003 by offering three courses: radiation protection, neutron transport theory, and nuclear radiation shielding. Eight courses are scheduled for the 2004–2005 school year: radiation protection, thermal hydraulics, radiophysics, nuclear criticality safety, radioecology/environmental aspects, radiobiology, radiation dosimetry, and scaling.

To date, according to Binney, distance students from Oregon, Washington, California, Arizona, New Jersey, and Rhode Island have enrolled in these courses. Inquiries have been received from other states and several other countries.—*E. Michael Blake, Dick Kovan, and Rick Michal*