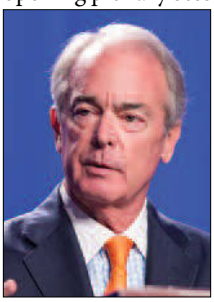
ANS WINTER MEETING

# Nuclear fission, 75 years later

Nuclear science and technology is a relatively young field, so when practitioners in that field reflect on its history, their own experiences can make up a substantial portion of that history. The American Nuclear Society's 2013 Winter Meeting, held November 10–14 in Washington, D.C., was presented partly as an observance of the 75th anniversary of the discovery of nuclear fission, an event that is beyond living memory of the participants but within the lifespan of others who have participated in other key events in the field.

James Rogers, chairman of the board of Duke Energy and general chairman of the ANS Winter Meeting, presided over the opening plenary session. He noted that five years ago, the nuclear industry was at the start of a renaissance. Now, he said, with Congress not having addressed the carbon tax issue, the landscape has changed dramatically. "The reality is," he continued, "if you're serious about addressing climate, you have to be serious about nuclear energy, because as you all know, it is the only way we produce electricity 24/7 with zero greenhouse gases."


Rogers

Rogers bemoaned the "illiteracy" of the public about energy and about how electricity is produced. "Each of us," he said, "has a responsibility to help educate the people of this country about how we fundamentally transform their lives every day by bringing electricity into their homes and businesses."

Rogers said that he anticipates that every currently operating nuclear plant will be retired by 2050 and that he isn't confident that plants can be run for 60 or 80 years through life extension. He expressed surprise that natural gas is being used to operate baseload electric generating plants, and, going back to commenting on the nuclear renaissance, he noted that just four reactors are currently under construction in the United States. This shows, he said, that "we are not taking the long view." In his opinion, the renaissance is coming late, but he believes that there will be one.

"We cannot lose focus on the vision and the role that nuclear can play in our economy," Rogers declared. He said that what the nuclear industry needs is the concept of "cathedral thinking," by which he meant that there were many individuals who spent their entire lives working on the Notre Dame Cathedral knowing they would never see the finished product. They had faith and a vision that it would one day be completed. Those who are involved in the nuclear industry need to think that way, he said, and to have a "vision about the future of nuclear"—faith that one day, the nuclear renaissance will be a reality here in the United States.

Energy Secretary Ernest Moniz extended the theme of nuclear anniversaries by pointing out that 2013 had also seen the 60th anniversary of President Dwight Eisenhower's "Atoms for Peace" speech and the 20th anniversary of the Megatons to Megawatts program. Regarding the latter, under which what had been Soviet nuclear weapons material has been converted to power reactor fuel for use in the United States, Moniz added that during the week of the meeting, the final shipment of downblended uranium would be leaving Russia.


Moniz

Neither Eisenhower nor anyone else anticipated global climate change back in 1953, Moniz said, and what is now seen as one of the major benefits of nuclear power is that it is an emission-free energy source. Moniz noted the recent open letter from four climate change scientists to environmental organizations that have traditionally taken an antinuclear stance, asking them

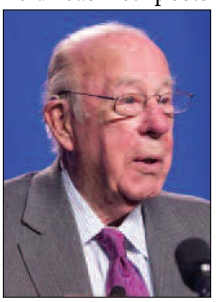
*Meeting session coverage:*

- *Anniversaries of fission, Atoms for Peace, and Megatons to Megawatts*
- *Nuclear in a carbon-constrained world*
- *Fuel cycle innovations*
- *Risk communication to the public*

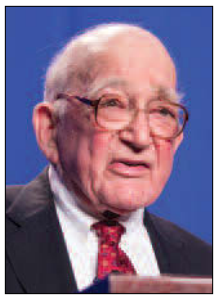
to reconsider their views (*NN*, Dec. 2013, p. 15). He then described the Obama administration's climate action plan and the Department of Energy's role in carrying it out. Much of this has been covered in these pages before; to summarize, the goals are to mitigate climate change, to adapt to the effects of climate change that might be beyond mitigation, and to pursue international cooperation to address the issue globally. He added that in his view, the question of whether there is anthropogenic climate change is generally answered in the affirmative; the focus is now on questions starting with what, how, how much, and when.

Moniz expressed confidence in the prospects for carbon capture and sequestration of emissions from fossil-fuel combustion, saying that carbon dioxide from the lignite-fired Kemper gasification plant in Mississippi will be used for enhanced oil recovery. He cited the administration's three principal thrusts in regard to nuclear energy: the loan guarantee for new power reactors at the Vogtle site in Georgia (for which the terms are still being negotiated), cost-shared funding for the design certification and licensing of small modular reactors (for which the second funding award was still pending), and the implementation of the recommendations of the Blue Ribbon Commission on America's Nuclear Future regarding the disposition of spent fuel and high-level waste. He said that he considers continued on-site storage as "politically unsustainable," adding that a bipartisan Senate bill to establish a consent-based repository siting process could soon move toward a vote.

The next speaker was George Shultz, who held cabinet posts in multiple federal administrations, including secretary of state under President Reagan, and who is now a distinguished fellow at the Hoover Institution. His talk could perhaps be seen in the context of events of the past 75 years, but within a narrow range: nuclear weapons negotiations with the Soviet Union in the 1980s. This began the process of arms reduction, which, among other things, included the Megatons to Megawatts program mentioned by Moniz. Shultz said that by 2006, the total volume of nuclear weapons was 30 percent lower than during the Reagan years, and he added that there has been progress in the ability to verify compliance with treaties. He also warned, however, that in his view there has been a deterioration of the "global commons," and that hard work needs to be done to address the weapons capabilities of Iran, North Korea, India, and Pakistan.


Shultz

Shultz was followed by Sidney Drell, professor emeritus of the Stanford Linear Accelerator Center, senior fellow at the Hoover Institution, and coauthor with Shultz and others of three books on efforts to limit nuclear weapons and with Shultz only of *The Nuclear Enterprise: High-Consequence Accidents: How to Enhance Safety and Minimize Risks in Nuclear Weapons and Reactors*. On the weapons side, he cited the bomb that accidentally dropped from a crumbling B-52 on Goldsboro, N.C., in 1961 (without detonation), and what he saw as worrisome in the routing mistake between Minot and Barksdale Air Force Bases in 2007. On the reactor side, however, he noted that the Fukushima Daiichi reactors are given grossly disproportionate attention given the loss of life elsewhere in Japan from the March 2011 tsunami.


Drell

Drell set out three guiding principles for both civilian and military nuclear applications: risk assessment calculations are fallible; there is a growing risk of accidents, mistakes, and miscalculations and of regional wars and nuclear terrorism, in part because nations new to nuclear may not have sufficient safeguards or regulatory capability; and no nation is immune from risks. He then offered four recommendations: that every level of the nuclear enterprise fully recognize the importance of safety and security; that regulation be fully independent; that independent peer review be incorporated into all aspects of the nuclear enterprise; and that threat reduction be organized around the goal of a global effort to reduce reliance on nuclear weapons, prevent their spread, and ultimately eradicate them.

Drell also reached deeper into nuclear history than the other speakers, citing the supposition in some quarters that human-induced fission had actually taken place before the Hahn-Meitner-Strassman work in 1938. He noted that Enrico Fermi, while still in Italy in 1934, had published a paper suggesting that his lab's bombardment of uranium atoms may have produced elements with atomic numbers higher than uranium's 92, and that perhaps because of the limited analytical tools available at the time, Fermi did not consider whether the uranium he was using may have fissioned. Fission was proposed a few months later in a letter by Ida Noddack criticizing Fermi's work, but Drell said that the letter was published in an obscure journal and no follow-up work was ever based on it.

The final speaker was Sam Nunn, former U.S. senator and for many years the cochairman and chief executive officer of the Nuclear Threat Initiative, a nongovernmental organization devoted to the reduction in the availability of weapons-grade fissionable material to rogue states and terrorists. Like Shultz and Drell, Nunn spoke mainly on what could be thought of as the downside of the nuclear enterprise: the geopolitical challenge of nuclear weapons and the control of special nuclear material. Whether intentional or not, this lineup of speakers had the effect of making the plenary session seem more about the hazards of nuclear energy than its benefits.


Nunn

Nunn expressed his view that for all of the Non-Proliferation Treaty's value, it doesn't show a path to the goal of a world without nuclear weapons. The NPT does not restrict civilian fuel cycle technologies, partly because at the time the treaty was developed, these technologies were under the control of a few countries. He said that materials security has advanced, noting the removal of high-enriched uranium from several countries, and that terrorists would target countries where HEU is most vulnerable. There are nearly 2,000 metric tons of weapons-usable material in the world and no effective global system to secure it, with 85 percent of it under military control and not subject to the rules that govern civilian nuclear programs.

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Nunn maintained that he favors civilian nuclear power, but only to the point where he believes that the spread of nuclear materials and technology could be put under a system of international controls. He said that the world has been reluctant to con-

front this issue, arguing that it goes beyond the high-visibility problems posed by Iran and North Korea. He mentioned an article in *Scientific American* in which it was projected that a nuclear war between India and Pakistan would not only kill 20 million people in those two countries, but would generate smoke and dust that would spread worldwide, shorten growing seasons, and perhaps lead to many millions more deaths through famine. He conceded that any serious effort to impose such controls would infringe on national sovereignty, but he said that existing international rules on aviation could serve as a model.

To some extent, the question-and-answer period amounted to a debate between audience members seeking to expand nuclear energy's benefits, through power reactor deployment in more nations and the adoption of spent fuel reprocessing, and panel members arguing for the limitation or prevention of such developments. Rod Adams, writer of the blog *Atomic Insights,* asked how much security would be enough, stating that half of the employees at a closed power reactor are there to secure the spent fuel. Shultz insisted that there could be no compromise on security. Another attendee asked whether a common liability regime could enhance materials safety. Nunn said he doubted that insurers would underwrite security. Former ANS president David Rossin argued against the United States' ban on civilian reprocessing, but Moniz stated the administration's backing of the recommendations of the Blue Ribbon Commission on America's Nuclear Future (to leave the long-standing federal position on reprocessing unchanged), and Nunn said that it has been difficult enough to get the government to take control of spent fuel in its current form, let alone as reprocessed fuel and waste streams.

## President's Special Session

Before opening the President's Special Session, titled "On the Path to Fission's Centennial and Beyond," ANS President Donald Hoffman presented awards to several individuals who have made exceptional contributions to nuclear science and technology and to ANS. As he introduced the session's speakers, he promised insightful views on nuclear science and engineering and their applications. The speakers certainly delivered on Hoffman's promise, providing not only their own insights about past achievements and future challenges, but inspiration as well.

The first speaker was Ralph Cicerone, president of the National Academy of Sciences (NAS), who highlighted the historical role and the importance of the nuclear sciences and their applications. Since the discovery of fission, he said, the science around it has matured to form the basis of numerous disciplines and applications, and today the techniques and tools of nuclear science address major societal concerns in, for example, medicine, national security, nonproliferation, nuclear forensics, energy technology, environmental and climate research, and many industrial applications. Nuclear science has also had an impact on astrophysics, particle physics, and cosmology, and helps describe the physics of complex systems. So what began as a "scientific curiosity," he said, is now central to many areas of fundamental science, and its developments have become integral parts of our economy and daily life.

Adding further historical context, Cicerone noted that a mere 25 years before the discovery of fission, Ernest Rutherford put forward his theory of the atomic nucleus, which marked the beginning of nuclear physics and the search to reveal what matter is made of—a search that continues today. There have been remarkable accomplishments and major discoveries in nuclear science in the past decade alone, he said, well beyond anything Rutherford could have imagined. The most recent survey by the NAS's National Research Council underscored the fact that the previous century's advances in nuclear science make it possible today to investigate very basic questions, such as how visible matter came into being and how it evolves, how subatomic matter organizes itself, and what phenomena emerge from those organizations.

While the NAS found that nuclear science in the United States remains a vital enterprise and continues to provide a steady stream of discoveries, Cicerone noted, many challenges remain. Meeting these challenges in today's economic and political environment, he added, will require renewed efforts to showcase the results of the past investment in nuclear science and to demonstrate its future potential.

*From the NRC chairman*

Allison Macfarlane, chairman of the Nuclear Regulatory Commission, offered her thoughts on the events that have shaped current perspectives on nuclear safety and on how best to keep the focus on safety in the years ahead. The Fukushima Daiichi accident has required the community to revisit established assumptions and regulatory priorities, she said. For example, she continued, as the accident unfolded, it became clear that a number of issues had not been adequately addressed in the past, such as risks posed by natural disasters and the consequences of an accident affecting multiple units at a site at the same time. The NRC is reassessing licensees' ability to mitigate seismic and flooding events and requiring them to ensure adequate emergency response training and communication to cope with prolonged accident conditions.


Macfarlane

Today, many countries are moving forward with new nuclear power projects, including nonnuclear countries, Macfarlane said, and the development of small modular reactor technology is likely to increase that number. Newcomer countries, she said, can take advantage of lessons others have learned by establishing a competent, well-funded regulator, promoting a healthy safety culture, considering the ultimate disposal of waste before any is generated, and communicating clearly with the public on each new step in the process.

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Macfarlane stressed that to be effective, a regulator must be independent of any political, economic, or other interest that could influence the regulatory body to make decisions that are not in safety's best interest. In the wake of the Fukushima accident, she noted, the Japanese parliament's Kurakawa Commission released a candid report that concluded that the accident was "man-made" as a result in part of "regulatory capture" wherein the industry has too great an influence over the regulator. The report also coined the phrase "nuclear safety myth" to characterize an unfortunate overconfidence that low-probability but high-risk events will simply not occur.

Macfarlane also warned about the current interest in the build-own-operate model for developing new nuclear projects in countries without established nuclear power programs, whereby a country would rely on foreign vendors and contractors to handle all aspects of its nuclear program, from

construction to day-to-day operations, and even regulation. "I believe this would be problematic for several reasons," she said. "If a country chooses to place its nuclear program in the hands of a foreign regulator, that country would relinquish its ability to ensure that it is adequately informing its own citizens about that program."

**Existing plants continue to operate with ever-increasing reliability and low cost relative to virtually all other options, and the prospects of extending their operation for decades longer are promising.**

For those who will be the stewards of nuclear regulation and the nuclear industry in the coming decades, Macfarlane emphasized the importance of maintaining the momentum on safety. "If the nuclear industry is going to be operating effectively at any size—if it's going to inspire confidence and public trust—then we must keep our focus on safety," she declared.

*Honoring the past*

Dan Mote, president of the National Academy of Engineering, began with his own tribute to two of those honored at this meeting: the late Harold Agnew, a past director of Los Alamos National Laboratory, who was posthumously awarded the Seaborg Medal, and Sen. Pete Domenici, who was awarded the Alvin M. Weinberg Medal. The careers of these "two true luminaries in the history of nuclear energy," Mote said, underscore why it is timely to celebrate the rich history of nuclear energy development. He noted that over the lifetimes of these two men, the utilization of nuclear fission has progressed from a scientific discovery in the 1930s to the vast national nuclear enterprise of today, which they helped engineer and implement in both the nuclear power and weapons domains.

Mote said that the challenges to moving this technology forward continue, and while the appeal of nuclear power as a carbon emission–free option for electric power generation has led to the first new nuclear power plant construction in the United States since the 1970s, "it is a fragile resurgence," and nuclear's future remains unclear. Polls show that a majority of the public supports nuclear power, he said, but this support is shallow, and nuclear power must clear high environmental hurdles for a true public acceptance. On the other hand, existing plants continue to operate with ever-increasing reliability and low cost relative to virtually all other options, he said, and the prospects of extending their operation for decades longer are promising. Nonetheless, he said, the environment for new power plant construction has fundamentally changed.

Today, Mote said, load growth remains uncertain, and natural gas–fired generation has become the default option for new electricity generation because of the technical advances in the recovery of shale gas. The exception, he noted, is where capacity additions at existing nuclear facilities are possible, or where state public utility commissions are supportive of the large investments necessary for nuclear construction. It is possible that a nuclear renaissance in the United States may come with the deployment of small modular reactors, he said, due to their passive safety features and reduced unit costs, coupled with an acceptable resolution of the nuclear waste issue. In the longer term, he said, the promise of nuclear power depends on the next generation of nuclear plant designs, along with federal policies that recognize the value of reduced carbon emissions.

In the United States today, Mote said, there are about 19,000 nuclear engineers working across many disciplines. The country's national laboratories, university education and research, and well-developed commercial nuclear infrastructure remain the envy of the world, he added. The challenge, he said, is for the nuclear community—including ANS—to reengineer the nuclear enterprise to suit today's circumstances, for the benefit of humanity and to meet the needs of society.

*Atoms for Peace*

While Cicerone referred to the 100th anniversary of Rutherford's discovery of the nucleus, Peter Lyons, assistant secretary for nuclear energy at the Department of Energy, noted the 60th anniversary of President Dwight Eisenhower's "Atoms for Peace" speech, which, he said, shaped many aspects of modern society. In the December 1953 speech, Eisenhower declared that peaceful power from atomic energy was no dream: that capability already existed. Lyons warned, however, that the management of the safety and security attributes of nuclear energy the president had presciently laid out in that speech must continue. One of the potential benefits of nuclear energy not considered then was as a carbon-free source of electricity. The threat of continued and accelerated climate change, Lyons said, affects all aspects of U.S. security—national, environmental, energy, and economic.


Lyons

But nuclear power is seriously challenged, Lyons said. Four power reactors were closed in 2013, and one more closure is scheduled in 2014. Three of the closures involved mechanical issues that could have been fixed if the economics were more positive. Lyons said that he considers the closure of Kewaunee and Vermont Yankee, however, simply a failure in the U.S. market structure. "When well-run, clean sources of energy are forced out of the marketplace due to a combination of reduced demand, low natural gas prices, and market structure, our markets are simply providing the wrong signals," he said.

Lyons said that advances in technology are a driving force behind expanding market opportunities, noting that several truly innovative, ultra-safe SMR designs are being actively developed. These SMRs have the potential of redefining how nuclear power is deployed in this country, he added, noting that the government's interest in SMRs is directly related to both climate change and national security. A significant SMR industry could also help maintain U.S. influence in global nonproliferation and safety standards, he said. According to Lyons, the goal of the DOE, which strives to maintain nuclear as a future contributor to the nation's clean energy portfolio, is to provide options for clean, safe nuclear system operations from which future solutions can be fashioned to address national requirements.

President Eisenhower's "Atoms for Peace" speech was also at the heart of the presentation by Susan Eisenhower, of the Eisenhower Institute, who referred to herself as an "intimate outsider" involved in efforts to reduce the threats, as well as working to resolve the issues holding back the deployment of nuclear technology, recently as a member of the Blue Ribbon Commission on America's Nuclear Future.


Eisenhower

Her grandfather's speech, Eisenhower noted, was delivered just 15 years after the discovery of fission, and only a few months after the Soviet Union had tested its first H-bomb. The president's objective was to address twin goals: to enhance international

security, and to fuel and drive the modernization of the world, bringing about an economic transformation that was sorely needed. The leadership demonstrated that day also made clear that this was an attempt to bring the Soviet Union back to the bargaining table on nuclear issues, and also to bring the "miraculous accomplishments" implied in these new developments to the rest of the world, but under international supervision.

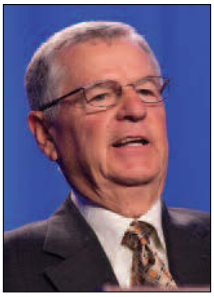
The controversy over nuclear power, Eisenhower said, boils down to one fundamental question: "Do we want to be leaders?" Is the United States going to exercise leadership, or is it going to give in to public perception and allow romantic views of how to meet our climate challenges to prevail? A sustainable strategy is needed, she said, although today, she admitted, this is a bit of a stretch for Americans.

Eisenhower outlined a few of the perceptions that need to be challenged:

- Natural gas is indeed a game changer, but a diversified energy portfolio is still vital. Good strategic management is about "having options, backup positions, contingency plans," she said. In particular, ways must be found to incentivize the private sector community around these longer-term goals, while government must recognize that it plays a significant role.
- The ongoing debate over the carbon issue must end. Eisenhower said she believes that the Intergovernmental Panel on Climate Change has put it to rest. This is an existential issue, she said, and climate legislation must be put back on the table.
- Sanctions and force are not the only way to solve nonproliferation issues. The example she gave was of the efforts undertaken by the United States to help resolve proliferation issues with Russia, which have been successful on many levels.

*Further technological advances*

The next speaker was John Browne, a past director of Los Alamos National Laboratory, who earlier had accepted the Seaborg Medal from ANS President Hoffman on behalf of Harold Agnew, who died on September 29 (*NN*, Dec. 2013, p. 71). Browne said that a week before Agnew died, he had asked Browne to accept the award on his behalf and to make sure that everyone in ANS knows how grateful he was to receive it, since it is named after Glenn Seaborg.


Browne

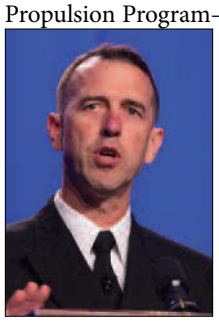
Given the theme of the President's Special Session—the 75th anniversary of the discovery of fission—Browne noted that there is still an incomplete knowledge of the fission process. With a more complete understanding of all that happens in nuclear fission events, he said, further important advances are possible, including, for example, more accurate modeling and simulation of fuel burnup, fission afterheat, and fission products.

Browne then considered other possible technological advances, such as in battery development, which could have significant implications. He also discussed possible game changers driven by "technical discontinuities." The biggest one, he noted, is in materials science, which is in the midst of major development and could have a huge impact on nuclear applications. Nanotechnology is revolutionizing new materials synthesis and providing new manufacturing techniques, Browne said, with the replacement of Zircaloy with silicon carbide ceramics as a cladding for nuclear fuel rods an example of what might be possible. The area of grain boundaries—where voids and cracks in materials occur—is also of particular interest, and a better understanding of it will allow engineers to take greater advantage of materials properties and features.

While the expected benefits of high-temperature superconductors have not yet been realized, Browne said, he believes that with the further development of materials, major advances will come. Exascale computing is another area offering huge potential for materials development, as well as many nuclear applications—for example, by helping to reduce the consequence of accidents through having better models and simulations. Also, he said, fusion technology will eventually open new vistas for energy concepts, much as Fermi's demonstration of the first controlled chain reaction did.

*The importance of Naval Reactors*

The final speaker was Adm. John Richardson, the sixth director of the Naval Nuclear Propulsion Program—or Naval Reactors—which is celebrating 65 years since Hyman Rickover was made the head of the U.S. Navy's nuclear propulsion program. As ever, Richardson said, Rickover's achievements continue to motivate the program.


Richardson

Richardson's discussion of the history of nuclear propulsion, starting back in 1939, also put in focus the importance it holds for civil nuclear power. From the start of the Navy's nuclear program, Rickover was also assigned to the Division of Reactor Development in the newly formed Atomic Energy Commission. This started dual-reporting responsibilities, which continue to this day, as Richardson reports directly to the secretary of energy and to the secretary of the Navy. The DOE work is what keeps the Naval Reactors program moving forward in reactor development, he said.

Richardson also noted that nuclear power changed everything about naval warfare and had a profound effect on many naval disciplines as well, such as rocket technology, inertial navigations, and communication and guidance systems. The first submarine core lasted for two years; today, reactor cores last for the life of the ship, 33–40 years, during which time submarines will travel over 1 million miles. The ability of submarines to remain submerged at all times also gave rise to a renaissance in oceanography, he added.

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Because of the success of reactors aboard ships, Richardson said, President Eisenhower made the Naval Reactors Program a centerpiece of the Atoms for Peace initiative, responsible for developing the Shippingport power plant, the world's first full-scale atomic power plant built solely for the production of electricity.—*Dick Kovan*

## Energy and the environment

With a focus on the potential of fast reactor technologies to provide the clean, carbon-free energy of the future, a panel of figures well recognized in both energy and environmental circles argued the case for nuclear energy in the technical program chair's special session, "Environmental Considerations in Long-Term Energy Policy, Including the Role of Nuclear Energy and its Contribution to Reducing Greenhouse Gas Emissions."

James Hansen, a former NASA scientist and an adjunct professor at Columbia University, began the discussion with a talk on the threat of anthropomorphic global warming. "The science is crystal clear to the

Hansen

relevant scientific community about climate change and the fact that we are at a point where we have a crisis," he said. Hansen, along with other climate and energy scientists, recently made headlines with an open letter to world leaders and environmentalists urging them to support nuclear energy as a means of mitigating the effects of global warming (*NN*, Dec. 2013, p. 15).

Hansen warned that the world cannot burn all of its fossil fuels and that coal emissions will need to be phased out, and most of the unconventional fossil fuels, such as shale oil/gas and tar sands, will have to be left in the ground. The challenge, he said, is that fossil fuels continue to be a cheap form of energy. "They're not really cheapest, because they're partially subsidized, but mainly because they don't pay their costs to society," he said. "The human health effects of air and water pollution are borne by the public. If your child gets asthma from air pollution, you pay the bill."

According to Hansen, the solution to cutting fossil fuel dependency is to put a gradually rising fee on carbon emissions, which will allow competition among energy efficiency, renewables, and nuclear energy. And while he said that he encourages the use of renewables, noting that the solar panels on his barn generate twice as much energy as his family uses, he argued that the 2 percent of the world's energy currently produced by renewables is less than one-year's growth in current global energy use and carbon dioxide emissions. "So it's just patently obvious that this is not adequate," he said.

Following Hansen, Nobuo Tanaka, of Japan's Institute of Energy Economics, discussed nuclear power's role in energy security and sustainability. He started off by noting that Asia, led by China and India, is greatly increasing its energy demand. According to Tanaka, renewable energy sources and nuclear power will supply much of that demand, but the majority, about three-fourths, will continue to be supplied by fossil fuels. "Fighting for the fossil fuels is the security issue," he said.

Tanaka also said that Japan is not prepared for the coming energy crisis. "We did not learn enough of March 11th's lesson: that we think about the unthinkable," he said, referring to the 2011 earthquake and resulting tsunami. The best way Japan can avoid the energy crisis is by restarting its nuclear power plants, but, unfortunately, the country is politically incapable of doing so at this time, Tanaka said.

In addition to the Fukushima Daiichi accident, a barrier to nuclear development in Japan is the storage and disposal of high-level radioactive waste and used nuclear fuel, which Tanaka said has become a "very serious issue" in the small country. According to Tanaka, Japan is looking to the United States for leadership on the waste issue, and he proposed the development of integral fast reactors that are capable of eliminating much of the waste by closing the fuel cycle.

Peter Lyons, assistant secretary of nuclear energy at the Department of Energy, took up the topic of fast reactor technology, discussing the DOE's advanced reactors program. He prefaced his talk by noting that the budget for advanced reactors is "austere." With the funds available, however, the Office of Nuclear Energy is primarily focused on the two areas of sodium-cooled fast reactor technologies and high-temperature gas-cooled reactors, he said, adding that the DOE, as it looks to the future, is also becoming more interested in fluoride salt-cooled systems for high-temperature reactors.

Lyons

Within its work on advanced reactors, Lyons said, the DOE is also exploring alternative power conversion systems, particularly the supercritical carbon dioxide Brayton conversion cycle, which he said "may offer some very, very impressive attributes for improving the efficiency of nuclear power, or improving the efficiency of almost any of the different power sources." Lyons said he believes that by using Brayton-cycle turbines, efficiency can be improved by as much as 20 percentage points over Rankine steam cycle turbines.

Lyons also said that given the lack of an operational fast reactor in the United States, the DOE is continuing to seek international collaborations. These include working with Russia and France on the MBIR and ASTRID reactor programs, respectively, as well as with Japan, which, he said, it is hoped will restart its Monju and Joyo fast reactor programs. Lyons also said that the Generation IV International Forum on advanced reactors "remains very active."

On the subject of public policy and nuclear energy, Tom Blees, president of the Science Council for Global Initiatives and author of *Prescription for the Planet*, said, "Public perception and votes drive policy, and nowadays there are a lot of people who are very passionate about environmentalism. They're very concerned about climate change, and they're very convinced that all we need is wind and solar and we can forget about nuclear and fossil fuels altogether."

As an example, Blees pointed to a *Scientific American* article, "Plans for a Sustainable Future," by Mark Jacobson and Mark Delucchi, which claims that the world can get all its energy needs from renewables—wind, water, and solar—by 2030. To test the feasibility of that claim, Blees looked at how much land would be required to produce all the energy needs for everyone on the planet, assuming a world population of 10 billion by 2050, using fast nuclear reactors (Blees used the PRISM reactor model) versus renewables. For assumed energy consumption, Blees used the amount of electricity the average German citizen uses today, noting that Germany has embraced energy efficiency to a high level while still remaining industrialized.

According to Blees, producing that amount of energy would require covering an area the size of South America with windmills and solar panels. In comparison, the footprint of the necessary PRISM modules, including recycling facilities, would equal the size of Buenos Aires. "So we have a city or a continent," he said.

The need to change public perception on the role nuclear can play in averting environmental upheaval was echoed by the next speaker, Joseph Shuster, author of *Beyond Fossil Fools*, who said, "The lurking catastrophes are an acute shortage of energy or the destruction of our environment."

Shuster exhorted those in the audience to do what they can to influence public perception and solve the world's energy problems. "We in this room are part of the minority that understands the problem and the solution," he said. "Consequently, we all have a serious responsibility to be heard, not just hear each other."

**A barrier to nuclear development in Japan is the storage and disposal of high-level radioactive waste and used nuclear fuel, which Tanaka said has become a "very serious issue" in the small country.**

Shuster suggested that nuclear professionals contact their elected representatives, give talks at colleges and other public forums, and write letters to the editors of newspapers and other publications. "Write about it, talk about it," he said.

The panel's next speaker, Daniel Meneley, of the University of Ontario Institute of Technology, offered advice on how to wean the world from fossil fuels using integral fast reactors. The model Meneley proposed was first combining fast reactors with light-water and pressurized heavy-water thermal reactors, with the fast reactors supplying fissile material to the thermal reactors. Meneley said he would expect that the fast reactors would prove to be better and cheaper, allowing the thermal reactors to eventually be phased out.

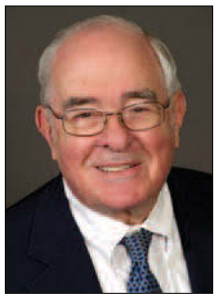
Addressing the audience, Meneley said that whatever reactor design is chosen, it is ultimately the plant's operator that decides whether or not the design is commercially successful. "You better remember those guys who run these plants when you design them," he said, "or you might end up with the famous old Ford [the Edsel], which was a great idea for a car design but nobody wanted to buy it. That is a very important lesson."

The urgency to bring fast reactors into commercial operation was highlighted by the session's final speaker, Charles Till, a nuclear consultant and former associate laboratory director at Argonne National Laboratory. Till, who led the Integral Fast Reactor program at Argonne from 1984 to 1994, noted that the only fast reactors currently being built in the world are in China, Russia, and India. "That's all, the rest are simply plans, and these plans run on into a future that I will never live to see," he said. "Is that really the way planning should be done for what was just described to us very convincingly this afternoon as an absolute crisis? Of course, the answer is no."

A sense of urgency is what is needed to keep fast reactor development moving along, Till said. "If you kept that [sense of urgency] in your organization, and people see the advances that come, almost like a metronome, one after the other after the other, the excitement builds and you get something done."

## The 10 CFR 52 experience

A session presented as being about the objectives and outcomes of new reactor licensing under 10 CFR Part 52 in fact took a much longer view, with the first two speakers generally covering the early history of power reactor licensing in the United States and comparing that experience with what has happened so far with new reactor design and license applications. Because none of the new reactor projects have yet reached the point of complete construction and approval for operation, it is too early to tell whether the Part 52 approach is indeed an improvement over the Part 50 system used for the reactors now in operation.



Cowan

Barton Z. Cowan, of the law firm Eckert Seamans and a member of the law school faculty of West Virginia University, recounted some of his experiences litigating for reactor license applicants, and he was sharply critical of the process that developed. The original scheme gave the Atomic Energy Commission broad power in licensing. In the early days of civilian nuclear power, Cowan said, it was decided that standardization would have to wait until the technology matured, and so issues resolved in one case would not necessarily be considered resolved in another. The two-step process, with separate hearings for a construction permit and an operating license, was not initially seen as a problem because there was little public opposition.

Before long, however, the scope of licensing changed to include an environmental review, following the enactment of the National Environmental Policy Act and what Cowan called the "infamous" federal court decision related to the licensing of the Calvert Cliffs plant. Cowan maintained that the hearings should have been limited to technical and safety issues, but the hearing rules came to be based on civil litigation. He also cited a passage from the Rogovin Report, a federally backed study conducted after the Three Mile Island-2 accident, stating that a construction permit hearing was too early in the process to be useful, and an operating license hearing was too late in the process to be effective.

Robert Bishop, former general counsel for the Nuclear Energy Institute, was more conciliatory to the public process, saying that some issues from Part 50 hearings were valid and were raised honestly. He also pointed out that not all of the reactor startup delays were caused by intervenor contentions: A four-and-a-half-year delay at Millstone-3 in Connecticut was caused by the cost of financing and the drop in demand after the 1973 oil embargo. Bishop did point out, however, that despite a 1973 standardization policy statement that was intended to ease the process for second or third reactors at a site that were essentially replicates of the first, decisions on which version of codes and standards would apply in each case were critical, and finality of the licensing decision was elusive.

Bishop

Matthews

David Matthews, director of the Division of New Reactor Licensing in the NRC's Office of New Reactors, mentioned at the start of his presentation that he would retire from the agency in January. Matthews was a key participant in two initiatives that have been hugely important to nuclear power in the United States: license renewal and new reactor licensing. As such, his look back on the 10 CFR Part 52 experience was effectively his last one as a participant from the NRC side. Some of what he said he has said before, such as his insistence on the importance of quality submittals by applicants for design certifications and reactor licenses. This time, however, he took the long view of the whole process, based in part on a Part 52 lessons learned study from April of this year. He said this derived in part from a September 2009 congressional inquiry into why new reactor licensing seemed to be taking longer than expected.

**A key lesson learned by both applicants and the NRC is that submittals should be based on current data and solid, approved evaluation methodologies and models.**

Matthews noted that revisions to Part 52 that were enacted in 2007 helped smooth out the approach that most applicants had taken, which was to apply for licenses while designs were still being certified and to either forgo early site permits (ESP) or use them as a step-up to licensing. The original version of Part 52 envisioned licensees obtaining ESPs, then applying for combined construction and operating licenses based on designs that were already certified.

Matthews said that a key lesson learned by both applicants and the NRC is that submittals should be based on current data and solid, approved evaluation methodologies and models, with appropriate parameters and fully justified conclusions about safety

margins. He added that finality cuts both ways: Design specifics can be counted on to stay as they are, but a licensee's flexibility to make changes is therefore limited.

Matthews was later asked whether the NRC has also learned from its own review activities, especially in regard to design certification. He said that it had, especially after the re-review that became necessary for the AP1000 shield building. During some reviews, he said, the design firms had stretched out their responses to the NRC's requests for additional information, and now technical issue discipline will be increased. And, he added, the NRC will drive the train, not ride it. Matthews said that this is what the NRC recently did regarding the digital instrumentation and control systems for Areva's U.S. EPR. The NRC will no longer review the I&C design as it is, he said, and will concentrate on other aspects of the design review until Areva takes a different approach on the I&C.

## DOE's fuel cycle R&D

The Department of Energy's Fuel Cycle Research and Development program is tasked with developing options for sustainable fuel cycles through improving uranium resource utilization, maximizing energy generation, minimizing waste generation, improving safety, and limiting proliferation risk. Some of the work being done in the fuel cycle program was discussed during the panel session titled "Progress in DOE's Fuel Cycle Research and Development Program."

The session organizer and chair, Andrew Griffith, of the DOE's Office of Fuel Cycle Technology, noted that his office works with a range of technologies covering everything from the front end of the fuel cycle, including extracting uranium from seawater, to the back end, which ultimately includes deep geologic disposal. The fuel cycle, Griffith said, is an optimized system where each technology and distinct area must integrate with the others. "In all of these types of approaches," he said, "we're looking for near-term applications that improve the relevance of the technology we're developing, as well as the long-term vision that is going to develop the sustainable nuclear fuel cycle of the future."

Andrew Gaunt, of Los Alamos National Laboratory, discussed research into separations processes related to reprocessing used nuclear fuel. Gaunt's presentation, "Extractant Design by Covalency," looked at some of the chemistry involved in separating actinides from the lanthanides in used nuclear fuel and the challenges that presents.

"The key chemical challenge, and what we're interested in on this project, is that the actinides must first of all be separated from the lanthanides prior to that [partitioning and transmutation] process, and that is a very difficult chemical separation to achieve," Gaunt said.

To achieve better separation of the actinides, Gaunt said, his team is researching certain "soft donor" extractant molecules, which have shown greater selectivity to actinides due to an increase in the covalency of the actinide soft donor bond relative to the lanthanide bond. While the selectivity of soft donor molecules has been known since the 1950s, there has been little experimental evidence that shows the details of the bonding and how it can be used to improve the separations process, Gaunt said. The goal, he said, is to "demonstrate that there is an electron scripture or covalency to the separation function relationship." This will allow them to develop tools to explain separation differences and propose new designs for separating actinides from used fuel.

Kyle Brinkman, of Savannah River National Laboratory, discussed research his department is doing regarding turning waste into forms amenable to safe storage and disposal. In his presentation, "Ceramic Waste Form Development," he explained that he sees his job as creating waste form options. He talked about the lab's experiences working with the synthetic rock product Synroc as an alternative to the use of borosilicate glass to solidify liquid radioactive wastes. A wide variety of nuclides can be captured into the lattice positions of the crystalline ceramic formed from Synroc, he said.

Synroc, which was introduced in 1978, is a powder that is formed into a solid ceramic through a compression process. Brinkman said that they are looking at the use of melting to form Synroc waste forms in order to take advantage of Savannah River's broad experience with melt processing of defense-related nuclear waste. He also said that melting Synroc waste forms at Savannah River will allow for increased scalability.

Using Synroc in combination with other materials, Brinkman said, they hope to develop options that will have the flexibility to incorporate many different waste streams. "Our task is to find our additives—our recipe—to combine with our waste," he said.

Maria Okuniewski, of the Idaho National Laboratory, talked about the behavior of irradiated metallic nuclear fuels in a presentation titled "Irradiation Induced Microstructural Evolution in Metallic Nuclear Fuels Subjected to Low Fluences." The research into metallic fuels began at Oak Ridge National Laboratory about five years ago, Okuniewski said, adding, "Now we're finally to see the fruits of our labor."

Metallic fuels present a number of challenges as they are irradiated, including spalling, constituent redistribution, restructuring, gas release, fission product transport, and chemical and mechanical reactions in the fuel cladding. Okuniewski said they are trying to better understand what is happening at low fluences to build better predictive models for the structural behavior of metallic fuels.

Covering the DOE's advanced fuels campaign, Kurt Terrani, of Oak Ridge National Laboratory, presented "Fabrication and Irradiation of Light Water Reactor Fully Ceramic Microencapsulated Fuels." The microencapsulated fuel Terrani was referring to is Triso (tristructural-isotropic) fuel particles, which are spherical particles of uranium about 1 millimeter in diameter that have been coated in a layer of carbon, followed by a coating of silicon carbide, with an outer shell of carbon.

According to Terrani, Triso fuels are just one of the accident-resistant fuel concepts being studied by the DOE, and the improvements in the fuel's performance over the years make it ideal for continued development. "The philosophy here is that when you start building big pressure vessels and containments to contain the fission products, let's have the fission product containment inherent to the fuel," he said.

**Triso fuels are just one of the accident-resistant fuel concepts being studied by the DOE, and the improvements in the fuel's performance over the years make it ideal for continued development.**

Ryan Winkler, of Los Alamos National Laboratory, talked about efforts to improve safeguards and security in a presentation titled "Microcalorimeter Arrays for Ultra High-Resolution Gamma-ray and X-Ray Spectroscopy." Winkler discussed the ability of microcalorimeter arrays to better measure radioactive materials as compared to more traditional radiation detectors. The effectiveness of materials safeguards is directly influenced by the accuracy and resolution of the detector, he said.

Continuing the safeguards and security discussion, Ben Cipiti, of Sandia National Laboratories, presented "Safeguards and Security Modeling for Electrochemical Plants." Using MATLAB Simulink, Cipiti created a performance model to analyze and

evaluate advanced security concepts at a hypothetical separations and reprocessing facility. The model has allowed the DOE to analyze scenarios in which materials are diverted, as well as to develop strategies for determining the optimal time for performing daily plant measurements of secure materials, he said.

## The perception gap

When it comes to communicating with the general public, nuclear professionals are well aware of the vast chasm that separates the real, known risks of nuclear technology and the unfounded, perceived risks. Trying to close the gap between the real and perceived risks can seem like a Herculean task, but that was the challenge taken up by a panel of experts in the session titled "Public Perception of Risk and Nuclear: Addressing the 'Perception Gap.'"

Katherine Rowan, a professor of communications at George Mason University, started off by offering nuclear power plant operators a new tool, the "deliberative meeting," for better communicating with the public. Using a hypothetical scenario involving emergency preparedness at the Cook nuclear power plant, Rowan said the deliberative meeting can be used to more deeply involve the local community.

"The goal of the deliberative meeting is to create a local context, a focus on concerns people care about in the immediate vicinity to reduce politicized concerns about whatever the conversation is," she said. Such meetings have been shown to go well if planned carefully, Rowan said, and she recommended that the media be invited and the attendees be compensated, possibly through a credit from the utility on their electric bill.

Rowan also offered a mnemonic device to use when communicating with the public to help earn their trust, while also being respectful of their fears and concerns: CAUSE—Confidence, Awareness, Understanding, Satisfaction, Enactment. "We want to use this as a heuristic to think about 'Am I taking steps to earn confidence, create awareness, deepen understanding, gain satisfaction, and motivate enactment?'" she said.

How people perceive risks was explored in detail by the next speaker, Leonard Greenberger, a partner at Potomac Communications Group. He began by pointing out that people are "notoriously poor risk assessors." This, he said, was not always the case (our prehistoric ancestors could quickly identify risks to avoid in their environment). "But as life has become both more complicated and safer, our skills at assessing risk have begun to atrophy," he said.

We are poor risk assessors because we tend to assess risk through a series of filters that distort the reality of a risk, Greenberger explained. These filters include trust, our sense of control, whether the risk is chosen or imposed, what the benefits of accepting the risk are, and whether the risk is equitably distributed and is natural or manmade. Using as an example the risks of driving a car versus the risks of nuclear power, Greenberger noted that the perceived risks of driving are greatly skewed because we trust ourselves as drivers, we feel we have control of the car, and it is our choice to drive.

Greenberger said we need to look for ways to change the dynamic of the filters. This includes emphasizing the benefits of nuclear technology whenever possible. "If people perceive the benefits associated with the technology, they'll be more likely to accept the risks that they see in it," he said, adding that demystifying the technology, which will take a sustained effort, also will help change the dynamic.

Following Greenberger, John Mueller, professor of political science at Ohio State University, proposed what sounded like a counterintuitive argument for evaluating the perceived risks and benefits of power reactors. "The argument is basically that nuclear reactors are much, much, much too safe," he said. "And the fact that they are too safe actually kills people."

According to Mueller, due to unnecessary safety requirements, such as protecting against the small risk of terrorism, nuclear power plants are becoming too expensive, which is raising the cost of power, which in turn is stunting economic growth. "Economic growth saves tons of lives," he said, "so therefore, artificially inflated energy prices—which is what safety is doing to nuclear reactors—basically costs lives, and it seems to me that's the way it should be looked at."


Mueller

Mueller also said that doing away with the linear no-threshold (LNT) model for quantifying the risks associated with ionizing radiation would help reduce the fear of radiation. He also suggested emphasizing the existence of background radiation and the minimal deaths that resulted from the Chernobyl and Fukushima Daiichi accidents, with the caveat that "if you tell people how safe something is, they become more afraid of it." Mueller noted that there is a reason airlines don't tout the safety of their airplanes.

Many meeting attendees recognized the panel's final speaker, Margaret Harding, from her past participation in American Nuclear Society meetings and the more than 30 years she spent working in the nuclear industry, as well as from her work explaining the events of the Fukushima Daiichi accident to the media on behalf of ANS. Noting that many in the audience have heard her presentations before, Harding said she did not prepare a speech for the panel. She did, however, offer some advice on thinking about what good communication means. "What a lot of us mean when we say we're communicating is that we are talking *to* people," she said. "We as a group need to think more about what that word [communication] means, and that it has the same root as 'commune' and 'community.' It's more about a dialogue."

**Due to unnecessary safety requirements, nuclear power plants are becoming too expensive, which is raising the cost of power, which in turn is stunting economic growth.**

One anecdote that Harding did share, in order to highlight the challenges the industry faces in gaining public trust, was how her mother recently refused to get dental X-rays for fear of receiving an excessive dose of radiation. That her own mother erroneously assessed such risks—especially "after I have worked in this industry for as long as I have," Harding said—demonstrates how difficult it is to bridge the perception gap. "The trust issue really is there."

Harding also addressed the controversy over the LNT model during the question-and-answer period of the session, saying that she doesn't like to argue LNT with the public. In response to comments made by one audience member in favor of the radiation hormesis hypothesis, she said, "Arguing linear no-threshold in a room full of the general public with someone who believes any [amount of] radiation is going to kill you makes you look like the extremist, because they get to hold up BEIR VII [report on the risks of low levels of ionizing radiation] and say, 'But BEIR VII says that linear no-threshold is the way we should function.' So then when you say, 'No, hormesis,' and you cite all these relatively anecdotal studies, you become the nut job, they win the argument."—*E. Michael Blake, Tim Gregoire, and Dick Kovan*