ANS/ENS WINTER MEETING

Commemorating—and advancing—the philosophy of Atoms for Peace

THIS YEAR'S ANS/ENS International Winter Meeting continued commemorations of the 50th anniversary of President Dwight D. Eisenhower's momentous "Atoms for Peace" speech at the United Nations and looked forward to the next 50 years, under the title *Nuclear Technology: Achieving Global Economic Growth While Safeguarding the Environment.* Reflecting Eisenhower's international vision for nuclear energy, this ANS meeting—held jointly with the European Nuclear Society, with cooperation from the Nuclear Energy Institute—heard from leaders throughout the world who are working to ensure that the future is not denied the great benefits of nuclear energy.

The meeting was also held in conjunction with the *Embedded Topical Meeting: Global 2003—Atoms for Prosperity: Updating Eisenhower's Global Vision for Nuclear Energy.*

The meeting had more than its fair share of highlights, not least being the backdrop of New Orleans. Delegates were also privileged to hear Rudolph Giuliani, the charismatic former mayor of New York who showed on September 11, 2001, and in the days following the terrorist attacks what real leadership is. Before then, Giuliani had made his mark leading the renaissance of New York City.

New York was also featured in the second main speech of the plenary session, given by Ed Tirello, who told members about developments on Wall Street that could sabotage plans for building new nuclear plants. It made uncomfortable listening, but reminded the audience that there is never room for complacency.

Before introducing the speakers, chairman John McGaha, of Entergy Nuclear, was able to open the meeting on a high note, announcing that this was already a record-setting conference, with over 1400 preregistrations. McGaha went on to say that this meeting does not just look at the issues from a technical standpoint. "If we are to meet the world's growing need for developments in all areas—medical, agricultural, space, energy supply, etc.—we must deal with issues of public perception, investor confidence, and policy-making."

Global 2003 general chair Yoon Chang, of Argonne National Laboratory, noted that the last time the Global conference was held in the United States, a small fragile U.S. nuclear energy research budget had just reemerged after being mostly stripped from the previous budget. The fate of research has changed substantially since then. Today, he said, "we are truly in a new era thanks to the vision and leadership of our DOE." The international advanced reactor program, Gen-IV, is moving from planning to real research, he noted, and the advanced fuel cycle initiative provides a vision of nuclear energy that has not been seen for some time. He added that even NASA has jumped on the bandwagon, declaring nuclear power to be an "enabling technology for future space exploration."

Greta Dicus, the honorary general chair, took the opportunity to give "my biggest thanks to you the nuclear industry." She explained that since she is no longer an NRC commissioner, she could now say what she liked. What she then said was: "You are the proof of the viability of this technology, whether it be the power plant, R&D, nuclear medicine, whatever . . . you have shown that this technology, which can be hazardous, is safe because you have made it safe and you ought to be applauded for that. I have no doubt you will continue."

Dicus, now a member of the International Commission on Radiological Protection, had one piece of advice, reminding the audience that "no matter how technically successful you are, if you cannot communicate, you will fail."

The theme of communication was taken up by the next speaker, Entergy Corp. President Donald Hintz, who is also chairman of the Nuclear Energy Institute. For the past 50 years, the industry has had its ups and downs, said Hintz, "but nothing compares to the drastic change we experienced on Sept 11, 2001." Communicating to a public feeling somewhat uncertain, scared, and skeptical became even more important for businesses of all kinds, he said. For nuclear professionals, the "trust me" mode would not answer the public's growing "show me" demands on safety and operational excellence. Nuclear's opponents are very savvy about public relations, he warned. They organize sophisticated and high-profile campaigns and other various media strategies to voice nuclear's perceived problems. "They understand the nuclear industry," he said, "and their agenda is to eliminate it."

So, how does this industry not only survive but thrive in this environment? "We must rely on you, the nuclear professionals, more than ever." Armed with the facts, the best way to defend the industry, he said, is through dialog, openness, and accountability. This is how the message that nuclear energy is safe, green, and a vital part of the nation's and the world's electric supply will be clearly heard. In the next 50 years and beyond, Hintz said, the industry has the opportunity to help this planet support a population that will double by mid-century and to sustain this world with its

Major points of the plenary:

- *"If you can't communicate, you will fail"*
- *A future of opportunity, responsibility*
- *"Relentless preparation" for emergencies*
- *"There are new financial risks out there"*
- *Tell the story for new baseload*

environment and its economy not only intact, but enhanced.

"I believe," said Hintz, "the coming decades represent not only an opportunity for our industry, but a responsibility to play an even greater role for bringing light where there is darkness, food where there is hunger, prosperity where there is poverty. We in the nuclear industry believe that we are up to the task, in the spirit with which we responded to President Eisenhower's leadership a half-century ago."

Introducing Giuliani at the plenary session, McGaha observed that from dealing with terrorist attacks to cleaning up the streets, the former mayor had "worked tirelessly to pass New York City to the next generation, better and more beautiful than it was before he entered office." Faced with some formidable challenges of its own, Entergy Nuclear engaged the mayor and his firm, Giuliani Partners, to advise on security and emergency planning issues. Their collective foresights in preparing for the "what-ifs," said McGaha, "will provide us with a fountain of knowledge and experience, a fountain we plan to share with our local, state, and federal law enforcement and emergency planning partners."

Leadership from Giuliani

Giuliani, whose theme was leadership, said that some of the lessons he has learned dealing with emergencies will apply to the nuclear industry. New York City, he noted, has already been through airplane crashes, building collapses, hostage situations, subway derailments, blackouts, all different kinds of crime, and other types of terrorist attacks. The city authorities and its emergency services, he said, had practiced for every scenario they could think of, including a simulated airplane crash and a seran gas attack at the World Trade Center. Detailed computerized emergency plans and instructions were in place, explaining who would do what, and how they would do it.

Despite the efforts made to anticipate all types of emergencies, Giuliani said, authorities did not expect airplanes to be used as missiles crashing into buildings and killing thousands of people. "We were in uncharted territory and had to make up our response. And we did. We had no other choice."

Afterwards, he realized that it would be wrong to say they were unprepared. Actually, they handled the event extremely well precisely because of all the preparation done. It involved "refashioning" what was already prepared. "We had done the planning for all of the elements. . . . So our reaction was not spontaneous. It was a very heavily rehearsed reaction."

The cornerstone, he said, for dealing with emergencies is "relentless preparation," which is also his first principle of leadership. The other five principles he listed were strong beliefs, optimism, courage, teamwork, and communication.

For describing strong beliefs, Giuliani used Ronald Reagan and Martin Luther King, Jr. as models. Reagan knew what he stood for. He developed his principles over many years, not just for the election. His ideas were not popular early on. But this was who he was and he stuck with his principles. King believed in nonviolence. He studied the works of Ghandi and others, developed the concept, communicated it, and became a great leader.

As for optimism, Giuliani simply noted that people respond to solutions to their problems, not the continual words of warning of how difficult the situation is. The other side is trying to distort public opinion, he said, and focuses entirely on risk. Rather than dealing with the risk part of nuclear power, he advised spending 75 percent of effort on putting forward the optimistic message of the value of nuclear energy, what it contributes, and how critical it is to the American economy, safety, security, and position in the world. When talking about risk, he advised talking about the risk of power shortages. The recent blackout in the Northeast probably helped more than anything else in creating new ground for discussing the need for nuclear power.

As for optimism, Giuliani simply noted that people respond to solutions to their problems, not the continual words of warning of how difficult the situation is.

By courage, he said he did not mean fearlessness. If a fire fighter is not frightened when going into a burning building, said Giuliani, he is insane, not courageous, meaning that it is the management of fear that allows achievement of the objective. In fact, fear is critical to courage. Without being afraid, he said, a person cannot display courage, which is properly understanding the danger (risk) and then moving forward. That is how nuclear power should be discussed, he added. The risks are small and they can be ameliorated, managed, and reduced so that the great rewards can be attained.

On teamwork, Giuliani emphasized a number of points. First, "being a leader is not about you, it is about everyone else." A leader also has to know his weaknesses and is able to go out and get help with those—and listen to those people. An example he gave was George W. Bush. As a governor, he had little to do with either foreign affairs or the military. These were two areas, when he became the president, where he went and found a very experienced team, "about the most experienced there had ever been."

As for communication, Giuliani said, "you do this by doing the other five things and then reaching out . . . to people." Members of the public, he said, "do not want structured answers, they want honest answers." He added that if you have strong core beliefs, if you train yourself to think in terms of solving problems, not just repeating them, if you have courage to deal with risks, if you prepare, so you really know what you are talking about, and if your team works well, you will be able to communicate the message honestly and effectively.

One final point about communication and leadership. "You have to love people to be an effective leader. You have to care for them." This is, he said, what he saw in President Bush on his first visit to Ground Zero on Sept 14, 2001.

Risks from Wall Street

For the past three years, Ed Tirello, the next speaker, worked on the investment banking side and is now a managing director and senior power strategist for Berenson and Co. He said his aim at the meeting was to describe developments on Wall Street that the nuclear industry must be made aware of. There are new financial risks out there, he said. "I think they can be managed, but you are going to have to take the time to do it and you are going to have to start right now."

Tirello first described some of the utility risks. While the spent fuel storage risk has "hopefully" been resolved, he said, regulatory risk is coming back. Not from the Nuclear Regulatory Commission or the Federal Energy Regulatory Commission, but from state regulatory commissions. Many companies expected that deregulation would allow them to cover their costs and in the future expected to do very well. This has not happened and deregulation is starting to be reversed. Utilities are now having to go back to state commissions and the con-

frontation is not easy. State commissions are rooted in local priorities made up of "grass roots"–type people who listen very attentively to the voters and the governor.

There is now a new group of people with no experience of nuclear projects, which take longer to complete than gas-fired units, are a lot more involved, and require more oversight, Tirello observed.

And there is a rising tide of ill-informed people opposed to nuclear plants. "And they have nothing better to do. This has to be nipped in the bud."

Utilities are now finding it very difficult to finance their operation, with some being forced into bankruptcy and many others on the brink, he said, and added that Duke Power's stations are now worth only 20 percent of what they were when they were built. Everyone is hoping that prices will go up, but right now they are not, he declared. Furthermore, there are 130 000 MWe of power plants up for sale in this country. In 2002, 62 power plants were sold, of which only two did not have contracts. Most of the plants now for sale have no power purchase contracts and are not worth anywhere near what they cost to build.

Tirello said he believed that this glut would soon be absorbed. Unfortunately, he noted, people are short-sighted, and nobody is building forward. By 2004, 200 000 MWe will be 40 years old, a big proportion of which are coal plants. In 2008, he reckons that shortages will appear again.

The question is, what will the new baseload power plants be? There isn't enough gas, nor will solar and wind be able to do enough. It is either going to be new coal technology and/or nuclear, he predicted. The answer, he added, should be both—but now is the time to start doing something in order to get that answer.

Tirello then explained the dramatic changes in Wall Street, which "were not positive." During the last round of construction in the 1970s, he said, there was in place a group of analysts who understood the nuclear industry, investment bankers who knew how to invest in it, and a capital market that was behind it. It all was tied together. The regulators were also behind it. Everyone was in sync.

But those people are not there any more. There is now a new group of people with no experience of nuclear projects, which take longer to complete than gas-fired units, are a lot more involved, and require more oversight, Tirello observed. In the old days, a lot of information was available and communication between the groups was easy. This has changed, particularly after the spate of scandals in the financial market. The government has set up rules intended to ensure that much more information is available than before, but they have actually worked in reverse. The amount of information available to analysts is 60–70 percent less than before, he noted. Utilities are afraid to say anything other than what they say in a conference call. New rules prevent bankers from talking to analysts, without someone from the legal department present. And if the rules are broken, they can go to jail. So people are just not talking.

Another troublemaker has also come on the scene, Tirello explained: the hedge funds. These make money by shorting stock, meaning that bad news is good for them and good news is bad. They also have the smartest analysts on Wall Street, he added. "To keep informed, they will call up the NRC 50 times a day, they will call every state commission, they call every environmental [group]. They will talk to everyone. . . . They know every aspect of what a company is doing. Their ability to make money depends on it."

What they then do, Tirello said, is short the stock and go public with their story. They will call up the Wall Street analysts and say what the analysts missed, Tirello said. They will call up the newspapers and the rating agencies. They do that all the time, he noted. They are a very potent force that is basically making money on the negative.

As for the other analysts, who are now mostly independent of financial institutions, they may know very little about nuclear power, but are still relied upon by the bankers, Tirello observed.

It is going to be very tough, he said, making a case to these different groups, particularly as the connections that were there before in research, banking, capital markets, etc., are no longer there. The answer is that probably the biggest education job ever will have to be undertaken, identifying the right people, and speaking to them—not once or twice a year at some big forum, but all the time, Tirello stressed. He suggested that the industry create "a mobile education group of industry and company experts" that will go out and talk to these people on a regular basis, pumping out the story. If placing an order for something two or three years from now is desired and the public is not primed, it never will succeed, Tirello predicted.

His message is that the industry should put a real global educational program together, covering both financial and engineering issues, to tell the story about why nuclear plants are the answer to new baseload. "Otherwise, you are doomed."

Atoms for Peace: Update

The *ANS/ENS Presidents' Special Session: From Atoms for Peace to Atoms for Prosperity* was held only weeks before the 50th anniversary of President Eisenhower's celebrated speech before the United Nations. "Eisenhower's words laid the foundation for our organization, our profession, our entire industry," said ANS President Larry Foulke during his opening remarks. "I believe he would be proud to know that today we live in a world of nuclear science and technology, and its wonders are still increasing."

Foulke

If the industry is to keep its wonders growing, it will eventually need to build new power plants in the United States. The Department of Energy's nuclear energy director Bill Magwood provided an update on the effort to build those new plants. "Nothing is more important, when we look at the challenges facing us today, as the breaking through of what I call the 'next plant barrier,'" Magwood said. "Much like the sound barrier of the 1940s and '50s, the next plant barrier is a psychological barrier as much as it is a technical barrier. We are going to have to overcome it if the nuclear industry is going to come back in this country."

Magwood

The DOE established the Nuclear Power 2010 program as a joint effort between government and industry to identify sites for new nuclear power plants, develop new technologies, and demonstrate the new regulatory processes in order to deploy a new nuclear power plant in the United States by the end of the decade. Magwood pointed out that as part of the program, the DOE completed scoping studies for two commercial sites and several federal sites more than a year ago. The department has also developed a business plan that has become a starting point for many of the congressional discussions on financing new nuclear power plants, Magwood said. And three early site permit applica-

tions have gone forward under the Nuclear Power 2010 program. "That's an accomplishment when you think where things were just a few years ago," he said.

Yet much more work needs to be done before a new plant can be built. The licensing process is still slow, Magwood noted. And the next task for the program, to demonstrate the one-step licensing process, is "the hard step, quite frankly," he said.

Magwood then informally announced that the DOE would soon begin seeking applications from the industry to partner with the department on licensing activities for new nuclear power plants. The solicitation will be open for one year, an unusually long amount of time, "but we think it's important to give industry plenty of time together to create the teams necessary to move forward to do this," he said, adding that proposals will be considered on a first-come, first-served basis. "We will not wait for everything to come in before we make selections. We'll review the proposals as they come in. We're very anxious to move forward with this next step."

Closing the fuel cycle

Jacques Bouchard, head of the Nuclear Energy Division of the French Atomic Energy Commission (CEA), is "deeply convinced" that nuclear energy will continue to play a major role in the 21st century and beyond. But in order to do so, the fuel cycles of next-generation technology must be closed—for greater sustainability, public acceptance, and progress for humankind, "following the route President Eisenhower opened 50 years ago," Bouchard said.

In France, removing plutonium from spent fuel and recycling it has been considered a top priority for some time. A plutonium recycling strategy was implemented in France on an industrial scale almost 20 years ago, Bouchard noted. A second priority in France has been the removal of minor actinides, to help reduce the impact of nuclear waste on the environment. He noted that these strategies have met with public acceptance of nuclear energy in France.

"Based on the feedback from stakeholders, including the most knowledgeable members of the French parliament, CEA can assert that implementing partitioning and transmutation of actinides—reducing the toxic lifetime of ultimate high-level waste from tens of thousands to hundreds of years—would certainly change political and public attitudes toward the feasibility and acceptability of HLW [high-level waste] disposal," Bouchard said. "Public acceptance is a prerequisite for nuclear energy development," he added.

Despite the overall unsuitability for use in nuclear weapons of plutonium from light-water reactors, the plutonium should nonetheless be burned as soon as possible after its extraction from spent fuel, Bouchard said, as France has been doing. "We consider that from the nonproliferation point of view, it is better to burn plutonium than to keep it in store," he said.

Proliferation-resistance for the so-called Generation IV technologies, which are in the infancy of design, will be critical to maintaining the attractiveness of nuclear power. It comes down to simply designing systems that are as intrinsically unattractive as possible, from a proliferator's perspective, Bouchard said. "Some characteristics [of Generation IV systems] are certainly interesting regarding nonproliferation, such as high fuel burnup, the full actinides recycling process," Bouchard said. "These integrated systems—with compact recycling technologies, remote handling, with minimization of transports—should obviously facilitate the implementation of external detection techniques and controls, strengthen physical protection, and restrict the accessibility to the nuclear materials. The capacity for safeguarding the systems should thus be taken into consideration."

Fujii-e said that opposing global warming, poverty, and what he called "the nuclear menace" are the goals of the next 50 years for nuclear energy.

Such systems will continue to be in line with the principles of President Eisenhower's Atoms for Peace speech, which called for an international agency to conduct verifications to be sure no country is diverting knowledge or nuclear materials for the wrong use.

Devastation to peace

Since the founding of the Japan Atomic Energy Commission (JAEC), Japan has adopted a strong position on the peaceful use of nuclear energy and nonproliferation, said Yoichi Fujii-e, JAEC chairman. And despite some occasional shakiness in world affairs over the past 50 years since Eisenhower's Atoms for Peace speech, "it is good news that nuclear weapons have never been used in wars in this period," Fujii-e said.

"Although Japan is the only country in the world that has experienced the tragedy of the atomic bomb, we chose to utilize nuclear energy to overcome our inherited geopolitical situation," which, as an island country, has fewer resources than larger nations, he said. "For Japan, the objection to the atomic bomb is closely linked to the peaceful use of nuclear energy on a fundamental level."

Fujii-e said that opposing global warming, poverty, and what he called "the nuclear menace" are the goals of the next 50 years for nuclear energy. Like Bouchard, Fujii-e also believes this can be done in part through closing the nuclear fuel cycle. He said going back centuries, Japanese people have had a strong instinct for recycling. "During the Edo period in Japan [roughly the 17th through mid-19th centuries], isolated from other civilizations for a few centuries, Japanese people created a recycling society centered on agriculture. We have a strong sense of thriftiness and of hating to waste things. Traditionally, we made use of all our efforts in saving and utilizing resources," Fujii-e explained. "From this point of view, it seems to be quite important to establish the closed nuclear fuel cycle in each region to ensure a harmonized and secure society for the people. I would like to stress that the building of a recycling society based on advanced nuclear science and technology is essential for promoting future Asian development.

"Japan is the only nation that has experienced the tragedy and devastation of the atomic bomb, and we yearn to control this power with mercy and wisdom and use it peacefully for humankind," he concluded.

Technical challenges

For the Technical Program Chair's special session, "Challenges for Nuclear Technologies in the 21st Century for Achieving Economic Growth in a Safe Environment," Maurice Ades, of Westinghouse Savannah River Company, introduced a distinguished international panel, who discussed how they saw their different specialties contributing during this century.

Bernard Roche, from Electricité de France (EdF), reminded the audience that nuclear power is alive and does have a big future. It already provides 17 percent of electricity globally, including 30 percent for Europe and 80 percent for France, and in many countries the costs are very competitive.

Europe's two main energy concerns are energy dependency and climate warming, said Roche. It imports 50 percent of its energy and this figure is growing.

Under the Kyoto commitments, the European Union is to decrease releases of CO_2 by 8 percent below 1990 levels during 2008–2012. A recent study, however, predicted that CO_2 emissions will increase.

Farther into the future, if all nuclear pow-

er plants are retired after 40 years, CO_2 production will increase by 4 percent. For CO_2 production to stabilize in the middle of the century, Europe will have to build some 85 new nuclear plants, Roche declared.

While believing that a number of European countries should build new nuclear units soon, EdF will not need new baseload or semi-baseload generators before 2020, Roche explained. The reasons include: its nuclear plants are relatively young (average age, 17 years); with deregulation, EdF expects to lose some customers; because cogeneration has not been developed in the country, EdF expects it will start expanding; and the use of wind power will grow.

Despite nuclear's dominance in France, a recent poll showed that 50 percent of French people think that nuclear power is associated with CO_2 emissions. "There is a lot of work to do to educate the public," Roche said. A lot of educating did take place during the national debate on energy policy carried out by the government in 2003. This public debate revealed a large consensus in favor of a low-carbon economy and support for strong governmental policies to ensure this happens. Just as important, said Roche, no move against nuclear power was seen. The government has already indicated its support of new nuclear construction, and it is likely that a bill will be introduced in parliament to allow EdF to order a reactor. It will also try to promote a reduction in consumption and an expansion of renewables, which are supposed to supply 21 percent of energy needs by 2010 under a European Union directive.

EdF thinks that Generation III reactors will need to be built over the next two to three decades until Generation IV systems are commercially available, around 2035–2040, said Roche.

EdF wants to begin connecting new plants to the grid from 2020 to replace the first tranche of its 900-MWe reactors as they reach 40 years, he added. To prepare for this, EdF would like to have a demonstration plant in operation before 2012, which means ordering one right now. The choice will have to be for a Gen III plant, as "we cannot wait for Generation IV reactors," said Roche. Although the preference for the demonstration unit is the European pressurized water reactor (EPR), in part because it has been cleared by the safety authorities, said Roche, by 2015, other proven Generation III+ designs will be considered. As for Gen IV systems, Roche said, France is particularly interested in high-temperature reactors, notably for hydrogen production, gas-cooled fast reactors, and sodium-cooled fast reactors.

Radiation in medicine

The first of the speakers on nonpower applications of nuclear technology was Richard Wainerdi, president of the Texas Medical Center in Houston, Tex. During the first half of the 20th century, including the immediate aftermath of the Hiroshima and Nagasaki bombings, a large amount of research was done on the use of radiation and isotopes in medicine and some applications. While this was still fragmentary and rudimentary, Wainerdi explained, it was starting to become clear that the effect of radiation on the human body and other living things was substantially different from what was expected.

Nevertheless, the use of low-level radioactive materials in medicine thrived from the 1940s, with many applications possible in no other way. The accidents at TMI and Chernobyl, however, raised extraordinary fears not only of exposure, but also of the disposal of radioactive materials used in medicine. This has led to more controls over the medical use of radiation, and today, whenever an alternative exists, he said, radiation is not chosen.

He added, however, that there continues to be considerable development in the use of nuclear technology in medicine. At the Texas Medical Center, a very aggressive program of focused-beam radiation therapy is taking place.

Machi pointed out that the economic value of nonpower (radiation and isotope) applications in Japan is about the same as power applications, nearly $50 billion.

The technology has advanced light-years since radiotherapy began using cobalt sources, Wainerdi said. Today, advanced focused proton beam facilities are being introduced throughout the United States. These facilities provide tremendous precision with almost no damage to other tissues, he explained. His center is building one at a cost of $125 million. Cyclotrons are also being used for fast neutron beam therapy.

A use of nuclear technology on the edge of medicine is forensic science. There is a great interest in developing better methods to identify materials as to age and environment. The use of advanced neutron activation analysis combined with other techniques can provide accurate trace matching for comparison purposes. It also has a growing role in supporting DNA identification.

Environmental and human protection

While Japan's dependence on nuclear power is well known, explained Sueo Machi, senior managing director for the Japan Atomic Industrial Forum, his country is equally committed to developing nonpower nuclear technologies for applications, such as environmental protection, food safety and productivity, health, and industry. Machi pointed out that the economic value of nonpower (radiation and isotope) applications in Japan is about the same as power applications, nearly $50 billion. He began with environmental applications, describing the use of electron beams to remove SO_2 and NOx from flue gases in coal-fired stations. He said that this technology was first developed by JAERI and Ebara in Japan. There are three electron beam plants in commercial operation, two in China and one in Poland.

Unlike conventional methods of separating these pollutants, said Machi, electron beams remove both sources simultaneously. The same process can also be used for removing dioxins and other chemicals. A pilot facility is now being used to clean waste water at a dye factory in South Korea.

Pests reduce world food production by 25–35 percent, said Machi, which is one reason growers use so much pesticide. The sterile insect technique (SIT), he explained, is being increasingly used to control such pests: Med flies have been eradicated in California and several countries including Chile, Mexico, Argentina, and Peru; tsetse flies and screwworm flies are two other targets for SIT. The IAEA is studying its use on the malaria-carrying mosquito.

Food irradiation is another technique whose use is growing, said Machi. The U.S. government is supporting this because thousands of people die each year from food-borne disease, he said. Irradiated meats for hamburgers are now sold in 5000 supermarkets. In Japan, 10 000 tons of potatoes per year are irradiated to inhibit sprouting. China irradiates 100 000 tons of food each year. Irradiation is also used for disinfestation instead of chemical fumigation.

The United States is a leader in the use of radiation-induced crosslinking of polymers to reduce their degradation through heat, chemical, and stress-cracking, for products such as heat shrinkable tubes, pipes, sheets, and tires. In Japan, said Machi, radiation is used to produce a super-high resistant silicon carbide fiber that is being used for the Space Shuttle. Applications continue to be found for this technique.

Laser-induced nuclear reactions

Joe Magill, of the Institute for Transuranium Elements in Karlsruhe (Germany),

has been coordinating an international effort in so-called laser transmutation, which promises to be an alternative method for producing nuclear reactions. Ten to twelve years ago, it was widely believed to be impossible to create a nuclear reaction using a laser. The situation has changed dramatically since then, and in 2000, the first laser-induced fission in uranium was achieved. In the most recent experiments, iodine-129 has been transmuted.

According to Magill, the laser beam creates a very high-temperature plasma that gives rise to a beam of high-energy electrons, which produce gamma radiation energetic enough to cause fission.

In the 1960s and 1970s, the highest power lasers were delivering about 10^{14} watts/cm^2. In the middle of the 1980s, there was a technological breakthrough that made extremely high laser intensities possible. The very first mention of using lasers to generate nuclear reactions dates back to 1988, but it took more than a decade to achieve the necessary intensities of 10^{19}–10^{20} W/cm^2.

Previously, when a laser was fired onto a target surface, processes were initiated such as vaporization, ionization, and some plasma formation. At intensities of 10^{19}, however, extremely high-temperature plasmas—typically 1–10 MeV—are generated. These are the temperatures "created one second after Big Bang," he said. In these plasmas, electrons, positrons, gamma rays, neutrons and ions—"essentially everything"—are found.

The first fission of uranium-238 was achieved using the high-powered Vulcan facility at the Rutherford Appleton Laboratory in England. This was soon extended to thorium. As Magill put it, for the first time, nuclear reactions could be initiated without the use of nuclear reactors or particle accelerators. While scientists have been concentrating on inducing fissions in actinides and transmuting long-lived fission products, this technique is quite general, opening up the possibility of creating stable and various medical isotopes. Fusion reactions are also possible.

According to Magill, the laser beam creates a very high-temperature plasma that gives rise to a beam of high-energy electrons, which produce gamma radiation energetic enough to cause fission. Within the last few months, the transmutation of iodine-129, a key long-lived fission product in power reactors, has been achieved. This was through the so-called gamma-n reaction, in which a neutron is knocked out of the 129 nucleus, creating I-128, with a half-life of 25 minutes.

A lot of development is needed to make this technique commercially viable, observed Magill. Vulcan provides only one or two shots per day, each producing only 10^6 fissions. A tabletop laser at the Jena University, in Germany, however, whose intensity is within a factor of 3 or 4 of Vulcan, was able to repeat the experiments. The experiment was also successfully carried out using a target suitable to create short-lived isotopes used in nuclear medicine. High-energy protons were produced in another experiment, which was confirmed by spallation tests.

The challenge, said Magill, is to develop compact and efficient tabletop lasers, which opens up the possibility of radiotherapy using proton or fast neutron beams. Lasers of 10^{28} W/cm^2 are already being proposed.

Waste: Changing perceptions

Sam Kelly, president of BNFL Savannah River Co., focused on the future of the back end of the fuel cycle. He quickly dealt with reprocessing. It is not new, he said, and the debate for and against has gone on for a long time. All he had left to say, he observed, was "The market will decide." If there are customers for the back end of the fuel cycle, it will survive, he said, if there are not, it will not.

Waste, "the Achilles heel of the nuclear industry," is another matter. Within the industry and within informed scientific opinion, Kelly explained, there are technical solutions to all aspects of waste management. If one looks at the risk versus benefits, this is probably one of the cleanest energy sources the world has ever seen, he added. That is not, however, the opinion of the general public, which perceives nuclear as a dirty industry, a threat to the environment, a threat to the unborn children of future generations. "I do not believe that is true, and I do not believe that the industry nor informed scientific opinion believes that," said Kelly. "That is perception."

Changing this perception will not be easy due to the growth of what Kelly calls the "antinuclear, regulatory, and environmental industries." Scientists, said Kelly, generally did not appreciate the changes in the society that emerged from the 1960s onward. In addition to the changing role of women, there was "what I call the challenge to credibility of Establishment organizations. . . . People are now prepared to challenge authority and Establishment figures in society."

The environmental movement had a major impact on the political environment and was a perfect vehicle for the antinuclear industry. "The explosion of this movement in turn led to an explosion of the regulatory industry," said Kelly. Nuclear power is probably the most regulated industry the world has ever seen in comparison with other industries that pose as much or more of a risk to the environment and to future generations. This has been translated into costs. He said the industry submitted to this because it was easier. He added that reprocessing and waste were easy targets, providing "a lovely warm moral high-ground position to take."

Kelly stated his belief, however, that the "times are changing." People are starting to become aware that the catastrophic dangers associated with the industry are not what they were led to believe, he added. There is a new recognition of the risks of energy shortages—underlined by events in California—and energy dependency. Whether climate change is real or not, it has also grasped the public's attention, and "following from the lessons of the antinuclear industry, we would be foolish to ignore it," Kelly observed. The debate is now alive, he said, and a few years ago it was dead. The media are now looking at this more positively—a sea change has occurred, he added.

The time is right to move forward and take proactive initiatives. He reminded the audience that the antinuclear industry is based on sentiment and fear, not factually based information, and is fueled by the communications industry. It is in that arena that this battle will be won, unless blackouts help to do it sooner, Kelly said. The tools of the communications revolution need to be used to remove these fears and perceptions, he added.

The MIT report

The MIT report "The Future of Nuclear Power" was the subject of a Special Plenary Session that gave panelists a chance to comment on the report's findings. Released last July, the report found that billions of tons of carbon dioxide emissions into the atmosphere could be avoided by 2050 by drastically increasing the number of operating nuclear plants, to 1000 GWe of generating capacity, by mid-century. The best choice to meet this expansion of nuclear power, according to the report, "is the open, once-through cycle."

The report found there would be hurdles to building new plants, including cost issues. "We insisted that our baseline costs would come from experience and not from engineer analysis and promises of how great it was going to be," said Ernest J. Moniz, a coauthor

of the report. (In the baseline, the costs were 6.7 cents per kilowatt hour for nuclear [$2000/kW overnight capital cost], and about 4.2 cents for coal and for natural gas.)

Moniz explained that the report's authors came together as a team with one common reference point: the need to meet global electricity needs without emitting greenhouse gases. Issues facing the team were the economics, safety, waste management, and nonproliferation challenges of enabling the construction of about 1000 GWe by mid-century.


Moniz

Moniz is a professor of physics and director of energy studies and the environment at the Massachusetts Institute of Technology. He served as undersecretary of the Department of Energy from October 1997 to January 2001. In that role, he had programmatic oversight responsibility for the Offices of Nuclear Energy, Science and Technology; Science; Fossil Energy; Energy Efficiency and Renewable Energy; Environmental Management; and Civilian Radioactive Waste Management.

Moniz said it was important to note that the team that authored the report was interdisciplinary, spanning four different schools: engineering, science, management, and humanities (one member was from the Harvard Kennedy School). There also was an external advisory panel, including environmental groups, statesmen, and the utility and financial communities. "I think one of the major unwritten observations from the report was the fact that while we could not expect that every member of that group endorsed every recommendation, there was an amazing unanimity among that group spanning such different perspectives," he said.

The team knew that if nuclear power was to be competitive with coal and natural gas, "industry must demonstrate its plausible but unproved plans of significant reactor capital cost reduction, and the social costs of greenhouse gas emissions need to be internalized," he said. "In the United States, we recommend explicitly electricity production tax credits for a set of first mover nuclear plants."

[T]he report found that billions of tons of carbon dioxide emissions into the atmosphere could be avoided by 2050 by drastically increasing the number of operating nuclear plants, to 1000 GWe of generating capacity, by mid-century.

Other recommendations are that long-term storage of spent fuel be systematically incorporated into waste management strategies, and that waste management R&D be expanded significantly. Also, the current international safeguards regime must be strengthened to meet the nonproliferation challenges of the global expansion of nuclear power. Safeguards should be implemented in a risk-based framework keyed to fuel cycle activity, he said.

Moniz added that a major international research effort should be launched to develop analytical tools and to collect scientific and engineering data for integrated assessment of advanced fuel cycles. In addition, public acceptance is critical to nuclear power expansion. "We note that the United States, from a poll we conducted, shows the public does not yet see nuclear power as a way of addressing global warming," he said.

Moniz stated that baseline costs for new construction could plausibly be cut, notably by capital cost reduction of 25 percent; that would result in a cost per kWh for nuclear of 5.1 cents. With the fossil fuels having to deal with costs for carbon sequestration up to about $100 a ton, "if the nuclear industry can work down its costs, especially capital costs . . . it's very competitive, especially in a carbon-restrained environment," he said.

The clean-air benefits of nuclear led to the report's principal recommendation, Moniz commented, "that there is a major public good to be recognized in providing incentives for first mover nuclear plants," he said. "We view that as absolutely critical to anything that follows." To that end, the report recommended a production tax credit structured similarly to the wind power tax break. Such a structure has been adopted in the 2003 Congressional energy bill conference report.

The report, according to Moniz, "also argued that thermal reactors will dominate the gross scenario in this century" and that the growth "should be based principally on the once-through fuel cycle for several reasons, particularly economics and nonproliferation." But, he emphasized, the report in no way excludes R&D on advanced fuel cycles. "Quite the contrary," he said, "we argued for a huge increase in advanced fuel cycle R&D—$100 million a year is what we explicitly state."

Ron Simard, senior director for new plant development at the Nuclear Energy Institute, commented on two points of the report—economics and public acceptance. In his discussion with vendors, Simard found they agree that first-of-a-kind plants will be in the $1500/kW range for capital cost, but that experience and improvements will result in 30 percent reductions down the line. "So, what is being discussed now in terms of the business case is a capital cost on the order of $1500/kW going down to something like $1200/kW," he said.


Simard

The report also assumes a five-year construction period that will fall to four years. The industry, however, is "not satisfied with four years," Simard said. "What we are looking at, based upon recent experience overseas and based upon the approved use of modularization and offsite fabrication, we are assuming construction periods of 36 months, perhaps 42 months, for the first few units from first concrete to fuel load."

Regarding public opinion, Simard said there has been "overwhelming support" from the local populations around nuclear plants that have sought license renewals. Since any new plant would be built at a site that already holds a reactor, the local community likely would welcome the addition to the neighborhood, he said.

Michael Corradini, a member of the DOE's Nuclear Energy Research Advisory Committee and a Distinguished Professor of nuclear engineering at the University of Wisconsin–Madison, agreed with much of the report's findings, but he questioned its call for $100 million annual funding for fuel cycle modeling analysis and simulation of commercial nuclear energy systems. "I guess my major concern with this initiative is that such a major program should be focused with clear-cut objectives and results," he said. Instead, as he understood it, the focus was on analytical tools development and small-scale benchmark experiments. "Without a long-term plan with clear-cut objectives and benefits, and


Corradini

appropriate experimental verification by data, I would question if this research would interest those who allocate the funds or those who do it," he said.

William D. Shipp, director of the Idaho National Engineering & Environmental Laboratory, was representing the directors of six national laboratories: Argonne, Oak Ridge, Livermore, Los Alamos, Sandia, and INEEL. The labs and the DOE last April issued their own recommendations to further the deployment and development of nuclear energy. Those recommendations match up with some of the MIT report's findings, said Shipp. For example, the recommendations agree with the MIT report that R&D is required to properly manage the back end of the fuel cycle.

Shipp added, however, that "even when Ernie was the undersecretary, we had some disagreements, and we wouldn't expect anything different at this point." Shipp said that the lab directors further believe the proper management of the back end of the fuel cycle is a matter of national security, and that closure of the fuel cycle to burnup plutonium and actinides is not only a necessity from the standpoint of reducing the growing world inventories of nuclear materials, but is the most proliferation-resistant approach for the long term.


Shipp

Andy Kadak, professor of the practice in nuclear engineering at MIT and a past president of ANS, said that while he questioned the report's exclusion of government support for building a new reactor, he understood how the authors reached that conclusion. "Basically," he said, "the belief was that if you have the government (help finance a new reactor), it's not a real test of the market, of what it is that the people will actually have to buy. But my sense is that you can issue a procurement that wouldn't be quite commercial in terms of demonstration. It would hopefully have a plant that would be built under commercial terms and conditions such that the other utility members are watching this thing and could use it as a reference."


Kadak

Offering the opinion of the ANS Nuclear Energy Renaissance Special Committee was Ted Quinn, past ANS president. The committee, consisting of 32 members, found unanimous agreement that there is need for near-term deployment of new generation reactors that would result in 1000 GW by 2050. "This expansion of nuclear generation would represent a threefold increase from today while maintaining the current percentage of nuclear in the generation mix," Quinn said.

Quinn came armed with questions from the committee, for later consideration, including why does nonproliferation appear to be more of a political issue than a technical one, and what confidence level was there in the cost of uranium over 50 years that would justify the report's uranium allocation in the open-cycle process?


Quinn

Jacques Bouchard, director of nuclear energy for CEA, commented that the report provided a "relevant vision" for nuclear energy, but that it failed to draw consistent conclusions and recommendations regarding the fuel cycle issue. "This conclusion," he said, "relies on an unbalanced appreciation of the relative risks and merits, in terms of economics, waste management, safety, and nonproliferation, of once-through versus reprocessing fuel cycle options, an appreciation which does not draw from the extensive European experience with used fuel reprocessing."


Bouchard

If implemented, Bouchard cautioned, such recommendations "would have a very negative impact on the development of nuclear energy." He said there was no option toward a sustainable development of nuclear power other than to develop and implement advanced fuel cycles that will minimize the amount of toxicity of waste, while making optimum use of natural resources.

Moniz, given end-of-session rebuttal time, commented that the report was never intended to be an "original statement by any means," but that it was put together by bringing in different perspectives.

On the economic front, regarding comments made that the report's construction-cost baseline was too high for new plants, Moniz said that while $2000/kW may seem extreme, the bankers "seem to think that it's the right place to start, and they are the guys with the money."

Regarding Kadak's point that government should finance demonstration plants, Moniz agreed, but with clarification. "We were talking about demonstration plants of . . . market-ready technology," he said. "The goal is really to prove its economic viability, and the government doing it gives you absolutely zero information on that."

On the question of closing the fuel cycle, Moniz noted that it partly comes down to figuring out how to value the "very long term." The answer, he said, is "we don't want to undervalue it. We propose a very robust analysis, research, development, and demonstration program to look at advanced fuel cycles for the future. But our focus is on enabling the nuclear option for robust growth over the next 50 years, a critical period for addressing climate change."

Moniz concluded that having a back-and-forth session such as this one made the two years he spent working on the report "worth it." He closed by adding, with a chuckle, "Next we're going to do coal."

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A preview of JIMO

The first mission for NASA's space nuclear initiative Project Prometheus, which was announced last year, will be to send a spacecraft to the moons of Jupiter. The Jupiter Icy Moons Orbiter, or JIMO, will orbit three planet-sized moons of Jupiter—Callisto, Ganymede, and Europa—which may have oceans beneath their icy surfaces. The ocean that may exist on Europa, and its possibility for harboring life, are the prime reasons the National Research Council recommended that NASA make exploration of Europa as high a priority as the exploration of Mars. The JIMO mission will also raise NASA's capability for space exploration by pioneering the use of electric propulsion

powered by a nuclear fission reactor.

The session *Control and Safety Strategies for Space Nuclear Reactors* featured two presentations that provided background on the JIMO mission, as well as its nuclear fission reactor forebears.

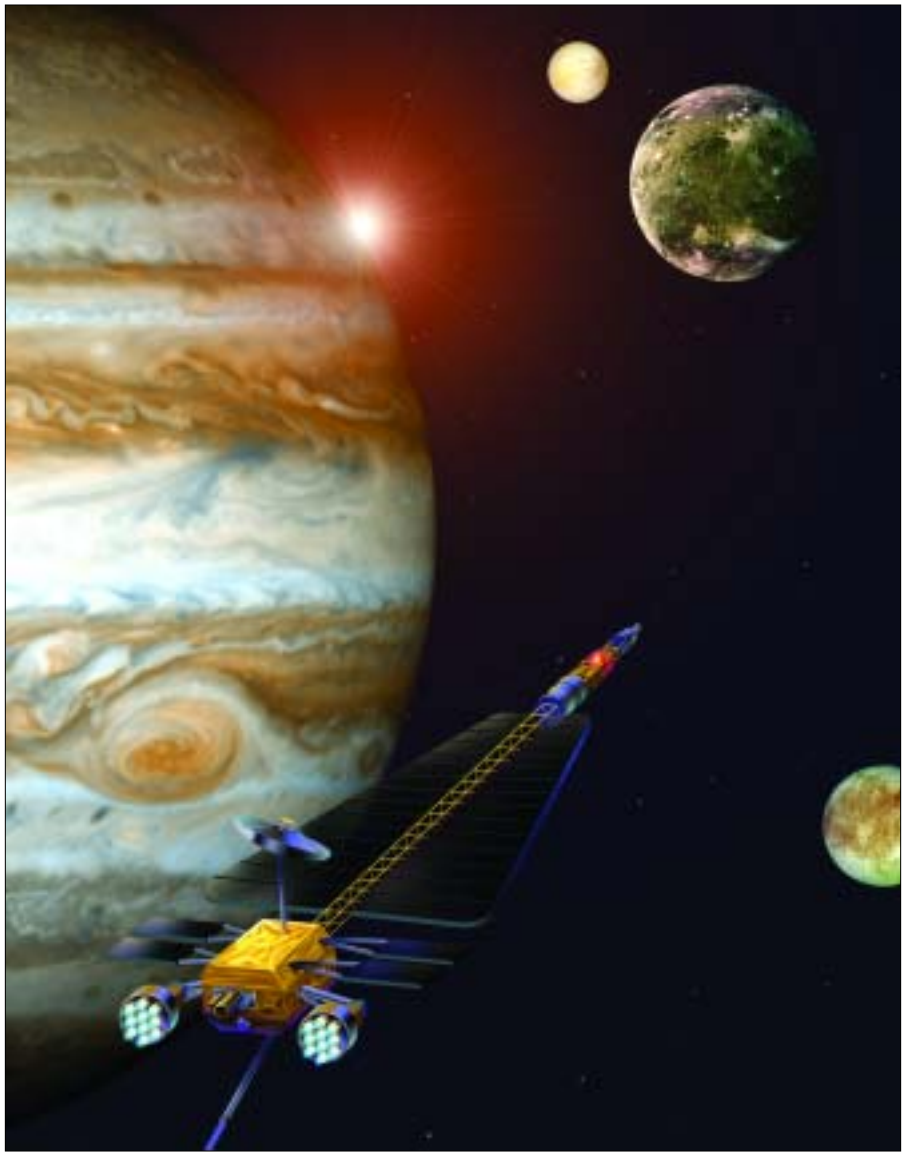
Matt Forsbacka, NASA's program executive for fission systems, described himself as the conduit between NASA and the Department of Energy for the creation of a space nuclear reactor. "Basically, I'm the guy who wakes up in a cold sweat at night worrying about all the things that could go wrong," he said.

He summed up Project Prometheus as "all about making lots of power and using lots of power." Instrumentation that will provide unprecedented levels of scientific investigation will be available on these spacecraft. And the power will also provide propulsion systems that will allow spacecraft to fly for long periods of time through space—actively.

"What we've done through this point in time is take satellites or little spacecraft and put them on a 15-minute thrill ride. It takes off and then it's basically playing intergalactic pinball as it goes through the gravity wells to get to its ultimate destination," Forsbacka explained. As a result, the spacecraft are launched into orbits that allow only for catch-as-catch-can scientific investigation. "Flying with the Project Prometheus–enabled ion propulsion systems actually allows us to fly into a very deliberate orbit around a target destination of interest and allows us to spend as much time as we want there. We can re-target on the fly if we find out we're not getting what we want out of that destination. We can spin out and go to the next spot. If we find out there's more interesting things to do, if we want to look at different orbital planes, we have that capability as well," Forsbacka said.

NASA has been successful in the past with radioisotope thermoelectric generator (RTG) systems, such as those used by *Galileo* and *Cassini,* and has been launching one or two per decade. The agency will now be looking to approximately double the amount of power available in those relatively modest systems, up to around 1000 watts, electric, Forsbacka said. "It's because of the success that we've had with the RTG program that's helped give NASA the confidence and the interest in the fission power systems. [NASA has] done a lot of great things with these small, putzy things and now we're ready to go off and actively fly through space and really break open the science," Forsbacka said.

In designing spacecraft for Project Prometheus, Forsbacka emphasized that safety is the most important design element. "Safety [in space] is different from terrestrial safety in the sense that we're flying a lot of rocket up 1000 km and higher," he explained. "The system has to stay in a subcritical state through all the normal launch environments and also in any of the credible accident environments."



An artist's concept of the Jupiter Icy Moons Orbiter, whose electric propulsion system will be powered by a nuclear reactor (Image courtesy of NASA's Jet Propulsion Laboratory)

Beyond safety, the designers are looking to make the spacecraft light. "We're very mass-sensitive, which is something that's paradigm-changing from terrestrial power systems, where you don't care about mass at all." The system also must be small enough to fit in a launch vehicle.

The JIMO mission will be setting the stage for what is hoped to be a series of fission-based missions. The other missions have yet to be determined, and economics as always remain a key variable, but "our intention is not to fly this one and go away and close up shop, but to fly a succession of these reactors," Forsbacka stressed.

The mission studies and conceptual design activities for JIMO, set to launch in 2012 or later, are currently under way. But contacts have already been let to some major aerospace companies, which have been teamed with various nuclear vendors, Forsbacka said. NASA and the DOE have set up an in-house team that's also doing design work so that "when industry comes with their answer, we'll have the means to say, 'We agree with this' or 'We have a difference of opinion,' and have to go back and arbitrate and figure out what's right."

The process for choosing the instruments for JIMO is also under way, with various teams of scientists recommending what sort of instruments will work well on the craft. "We're not just carrying along a dead system," Forsbacka said. "We have a system that creates heat, creates vibration. So, we need to have all those environments well characterized so the spacecraft [and its instruments] will stay in good shape."

Space reactors, past and future

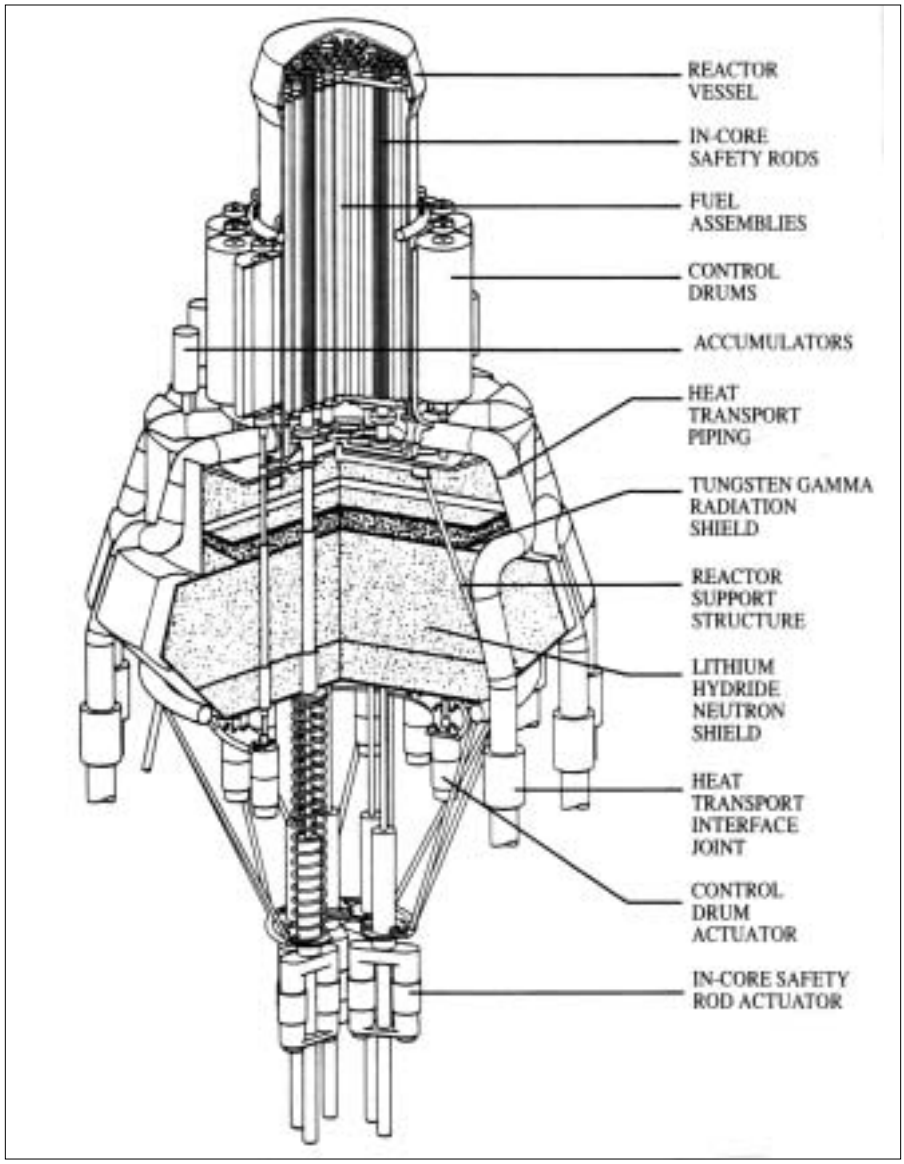
Decades later, the United States is revisiting spacecraft technology that was first used in the mid-1960s. The SNAP-10A spacecraft, the first space reactor the United States has flown, was launched when

"Star Trek" was still a regular television series, noted William Kelly, of the Boeing Company, NASA's largest contractor. He gave a history of two significant reactor-powered space systems in the United States, as well as a preview of JIMO. When the SNAP-10A was in development, the Nuclear Navy had only about 20 submarines, two of which were the first two nuclear submarines, *Nautilus* and *Seawolf*. And there were only six nuclear power plants operating in the United States.

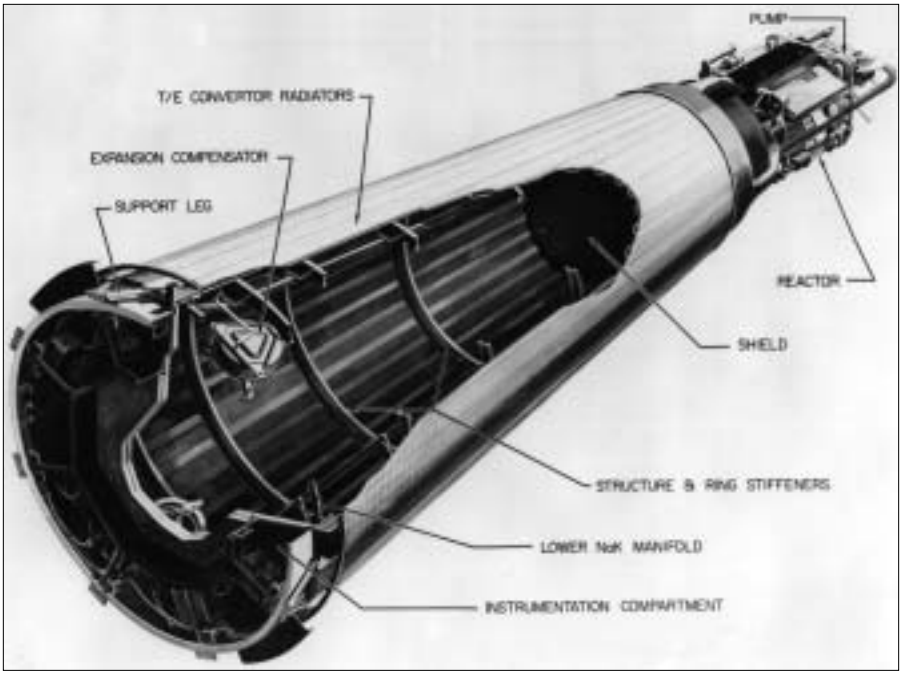
The spacraft was to demonstrate that nuclear-powered electrical sources could indeed work. Because it was the first of its kind, its planned operational lifetime was only one year.

The most remarkable aspect of the craft's startup was the fact that it was assisted only by nature. "SNAP-10A was started up by galactic cosmic rays. The beryllium reflectors have a gamma-n reaction that creates neutrons. All of a sudden it started up. We sent out no neutron source. It just went up there and all of a sudden it was going," Kelly said.

Because it was the first craft of its kind, the coolant temperature was kept low to help make sure it could complete the mission. A very small number of fuel pins was used. And, at around 0.5 kilowatts, electric power on SNAP-10A was well below the levels of today's craft. "They actually wanted to let this thing start up with timed insertions of reactivity—a very slow startup—and approach the criticality," Kelly explained. "And then [they would] turn the automatic control system off and let it gradually wind down in power until the end of its mission. The projected power profile had it decreasing in power with increasing fuel burnup—just kind of last for a year and see what happens all the way along. A first shot—that was it."



Schematic of the SP-100 reactor, shield, and heat transport subsystems (DOE, 1987)



The SNAP-10A system (AEC)

The reactor was launched into orbit in April 1965 and functioned for 43 days before an electrical problem in the booster section caused it to shut down. The malfunction was not related to the nuclear systems. Despite its short life, the mission was still a success in many ways. "All the reactor startup objectives, all the things they wanted to learn about how to run one of these things, was actually obtained," Kelly said.

Perhaps because of President Kennedy's encouragement to put a human on the moon, Kelly surmised, resources were diverted from the SNAP program, which was eventually scrapped. "We got to the moon but we left SNAP-10A in the garage," he said.

Unlike the short-lived SNAP-10A, the reactor-powered SP-100, whose development originated in the early 1980s, was to have a 10-year mission lifetime. The craft was to provide power to orbiting systems as part of President Reagan's Strategic Defense Initiative.

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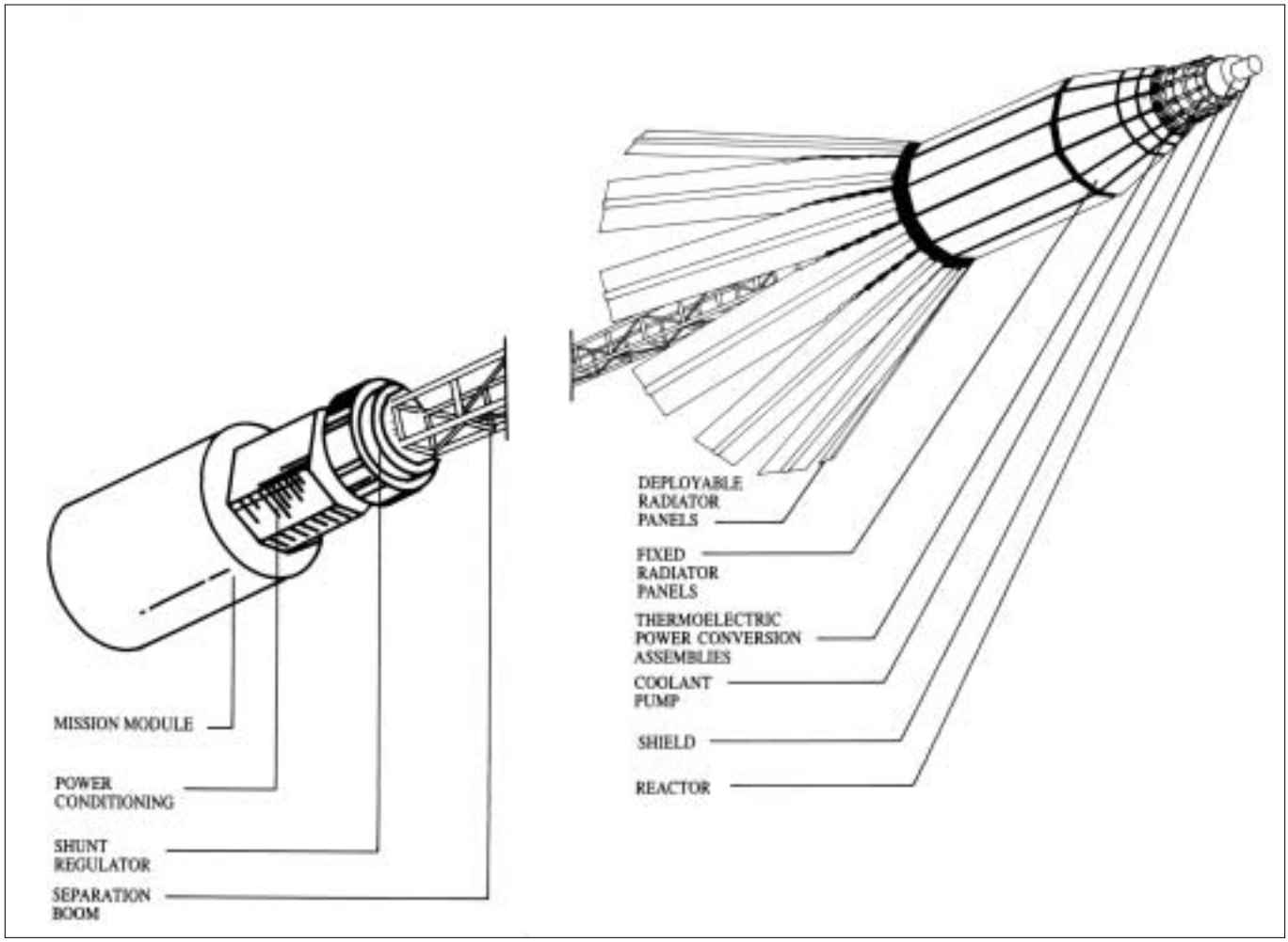

Major components of a typical SP-100 space reactor power system (DOE, 1987)

One challenge that SP-100 would have to overcome before it could be launched was the existence of space debris in the earth's atmosphere. A decade-and-a-half after the space race began in earnest, there was a lot of spacecraft debris floating in orbit, including 34 or so Russian nuclear reactors that had been leaking potassium and sodium for the better part of 20 years, Kelly said. There are also alumina particles from the exhaust of solid rocket boosters.

"There's a lot of junk now floating around in space at all sorts of different orbits and all sorts of different concentrations," Kelly said. "You see sizes greater than 12 centimeters. If they're going fast enough, they can cause damage to instrumentation. You have to think about shielding and protection when you get up there. It's a challenge for the instrumentation guys."

Regarding instrumentation, the biggest achievement was development of a radiation-hardened MUX amplifier, Kelly said. "We probably wouldn't use it today with today's electronics. But that was a large success for instrumentation and control back then."

The craft, however, was never launched.

JIMO will have a mission life of around 12 years: two or so years of orbiting the earth and moving out of earth's orbit, six or eight years to travel to Jupiter, and two more years in the Jovian system. All the while it will be going through extremes of radiation and temperatures. As such, it will be traveling the moons of Jupiter from the outside in—Callisto, Ganymede, Europa, then Io—or, in other words, from the best environment to the worst.

"As you gradually move in, [the radiation field] gets nastier and nastier," Kelly said. "When you get to Io, you're actually having to deal with volcanic particles. Io is a volcanic moon and is shooting a lot of debris into the orbit around Jupiter. What you wind up with is this veil, this torus, where particles get big and fast. It's terribly ugly in there."

Because of this harsh environment, a premium will be placed on system reliability. "When you let something go and you're not going to be able to touch it for 12 years, you have to think about extremes or more serious measures for keeping the system reliable," Kelly said. "Operating experience is still an issue with us. We haven't had a lot of operating experience—any operating experience, really—with these sized reactors."

The program is yet in its infancy, with various concepts for reactor instrumentation and control still being developed. Nonetheless, a few details have emerged. The craft may be using fission chambers, Kelly said. "The operating experience of the world's breeder reactors, in Japan, in France, are all pointing to the ability of fission chambers to give you a good signal for a long time with a lot of accumulated neutron exposure. It's very promising for that," Kelly said.

Designers are also looking at failure detection, isolation, and recovery technology, or instruments in the vehicle that watch for systems to malfunction. "The Space Shuttle is starting to use this in their health monitoring systems," Kelly said. "They're watching things like turbine vibrations and turbine speed. And with embedded algorithms, they're able to tell a control system to 'back off here' or 'speed up there' or 'don't operate in this range.'"

Also, the craft will need to have great resources for autonomy. A signal from JIMO will take a half-hour or more to reach earth, so the vehicle will need some capacity to problem-solve on its own. "There's no other way to survive. Something happens out there, it's going to take us a half-hour to figure what to do about it. The vehicle itself will have to be more autonomously controlled than anything we've attempted in earth orbit," Kelly said.

Nonproliferation challenges

In introducing the "Nonproliferation Challenges in the 21st Century" panel,

James Chapek of Sandia National Laboratories noted that it took the Manhattan Project just three years to overcome the three major hurdles to produce a nuclear weapon—possessing the fissionable material, scientific knowledge, and technology. Concerns about proliferation emerged even then, he said, and efforts were begun to prevent it. That took longer. Nonproliferation was one of the principles guiding President Eisenhower in 1953, when he proposed his Atoms for Peace initiative. This led to the creation of the International Atomic Energy Agency (IAEA) and the Non-Proliferation Treaty (NPT).

More recently, the fall of the Soviet Union and the rise of the "threat matrix" of rogue states and terrorists has significantly changed "the calculus for world peace," he said. The possibility of a country or other entity possessing nuclear weapons as a deterrent, equalizer, or terrorist tool has taken on an increased importance.

The first speaker, Victor Reis, senior vice president of Hicks Associates, where he leads the nuclear strategies project, a multi-organizational venture whose purpose is to help develop strategies for the international nuclear enterprise. Reis is a member of the strategic advisory group of the U.S. Strategic Command; previously he led the DOE stockpile stewardship program and had been director of defense research and engineering at the Pentagon.

Reis started with a different angle on the subject, explaining that he was looking at nonproliferation opportunities, rather than challenges. Eisenhower's vision was large, said Reis. It included avoidance of nuclear war and the arms trade, containment of Soviet expansion, and enhancing international cooperation. There were also domestic benefits, such as helping to keep the budget down. Under his Atoms for Peace deal, weapons states would provide assistance to nonweapons states to avoid proliferation while also moving towards the elimination of their weapons.

Looking ahead 50 years, Reis suggested another vision, which includes: global expansion of electricity; reduction of carbon and other pollutant emissions; international security (including the removal of rogue states), and international relations (leading to greater world stability). They are all connected, he said.

Nuclear power can contribute to this vision, he explained, by:

1. Generating a lot of carbon/pollution-free electricity—"producing a little is not going to get you very far," he said.
2. Reducing the stockpile of weapons and eliminating excess material.
3. Providing a platform for international cooperation, in terms of proliferation and fuel cycle management.

Reis's vision also involves a new deal in which there are two categories—fuel states and reactor states—where fuel states lease fuel cycle services to reactor states, and all states accede to appropriate safeguards.

Reis's vision also involves a new deal in which there are two categories—fuel states and reactor states—where fuel states lease fuel cycle services to reactor states, and all states accede to appropriate safeguards. An immediate benefit of this, he said, is that it would be a lot cheaper. If a state only has reactors, a lot of safeguards are unnecessary, and from a proliferation point of view, there are fewer states to worry about. In this way, there can be a substantial growth in nuclear power, without making the proliferation issue any more difficult. It may even be better, said Reis, by encouraging nonweapons states to forego any plans.

This idea, he said, has been likened to the relationship that France and Germany forged after World War II, built on their steel and coal industries. This cooperation led to a treaty involving other countries that eventually became the European Community.

The development of a large international nuclear industry, says Reis, could also become an important "currency" for international relations, a potential that Eisenhower saw. Everything is there already, said Reis, the resources, the technology, and the international relationships, as in the IAEA. It is mainly a diplomatic issue, he said.

Directions and digressions

Richard Stratford, director of the Office of Nuclear Energy Affairs in the Bureau of Nonproliferation at the U.S. State Department, warned that he spoke strictly for himself, not his agency. He called his talk "directions and digressions, things we are doing and things we need to do." Digressions refer to ideas put out there that are often complex and expensive, but that will not actually achieve nonproliferation goals.

According to the police, explained Stratford, preventing crime requires either removing opportunity or changing motivation, or, ideally, both. In the nonproliferation arena, he said, removing opportunity means keeping weapons-usable fissile material out of the hands of those who can't be trusted. The basic proliferation prevention measures are: account for nuclear material; lock up and protect nuclear material; track down anybody who has illegitimate possession; and deal as effectively as possible with those states that opt openly or clandestinely to pursue a weapons program.

Stratford provided an overview of several aspects:

1. *Material accountancy*—Initially, IAEA safeguards were primarily an accounting system designed to ensure that declared nuclear material remained where it was supposed to be. The discovery of Iraq's nuclear weapons activities over a decade ago showed up the system's inherent weaknesses and triggered an effort to upgrade it. This led to the creation of the Additional Protocol, whose purpose is to be able to prove that a state is not engaging in undeclared nuclear production activities. That is what is being called for in Iran, following the disclosures that it was secretly developing a centrifuge enrichment capacity.
2. *Physical protection*—This subject is getting a lot of attention. The IAEA is undertaking a large international assistance program. The United States is also engaged in various activities, many in association with Russia. One program is under way to assess physical security and fix problems in countries that receive U.S. enriched uranium, another involves converting research reactors to the use of low-enriched uranium, and a third is intended to take back U.S.-origin high-enriched uranium. Stratford also noted efforts by the Departments of Energy and Defense to protect and secure material under the Cooperative Threat Reduction Act.
3. *Methods to detect material if stolen and prevent illicit trafficking*—Measures to find material after it is stolen include border controls, detection devices, the DOE's second-line defense program, and customs efforts to inspect cargo containers for nuclear materials and other weapons of mass destruction–related items.
4. *International cooperation*—All the above measures need international cooperation, said Stratford. He also discussed efforts to upgrade the Convention on Physical Protection of Nuclear Material. As it stands, the convention requires parties to apply physical protection to nuclear materials in international transport: It does not require parties to protect material at home within national borders for domestic use. It is a glaring omission, he said, but the United States could not get these provisions 20

years ago. In 1998, the U.S. initiated another effort to plug that loophole. "We are almost there," said Stratford, but there remains some diplomatic work to resolve certain issues.

Dealing with motivation is a lot harder, Stratford said. "I do not think you can change motivations of terrorists. People who have it in for us are not going to be talked out of their hate." Every precaution to prevent terrorist incidents has to be taken while seeking to find and arrest those dealing in international terrorism. State motivations are also difficult to deal with, he said. They arise in very different circumstances, are frequently prompted by regional tensions and/or by a desire to project power, and be seen as a major player in the region or the world.

Even if their cores cannot be used to produce plutonium, however, the reactor can provide a cover for other acquisitions and contributes to a nuclear infrastructure that can support a weapons program, he observed.

Next, Stratford asked what the digressions are. One is the proposal, relaunched recently by the director general of the IAEA, to create international fuel cycle centers to place enrichment and reprocessing under multilateral auspices. Basically, he explained, the United States does not believe that these facilities should proliferate, adding that location could pose a difficult political issue. Furthermore, he added, there is already plenty of capacity out there, and "we are comfortable with the fuel cycle programs of our cooperating partners."

On proliferation-resistant reactors, Stratford said that he probably sounded most heretical. He agreed that the idea makes sense when designing future reactors. Even if their cores cannot be used to produce plutonium, however, the reactor can provide a cover for other acquisitions and contributes to a nuclear infrastructure that can support a weapons program, he observed. Basically, he noted, it is not a good idea to engage with countries that are not trusted.

Good technology governance

Elizabeth Turpin, a senior associate and codirector of security for the new century project at the Henry L. Stensen Center, and who previously worked for Sen. Pete Domenici, offered her thoughts on challenges in nonproliferation.

Initially, the NPT derived its authority mainly on political will, she explained. During the Cold War, the superpowers maintained control on the aspirations of their client states. The collapse of the Soviet Union ushered in new realities, including a lifting of the cap that kept potential regional powers in check, rapid erosion of Russian conventional power, development of an overwhelming conventional military superiority of the United States; and the pursuit by some states of other "advantages," including the possession of weapons of mass destruction. These have all led to increasing stresses on the nonproliferation regime, which she says needs reinforcing, from the top.

Turpin stressed that she is particularly concerned, however, about the human dimension to the proliferation threat, for which a case is very difficult to make in Washington. U.S. policy-making structures and perceptions are still mired in the Cold War, she said. In more than a decade of threat reductions efforts, no solid bipartisan agreement has been reached that allows U.S. agencies to be involved in making sure that ex-Soviet scientists and technicians involved in weapons production "had a steady income"—that is, ensuring that they have little incentive to use/sell their services for unacceptable purposes. The U.S. must, Turpin said, overcome ossified institutional barriers and revamp its perceptions of what items comprise spending on security.

Eliminating weapons material

Edward Mastal's current program responsibilities at the DOE include the development, negotiation, and implementation of U.S. transparency operations in Russia in the context of U.S.-Russian agreements to dispose of fissile material. His group monitors four Russian processing facilities and also provides support for Russian transparency activities at five facilities in the United States. Mastal spoke about actually eliminating weapons and fissile material.

With the end of the Cold War, Mastal noted, the world is still left with nuclear weapons, nuclear technology, and a growing stock of surplus weapons-usable material. There is a range of activities, he said, to reduce the numbers of weapons and eliminate fissile material. Russia and the United States have stopped producing HEU and weapons plutonium (except for Russia's three remaining production reactors, which are due to close soon). There are also many programs to control access to material and to eliminate it, Mastal explained:

- The 1993 HEU purchase agreement in which 500 metric tons (t) of material from Russia's dismantled weapons is downblended and converted to reactor use. Since material began to flow in 1995, some 200 t (8000 warhead equivalent) of material were permanently downblended and made into fuel elements. It is now converting HEU at a rate of 30 t per year, to be completed in 2013.
- A program to downblend HEU oxide to less than 20 percent enrichment, which can be used in research reactors. That has been going on for about three years.
- The agreement for the disposition of plutonium (34 t by each country). In 2002, the two agreed that the additional plutonium coming from Russia's three remaining production reactors will be subject to the same agreement.

While information cannot be controlled, said Mastal, its flow can be slowed and redirected. This is a reason to help countries speed up the modernization of their political and social systems to become more user responsible, he observed. The DOE has programs to help Russian weapons scientists and engineers put their know-how to more peaceful uses. He also said that everyone has a part to play. "Are you a good steward of knowledge of nuclear technology?" Mastal asked listeners.

A new fissile material convention

After 24 years in the IAEA safeguards office, Thomas Shea is leaving to become the director, defense nuclear nonproliferation programs for Pacific Northwest National Laboratory. Looking to the future, Shea described his vision for a new convention designed to control fissile material that he believes will avoid proliferation and support disarmament. He called it a "treaty banning the production of fissile material for use in nuclear weapons or other nuclear explosive devices."

Today the nuclear nonproliferation regime is mature, but far from perfect, and it needs fixing, Shea explained. As for disarmament, a 10-year attempt by the UN to forge a treaty has made virtually no real progress, and Shea thought that maybe a totally new approach is needed. This led him to consider what a new treaty might look like, based on the security problems of today, not those of a decade ago.

Shea said he wanted to be as broad and encompassing as possible, while also solving some real problems. But he tried to avoid showstoppers: There is no ban on peaceful nuclear facilities or nuclear sub-

marines. "It is not an intention to deny the use of fissile material but to control it," Shea said. There are no actual disarmament requirements, he said, although these may come later.

His proposed treaty basically bans future production of plutonium and HEU for nuclear weapons. Any production has to be justified on the basis of peaceful activity or a nuclear submarines program; anything else would be a violation. It also would provide for submitting excess material stocks for verification.

From a disarmament standpoint, the treaty would:

- Cap the inventories of fissile materials available for weapons use.
- Provide for verification of materials released from defense programs (ensuring that this material is not available for reuse in a weapons program).
- Encourage improved safety and security of existing weapons.
- Reduce the special status granted to NPT weapons states, which should facilitate progress on nuclear disarmament.

The benefits also would include:

- Putting all civil facilities under IAEA safeguards with common standards of accounting and measurement.
- Ensuring that activities are approved by a conference of states parties based on what is considered prudent, and legitimate peaceful and nonexplosive military applications.
- Establishing a universal export control regime.
- Designing proliferation-resistance into future nuclear energy systems (or even present ones).
- Providing a universal basis for verification.

Shea explained that his treaty would take account of problems he has observed in how organizations, such as the UN Security Council, and treaties, such as the NPT, operate, and would include ways to avoid them. He said it will also strengthen the NPT regime. The burdens of the new treaty, financial and otherwise, would be mainly on those countries that possess nuclear weapons, Shea stressed.

With the end of the Cold War, Mastal noted, the world is still left with nuclear weapons, nuclear technology, and a growing stock of surplus weapons-usable material.

Nonproliferation fuel

Since 1995, Claude Degueldre, who is based at the Paul Scherer Institute in Switzerland, has been the coordinator of an initiative to develop Inert Matrox Fuel. IMF, says Degueldre, is a proliferation-resistant technology that is simple, robust, and straightforward. The fuel's isotopic content makes the material practically unusable for weapons production after irradiation. IMF, says Degueldre, is also more efficient at burning plutonium than MOX. Switzerland is interested in this concept for dealing with excess plutonium from its own reactors.

IMF is also particularly suitable for geological disposal, he explained. It has low solubility, a low leaching rate, and shows excellent behavior under irradiation. It is, said Degueldre, better than glass in resisting chemical dissolution, being insoluble in nitric or fluoric acid. It is also resistant to milling and crushing. IMF fuel rods have been irradiated in the Halden reactor (Norway) and the high flux reactor in Petten, (the Netherlands), and tests have been done in Japan.

Russia and the United States have stopped producing HEU and weapons plutonium (except for Russia's three remaining production reactors, which are due to close soon).

Communicating to the public

Several years ago, Denis Beller, intercollegiate programs coordinator for the Transmutation Research Program at the University of Nevada, Las Vegas, came across a quote by noted author and nuclear industry supporter Richard Rhodes. During a roundtable discussion at an Institute of Nuclear Materials Management conference in 1997, Rhodes said, "People didn't really know that nuclear power has a great safety record, that waste disposal isn't a deep mystery beyond the power of science, and so on."

How to get people to understand these points was the topic at hand in the session *Innovative Public Communications*, chaired by Beller. The public's attitudes toward nuclear power cannot be changed through trying to teach them about nuclear energy, he argued.

"We don't need to educate the public," said Beller, who chairs the ANS Public Information Committee. "We have been saying this, 'We simply need to educate the public,' for 25 years. The definition of insanity is doing the same thing over and over and expecting different results. Ben Franklin told us that a long time ago."

Beller said it's actually easy to gain public acceptance for nuclear power, and pointed to a 1998 Nuclear Energy Institute study. The results of the study, during which subjects were read a 20-second positive statement about nuclear energy, underscored his belief. Before the statement, 23 percent of the people strongly favored nuclear power; after, 34 percent were strongly in favor. Before, 13 percent strongly opposed nuclear power; after, the number shrank to 7 percent. The net effect was a 20 percent swing in attitudes, from opposing to favoring, Beller said—a gain of 10 percent favoring and a reduction of 10 percent opposing.

That would seem to belie Beller's statement about education not working to change people's minds.

"But remember, that's the whole population—the whole population of the United States is 280 million people. How many people do we communicate to as the American Nuclear Society?" Beller asked. "If just 10 percent hear that same statement, and we use the same mathematical [means] to get to the answer using a matrix calculation, you get a 1 percent change in 'strongly favor' and a -1 percent change in 'strongly oppose.' It is a change, but with 10 percent of the population, or 28 million Americans hearing this message, you could expect a 1 percent change."

That certainly is better than no change. But then what happens after the next negative statement that is floated out into the national media? Beller guesses those changes would disappear.

"We have to do things that make a lasting, positive impact on public opinion," he explained. "To do that we have to either target a specific, large audience, or you have to target the whole population. You have to figure out a way to get a message to 280 million Americans or billions of people worldwide, to make a lasting effect. And you have to do it repeatedly because

they're going to be hearing the other message at the same time. If we put an ad in the newspaper, we can guarantee that one of the antinuclear organizations is going to put in a bigger and better ad, with more emotional impact."

And emotional impact, Beller emphasized, is one of the keys to delivering a message that will last in the public's mind. The antinuclear organizations have been using fear for decades, he said. But, given the public's concerns over global warming and blackouts that stretch for hundreds of miles, the nuclear industry may now have fear on its side. Figuring out how to leverage that, however, remains a challenge.

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"We have a very dull story to tell. We are not exciting. The only time it gets exciting is when things go bad. If a nuclear power plant is clicking along at 100 percent for days, it's just not exciting. And we don't want it to be exciting. So, we have to figure out another way," Beller said.

Another element of communication that can enhance public acceptance is familiarity. Beller cited fears about boilers at the turn of the last century, pasteurization of milk, and horseless carriages as technologies that required time for the public to get comfortable with before they were accepted. Beller wondered if conducting 1 million nuclear power plant tours per year would help.

"We drive down the freeway next to 300 000 shipments of petroleum a day in the United States. We accept that now. We can do something like that if we do a million plant tours a year. But if we did something like that, we would miss 270 million people in 10 years."

The key, Beller said, is not massive education, but massive communication. People want "what we have," Beller said. They want information from someone they trust, and they already trust scientists and engineers. They want someone to tell them that nuclear power is okay, Beller said. And the industry needs to simplify its message to a handful of words to get its point across more effectively.

"Can you say, 'Nuclear power is safe'? I don't hear it very often. I hear a 100-word essay or a 1000-word essay when a reporter asks the question. . . . And that's what we need to say. And we need to say it to our friends and families and the public."

The ANS grassroots movement

Laura Hermann, a staffer in the ANS public information department, has been getting the society's recent Grassroots Initiative off the ground. The effort was inspired by former New Hampshire governor John Sununu's address during the 2002 ANS Winter Meeting. "We must understand," Sununu said in November 2002 in Washington, D.C., "whether we like it or not, until more of us get involved in the political process, that in the long run, the ultimate decision on hard issues . . . will be made by people who have no instinctive feeling about the difference between a part per million and a part per billion."

Getting members involved in the political process is the goal of the Grassroots Initiative, with the ultimate objective that ANS be seen as a credible source of information about nuclear science and technology—particularly to policy-makers and opinion-shapers. For instance, ANS has a number of "talking points" on its Web site at <www.ans.org>, with facts that people can use to build a case for, say, waste disposal or new plant construction, when meeting with people outside the industry.

"We recognize that in order to impact policy, we need to be educating our policy-makers about what we know about nuclear science and technology," Hermann explained. "Being a professional society, we know a lot more than the general population, certainly more than policy-makers. . . . Sununu talked about the importance of making ourselves available and going out and developing those relationships."

ANS began the program, which was just over a half-year old when Hermann gave her presentation, by sending a letter to all its members, inviting them to introduce themselves to their local elected officials. The society began to examine what kind of impact its members were having on their local areas and what kind of resources they were using from ANS. An early product of the first six months of the Grassroots Initiative was the publication of a brochure, titled *Clear Thinking on Nuclear*, that members can give away.

"These brochures help our members identify what they have to offer, and they can leave it behind when they meet with the policy-maker," Hermann said. "We have technical resources. We have educational resources. This brochure talks about the meetings, what we do here, some of the decision-making processes that go through the society. We hope it will be a useful resource. It's something that people identified as a need."

While the program is young and is still growing (only 20 people have yet filled out the online form ANS uses to track the effort, Hermann said), it has had its successes. Last summer, one member scheduled an appointment with a representative for Rep. Eric Cantor (R., Va.). Shortly after making the appointment, the cascading blackouts swept across the northeastern United States and southern Canada. "What had gone from a meeting with a legislative assistant was suddenly raised in importance. Not only was the congressman there, but a bunch of staffers were there to listen because suddenly the nuclear issue was one that was relevant to all his constituents," Hermann explained. A few weeks after the meeting, the member was at a local function in his community and was introduced to the county supervisor, who had heard about the member's meeting with the congressman. The county supervisor, who happened to be the manager of radiological response in Virginia, said to the member, "I heard that you met with your congressman to talk about these issues because you know about them. I need to know about them as well." And the member was able to set up an additional meeting.

"This is what I think is so significant about the Grassroots Initiative," Hermann said. "It's not just about meeting with those elected officials. We recognize the significance and importance of having that interaction. But what has happened is we have one member meet with one congressman, who then goes and meets on a state level with a local agency, develops that education tool there, and has affected now 10 people in having one meeting because he's been able to build a relationship, establish himself as a resource, and been able to link them back to other resources at ANS."

She added, "That's really what we want to be able to model throughout the organization."

Message for the public

Carl Crawford, nuclear communications manager for Entergy Nuclear, believes in focusing the message when addressing the public. He discussed the slide presentation that Entergy Nuclear staffers are encouraged to work from when delivering a talk about nuclear power, and showed some of the stronger and clearer facts that can be made in support of nuclear energy.

One point that can be made is that the nuclear industry is an astonishingly safe place to work. According to the World Association of Nuclear Operators and the U.S. Bureau of Labor Statistics, the U.S. nuclear industry has suffered fewer accidents per

200 000 worker hours than not only the nation's manufacturing industry, but even the finance, insurance, and real estate industries. In other words, a nuclear power plant is a safer place to work than an office. "In every presentation, we try to get across the safety message. And this little slide blows people away," Crawford said.

Also, highlighting nuclear energy's environmental benefits is helpful. Nuclear energy is the largest source of emissions-free electricity generation, by a wide margin. And, adding to that, the United States is emitting more carbon dioxide than the next six countries combined. "We think that preaching the environmental benefits is very much a focus we need today," Crawford said. "And this one shows that we in the United States are going to have to come to grips with the problem."

Another environment-related slide shows what is needed to generate 1000 MWe among a host of renewable sources: 3000 wind turbines, 30 000 km^2 of wood for biomass, 100 km^2 of cells at 10 percent efficiency for photovoltaics. Nuclear energy requires less than 1 km^2 of space for a plant to generate that amount of electricity. "Our vice president who uses this slide most often calls this his 'Pigs and Chickens' slide, because it shows that to equal the output of one nuclear plant, 60 million pigs or 800 million chickens would be needed to produce that much energy through biogas."

The future for hydrogen demand and production is also good to point out. Because much of the sweet Texas crude oil has been used up, a lot of hydrogen is currently being used to refine the imported sour crude oil, Crawford said. "Sour crude requires the injection of hydrogen in the refining process to raise its heat content and energy content. So, the more cars we have, the more gasoline we're going to need to import, and, further, the more hydrogen we're going to need."

In the future, the demand for hydrogen will be up to 40 times what it is now, Crawford said. Where will it all come from? This is where nuclear can be stressed as a long-term solution to the hydrogen demand, he said.

There are two ways to get hydrogen from nuclear power–related processes. Electrolysis gives an efficiency of around 25 to 40 percent and can be used with many of the current generation of plants. "All electrolysis needs is power and water. The power can be used to split the water into hydrogen and oxygen at the point where you want to use the hydrogen," Crawford explained.

The other way, and perhaps a better long-term solution, would involve thermochemically splitting water using Generation IV reactor technology. "The higher-temperature, gas-cooled reactors can be 50 to 60 percent efficient in making hydrogen. And they can do it by actually being so hot they will split water into hydrogen and oxygen right there in the reactor," Crawford said.

Last, Crawford said he believes public attitudes toward nuclear can be positive if the public is given the right information. That information can include reminding people that the majority of people in the United States favor building new plants. According to figures from Bisconti Research, Inc., the number of people definitely agreeing that more nuclear power plants should be built in the future rose from 45 percent in October 1999 to 65 percent two years later.

The number of people definitely agreeing that more nuclear power plants should be built in the future rose from 45 percent in October 1999 to 65 percent two years later.

"In all our presentations, we include this key message. We don't want people to think that nuclear is evil. We want to show that generally, the public, two out of three, understand that nuclear energy is beneficial today and they definitely think we should build more power plants."

Money savers

What do plate-type heat exchangers, fiber-reinforced polymers, and reactor power uprates have in common? They all have helped nuclear power plants control their bottom lines. To that end, money-saving ideas, lessons learned, and benchmarking tips were the sorts of information available at the "Financial Performance Enhancements at Operating Nuclear Power Plants" session.

The Omaha Public Power District's Fort Calhoun is undergoing renovation in order to operate into the 2030s. The plant, a 478-MWe (net) Combustion Engineering pressurized water reactor located in eastern Nebraska, was approved last November for license renewal by the Nuclear Regulatory Commission.

Gayoso

Michael Gayoso, Fort Calhoun's manager of planning and costs, said that new steam generators and a new reactor vessel head will be placed in service in 2006, a power uprate of up to 100 MW is scheduled to be completed in 2008, and other plant improvements will be accomplished during the same timeframe. In total, more than $400 million will be spent on rehabbing Fort Calhoun. "Now more than ever," Gayoso said, "a well-managed planning process is essential to maintaining cost competitiveness."

The planning process entails a strategic business plan that covers the next six years. A complementary document—Fort Calhoun's financial plan—"is the translation of the strategic business plan into dollars and cents," Gayoso said.

The strategic plan provides guidance to managers who have to deal with unbudgeted expenditures that arise during the course of business. The guidance "is simple and effective," he said. "It requires teamwork, trust, integrity, and simplicity. We call it the Ten Step Process."

The Ten Step Process includes such actions as determining whether or not the added expenditure can be absorbed into the department's existing budget and, if not, meeting with division managers to see if funds can be shifted from one division to another. "This process is no panacea, but it is working for us," Gayoso said. "So far, there has not been a need to go to step 10," which entails getting the chief nuclear officer involved to decide whether to revise the original budget to appropriate funds.

At Tennessee Valley Authority's Browns Ferry nuclear plant, in Decatur, Ala., an extended power uprate is planned for the plant's three units, which are General Electric boiling water reactors. Units 2 and 3 are currently operating, while Unit 1 was shut down in 1985 and is undergoing a recovery project that will restart the unit in 2007. Units 2 and 3 are each rated at 1118 MWe (net), and Unit 1 is at 1065 MWe (net).

To increase power, Browns Ferry will use a technique developed by GE for "maximum extended load line limit analysis conditions," explained TVA's Wally Justice. According to Justice, the technique will allow each Browns Ferry unit to achieve an output of 1280 MWe. Because of the increased power, plant modifications will be done to handle the increased flows and pressure, and as such, a few issues have been identified for resolution. For example, "the high-pressure turbine pressure is predicted to approach the design limits on the high-pressure heater shell," he said. Justice added that engineering studies were under

way to evaluate possible options, and a study also was being completed to address recirculation system vibration.

Uprating the units will add approximately 375 MWe of generation to Browns Ferry, said Justice. "Coupled with a license extension for the units, the economics of increasing the generation capacity of an existing facility are very positive," he said.

Preventing stress corrosion cracking (SCC) of steam turbine rotors was the subject of Olivier Mandement's talk. Mandement, of Alstom Power, detailed a wide-scale retrofit program launched by Electricité de France for its nuclear units. Three main factors influence the extent of susceptibility to SCC of a steam turbine rotor, he said: the material yield strength, the stress levels, and the operational environment. "Materials of high yield strength are much more susceptible to SCC than materials of low yield strength," he said. "Tests clearly showed that SCC can occur at applied stresses significantly lower than the material yield strength" (below 70–80 percent). "Therefore," he continued, "maximum resistance to SCC is obtained by specifying the lowest possible rotor yield strength and by keeping the peak stresses as low as possible and always below the SCC threshold stresses."


Mandement

There are two basic design principles to prevent SCC: first, the use of welded rotor technology, and second, "a careful mechanical design," he said.

Mandement explained that the general level of tangential stresses is typically 35 percent lower in a welded rotor than in a shrunk-on discs rotor. "Welded rotor technology leads to reduced levels of component stresses and, therefore, consequent high material strength is eliminated," he said. "This technology allows the use of lower yield strength materials with a higher SCC resistance."

Welded rotor technology has been used by Alstom since the 1920s. It has been applied on nuclear steam turbine rotors since 1965 and, so far, Alstom has supplied more than 200 large welded LP rotors worldwide. But use of welded LP rotor technology alone is not sufficient to eradicate SCC, Mandement cautioned. Attention must also be paid to the mechanical design in order to limit the peak stresses to a minimum in critical areas such as "blade root fastenings or fillet radii between rotor disc and hub," he noted.

Less than five years after installation of the original tube-and-shell aluminum heat exchangers, Cassells said, significant tube leakage developed due mainly to tube vibrations at the baffles.

Mark Cassells, of the National Institute of Standards and Technology, explained the benefits of plate-type heat exchangers, which, at nuclear power plants, are primarily used in auxiliary systems. The 20-MW research reactor at NIST is heavy-water moderated and cooled.

Less than five years after installation of the original tube-and-shell aluminum heat exchangers, Cassells said, significant tube leakage developed due mainly to tube vibrations at the baffles. Special aluminum plugs had to be designed to seal the leaky tubes. The aluminum heat exchangers were replaced by tube-and-shell stainless steel units. Immediately after installation, significant tube rattling was noted in the vicinity of the U-bends. A window was cut in the shell, and the tubes in the area were laced to provide added support.

This fix seemed to have worked well for a few years until tube leakage again developed. The decision to eventually switch to plate-type heat exchangers was made "because they provided the best assurance for reliability and zero cross leakage when properly designed, specified, and constructed," Cassells said.

Cassells explained that plate-type heat exchangers are a series of grooved plates sealed by gaskets with alternating cross flow of primary and secondary water in between the plates. "In millions of hours of operation, there has never been any leakage through the plates," he said. However, fouling due to impurities in the water and degradation of the gasket material seemed to occur rather frequently, requiring disassembly of the unit for cleaning and replacement of the gaskets. Six design specifications were made, such as, for example, that the heat exchangers had to be made of stainless steel type 316 L.

Three heat exchangers were installed in the NIST reactor in the same space as the previous two. The total cost, including added features and modifications, was less than one-fifth of the cost of two tube-and-shell heat exchangers with similar performance specifications. "The heat exchangers have been operating flawlessly since their installation in 1995," Cassells concluded.

A new technology is increasing the usable life of components and structures at nuclear plants, according to John Charest, of Universal Utility Services. The technology, known as Fiber Reinforced Polymers, or FRP, uses carbon fibers and high-strength epoxy resins to restore or enhance the structural or pressure boundary capacity of plant equipment and structures such as piping, pumps, and heat exchangers.

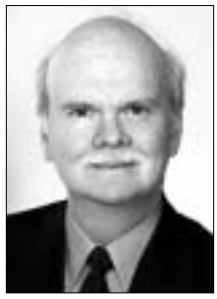

Charest

Repairs are typically accomplished in-place with small crews and completed during a relatively short time. For example, Charest explained, two- or three-man crews with minimal equipment perform the work. "The work often can be completed during regularly scheduled shutdown times," he said. "These crews can work around existing obstacles and do internal pipe strengthening with access only through a manhole."

Prior to FRP installation, the repair area is worked to eliminate any degradation of the base material. There are two types of installations: "contact critical" and "bond critical," he said. A contact critical installation involves applying the FPR, which is put on like wallpaper paste, completely around the component until it "re-bonds to itself," he said. Then there are bond critical applications, which require a bond between the FRP and the component.

FRP repair has been done to piping at Duke Power nuclear plants, as well as at Millstone and Indian Point, according to Charest. The bottom line, he said, is that FRP repair of pipes and components can be done at about 20 percent of the cost of installing new parts.

Ken Ferguson, of Aspen Systems, made observations about nuclear plants in the post-license renewal environment. There is much optimism about license renewal, Ferguson noted, but there also are new issues for the industry. For example, while the NRC can renew a plant's license for 20 extra years, that plant's management now has to determine how to reliably and cost-effectively manage the plant. Focus now can be placed on systems, structures, and components that were not neces-


Ferguson

sarily key contributors to safety, he said, "and $600 million later, you have the plant you want to go into the future." In this sense, Ferguson added, license renewal is an "interim achievement, it's not the end one."

Ferguson observed that a plant's attention to information management is important for dealing in a business-effective manner as a plant moves forward. "Key organizations need to be involved in a common understanding of work processes that exist or should exist at the nuclear plant," he said.

The plant organizations that would be involved in establishment of information management enhancements, he said, would include operations, maintenance, engineering, and nuclear safety and licensing, for example. Some key nontechnical organizations that would have their own information management needs would include procurement, quality assurance, human resources, and financial organizations. "Additional overarching concerns such as plant power level upgrades, outage management, inventories of parts and materials, and security will need to be represented as well," he said.—*Dick Kovan, Rick Michal, and Patrick Sinco*

TOPICAL MEETING

Atoms for Peace—Updating the vision

A HALF CENTURY HAS passed since President Dwight D. Eisenhower made his "Atoms for Peace" speech to the United Nations. His vision was to avoid nuclear war and an arms race with the Soviet Union, contain Soviet expansion, and prevent proliferation worldwide. During his talk, on December 8, 1953, Eisenhower proposed that the world should work together to devise methods that would allocate nuclear materials "to serve the peaceful pursuits of mankind." Experts would be mobilized to apply "atomic energy," as Eisenhower noted, to the needs of agriculture, medicine, and other peaceful purposes. (See *NN*, Nov. 2003, p. 38 for the full text of the "Atoms for Peace" speech.)

Fifty years later, Eisenhower's vision has been and is being realized, as today nuclear technology benefits the world through various applications. An embedded topical meeting, *Global 2003—Atoms for Prosperity: Updating Eisenhower's Global Vision for Nuclear Energy,* offered sessions dealing with some of those applications. Topics included the importance of international cooperation to the expanded use of nuclear technology, the efforts made worldwide to develop next-generation nuclear energy systems, and the success of Russian-American fissile materials disposition programs.

One session, "Atoms for Peace 1953–2003: What are the promises of the future?" provided comments on Eisenhower's path to "Peace," some predictions about where nuclear technology is headed, information on nonpower applications of the technology, and news on national security issues.

Eisenhower's task in 1953 was much as it is for today's leaders, according to Mike Wheeler, of SAIC. That task was to allow the spread of peaceful applications of nuclear technology while protecting against the spread of nuclear weapons. In that regard, the speech was, for its times, "fairly amazing," Wheeler said. While Eisenhower realized the importance of nuclear weapons to Western security, he wanted to stabilize the arms-race situation with the Soviet Union. "He was looking for modest openings in terms of being able to make progress with Russians," said Wheeler. "He wanted to have a dialogue under way."

Eisenhower also recognized that even if the United States had not taken the initiative, commercialization of nuclear power was going to be inevitable. "It already was happening elsewhere," Wheeler said, "but he wanted to put the United States in a leadership position."

All of this was done in an atmosphere where even some of Eisenhower's administration were not interested in arms control. Without the President's resolve in making his speech, Wheeler said, "we would probably not have the kind of proposal that was made in December 1953."

John Taylor, retired from EPRI, commented that Eisenhower's vision has been "very successful." For example, he said, the spread of nuclear weapons, which had been predicted to be in the hands of at least 25 countries in the years following the speech, "is today [in] about seven [countries] . . . maybe nine, depending on what really has happened," he said.

There have been setbacks however, Taylor noted. These include the deficiencies in worldwide inspection, export control, and compliance measures, and the fact that more nations are now undertaking weapons development. Still, he said, the foundation

Major points of the session:

- *Ike's speech was "fairly amazing"*
- *His vision was "very successful"*
- *Create a "new partnership"*
- *A proposal for "fuel leasing"*
- *"Contributed enormously to humanity"*
- *Focus on security "before all else"*
- *Security from U.S. leadership*

of Eisenhower's vision has been laid: There are 441 nuclear power reactors worldwide, providing 16 percent of the world's electricity; 32 plants are under construction, most in Asia; many countries depend critically on nuclear's contribution to electricity generation; the average capacity factor at U.S. nuclear plants is at record levels, exceeding 90 percent in 2002; and production costs of U.S. reactors were 1.71¢/kWe in 2002, and in 2001, at 1.68¢/kWe, a record low.

Future prospects for nuclear are good, Taylor said. Various projections call for electricity growth ranging from 140 percent to 480 percent by 2050, depending on economic conditions. A challenge for nuclear will be staying cost competitive with other generators, he observed. General Electric ABWRs (being built in Japan) are estimated to run at $1400–$1600/kWe. The Westinghouse AP-1000 is estimated at $1000 to $1400/kWe, and modular direct-cycle HTGRs are estimated in the same general range. New nuclear plants would be competitive with combined-cycle gas turbines, Taylor said, if gas prices are between $3.80 and $6/million Btu. Gas prices, incidentally, over the past decade have run as low as $3/million Btu, but now are edging up to the $5–$6 range, he added.

Taylor explained actions that are needed to shape the global future and to keep alive Eisenhower's vision. These include defining a collaborative international regime to foster economic contributions to energy and social needs, and maintaining high standards of safety and proliferation resistance.

Other actions, he said, include increasing the inspection and monitoring abilities of the International Atomic Energy Agency; strengthening export controls and MPC&A (materials protection control and accounting); providing international regional fuel services; and ensuring "that security comes first, that the nuclear future is what we choose, and not the result of drift and inattention."

Ernest J. Moniz, professor of physics and director of energy studies at the Massachusetts Institute of Technology, and past undersecretary of the Department of Energy, posed the question, "Where are we in the legacy of nuclear materials over these last 50 years and what are the implications for going forward?"

The legacy of the weapons programs, especially in the United States and Russia, provides "considerable opportunity," Moniz said, in that the future will include "all kinds of nuclear activities, including civilian nuclear power."

Moniz advocated development of a new partnership, now during this time of the 50th anniversary of Eisenhower's speech. The partnership would pull together stronger safeguards and materials protection control; bring collaboration on nuclear terrorism, smuggling, and international violations; add protocols that would be universally applied; accelerate disposition of weapons materials using market forces in the nuclear fuel cycle; and view international spent fuel as a nonproliferation benefit.

Thus, if carbon-free, pollution-free electricity is to expand, and if nuclear weapons stockpiles are to be reduced, the world will need to cooperate to go forward with nuclear.

There also would be cooperation, he said, in advanced plutonium R&D, in waste management, "and in devising off-ramps for those who are not collaborating properly within the international regime."

What remains, he said, is the question of leadership, finding "someone to come forward and see that these threads can be pieced together and really give a second 50 years of 'Atoms for Peace' with a much improved nonproliferation, and with a situation of potentially opening up a genuinely new fuel cycle for the future."

Victor Reis, a senior vice president of SAIC, proposed a concept called "fuel leasing" as it relates to "Atoms for Peace" in the year 2050. Under Reis's scenario, there would be two types of states: the first a fuel-cycle state and the second a reactor state. The former state would lease fuel-cycle services (such as fuel supply and fuel recycling) to the reactor state.

Reis

The fuel-cycle states would be what are today the weapons states plus Japan, while the reactor states would be all others. The goal of the fuel-cycle states (which themselves would have operating reactors) would be to receive half of their electricity from nuclear power within 30 years from today, while the reactor states would receive half of their electric power from nuclear within 50 years.

The scenario is possible, Reis said, because there is a need for global expansion of electricity, but without carbon and pollution emissions. There also are the security issues. "In terms of international security," he said, "we want no major wars, no or very [few] rogue states, no international terrorism, and regional conflicts settled. And, in terms of international relations, we'd like to have international norms on national behavior and extensive trade. All of these things are basically coupled."

Thus, if carbon-free, pollution-free electricity is to expand, and if nuclear weapons stockpiles are to be reduced, the world will need to cooperate to go forward with nuclear. But, Reis concluded, this would not be a challenge for the nuclear industry, but would be an opportunity.

Other applications

In addition to nuclear power, Eisenhower stressed applications in other areas such as medicine, agriculture, and industry. Additional areas today include environmental protection, public safety, and space applications.

Alan Waltar, director of nuclear engineering at Pacific Northwest National Laboratory and an ANS past president, provided statistics that showed that nonpower applications of nuclear technology had an impact on the U.S. economy in 1995 of $331 billion in sales while providing 4 million jobs. (By comparison, for that same year, nuclear power itself had $90 billion in sales and provided 440 000 jobs.)

Waltar

The main mover in those nonpower numbers is medicine, according to Waltar. Gamma rays sterilize surgical dressings, sutures, catheters, and syringes, while more than 80 percent of all new drugs in the United States are tested with radioactive tagging before government approval is issued. Also, between 200 and 300 radiopharmaceuticals are in routine use.

Diagnosis is the area in medicine where nuclear has the largest impact. There are X rays, imaging using technetium-99m, and the SPECT (single photon emissions computed tomography) and the PET (positron emission tomography) systems. "There are about 12 million patients a year in the United States alone that benefit from nuclear medicine," said Waltar. "One in three patients that enters our nation's hospitals and clinics benefit from nuclear medicine."

Waltar then turned to nuclear's applications in agriculture. "There are ways of us-

ing radiation to get these kinds of attributes: better crop yields, improved nutrition, improved processing capabilities, and better disease resistance," he said.

Since the 1920s, more than 30 nations have developed about 2250 new crop varieties, and of that, radiation was used to develop about 90 percent of them. Sixty percent of those new crops have been added since 1985, which has benefited China enormously, Waltar noted. "Over one-fourth of the crops of food produce grown in China is due to radiation," he said, "and in the United States it's about 6 percent."

Isaacs added that he wasn't convinced the world could continue "in a regime that continues to make such a crass distinction of haves and have nots at the same time."

Other interesting insights: In Scotland, most of the ales, whiskeys, and beers are a result of the radiation industry. In Italy, since 1984 more than half of the wheat grown was due to radiation. In Pakistan, a nation that was close to exiting the cotton business, a new variety due to radiation development techniques resulted in a doubling over the past five years of new cotton strains.

There also is food irradiation, which is gaining a lot of attention these days, Waltar noted. "In the United States alone," he said, "you have about 5000 deaths every year and 76 million cases of food poisoning." Irradiating certain foods before they are consumed could have an impact on lowering those numbers.

In the United States, the federal government has approved irradiation of spices, poultry, and red meat. Such food is already consumed by, among others, astronauts and open-heart surgery patients. "The exciting thing," Waltar said, "is that just within the past year or so there are places like Albertsons, Safeway, Giant Eagle, and Winn-Dixie that are starting to put some irradiated foods in their markets."

In industry, radiation is used in process controls for thickness gauges (for sheet metal, paper, and textiles) and density/level gauges (oil and food). For materials testing and inspection, radiation is used to detect engine wear, check for weld defects in airplane parts and in oil/gas pipelines, and look for corrosion in metals. For personal care items, it is used on contact lens solution, bandages, cosmetics, and disposable baby diapers.

Radiation applications are used in environmental control (such as measuring CO_2 levels in seawater), security measures (luggage inspection), and in home use (smoke detectors).

In outer space, NASA uses radiation from plutonium-238 for for electricity and heating in space probes, and has plans for nuclear propulsion for missions to Mars and back.

The bottom line, Waltar said, is that about 5 percent of the gross national product in the United States (and, similarly, in Japan) is due to the nuclear industry. So, while progress has been made and there are still issues to be tackled, "I think," he said, "we can all say we can be very proud to have contributed enormously to humanity."

Ike's intent

What the industry must realize is that Eisenhower's speech was not a blueprint for design, but rather a framework for how to think about nuclear expansion, according to Thomas Isaacs, director of Strategic Policy and Planning Activities at Lawrence Livermore National Laboratory. In today's world, where concern about terrorists' obtaining quantities of nuclear materials is high, it is no longer business as usual, he said. Instead, there must be a focus on security before all else. "My own view is that security first has got to be the mechanism by which we think about things nuclear in the future," he said.

Isaacs

Isaacs remarked that most people hold varying opinions about the security measures needed. Some believe that a threat is imminent and that there is the potential for detonation of nuclear weapons in major cities around the world. Then there are others who believe that the IAEA system works fine and there is no real concern. "That sense of urgency has got to be discussed, argued over, and reconciled," he said. "In my own view, it is a sense of urgency we need."

The problem the world faces, he said, is one of the "haves and have nots." This problem had its roots at the beginning of the Non-Proliferation Treaty in 1968, when the five nuclear weapons states at that time—the United States, the Soviet Union/Russian Federation, the United Kingdom, France, and China—were grandfathered in to allow them to behave in one way, while all the other countries in the world were told, "You don't get to develop these weapons and if you promise not to misuse these materials, we'll give you access to civilian [nuclear] technologies," he said.

Isaacs added that he wasn't convinced the world could continue "in a regime that continues to make such a crass distinction of haves and have nots at the same time." He noted that new rules have to be figured out in order to allow nuclear power to grow and develop. "Somehow, we've got to move in the direction where somebody exercises a sense of vision that brings the nuclear community together and has the leadership to actually make it happen," he said.

Eileen Verbino, talking on nuclear technology governance issues, commented that nuclear knowledge, nuclear civilian applications, and nuclear weapons are going to be a part of the world for a long time to come. "Regardless of whether you believe in the abrogation of nuclear weapons, we have a legacy we're dealing with," said Verbino, of LLNL. "Nuclear weapons are not going to disappear overnight. Therefore we need a governance regime where we work toward the time where nuclear knowledge, technologies, and materials contribute to international stability and they provide the underpinnings for prosperity, free trade, and travel."

Governance can balance the need for maintaining national sovereignty and international security, she noted. The objectives are to provide effective international agreements to prevent the acquisition and use of nuclear weapons; establish an effective, affordable international system to reduce the probability of nuclear terrorism; have an effective regime for verification, compliance, and enforcement; and construct a nuclear regime in which there is little usable material available.

Public communication also holds a place in security matters, Verbino said. In the minds of the public, nuclear weapons and nuclear technology are linked. "What needs to happen is there has to be a dialogue with the public about the value of nuclear technology," she said. "It's an engagement process. I bristle every time I hear the word 'education.' It is about engagement."

The industry needs to understand "how to communicate the uncertainty about terrorism, about the nuclear materials, about the governance system, about our decision process," she said.

Verbino ended by noting that the world looks to the United States first in matters concerning nuclear. "The U.S. will go a long way toward the goal of security, while promoting the use of nuclear technology, by providing leadership," she said.—*Rick Michal* NN