ANS ANNUAL MEETING

The global nuclear energy enterprise: A changing landscape

The theme of the 2014 ANS Annual Meeting, held June 15–19 in Reno, Nev., was "The U.S. Role in a Global Nuclear Energy Enterprise." For the opening plenary session, Adm. John J. Grossenbacher, director of Idaho National Laboratory (INL) and the general chair of the meeting, chose to address what is likely the top and most controversial aspect of that theme: the future influence of the United States in this global enterprise.

Grossenbacher noted that the United States led the development and deployment of nuclear energy technologies for many years, but today, the situation is quite different. The nuclear enterprise is global, with industrial and technical leadership found in Asia, in Europe, and elsewhere, as well as in North America. Some of the forces shaping the global nuclear enterprise today, he said, include the technology's cost and complexity, public concerns over nuclear safety, and the significant role of governments with respect to nuclear materials and technologies, including proliferation risk.

Grossenbacher

This is the context in which this plenary was planned, Grossenbacher said. The session featured individuals representing a vendor with a historical perspective; a private sector institution that is developing highly innovative nuclear technologies; two research organizations, one American and the other British; and a leading Asian country with enormous energy requirements.

Kathryn McCarthy, director of the Light Water Reactor Sustainability Program Technical Integration Office at INL and the assistant general chair of the meeting, introduced the panelists, noting that they had been asked to have a candid exchange on the issues being discussed. She invited the audience members to submit questions on cards that had been provided for that purpose. To start the session, each member of the panel provided a prepared answer to a specific question (submitted in advance) of particular relevance to his expertise and organization.

McCarthy

McCarthy directed the first question to Jiang Mianheng, a former president of the Chinese Academy of Sciences and currently the president of ShanghaiTech University, who has been engaged in directing high-technology research and development in many areas, including space technology, energy, and advanced materials, and who also served as the director of China's thorium-based molten salt reactor program. The question for Jiang went to the heart of the session: What is your perspective on the U.S. role in the world nuclear market?

Jiang

Jiang provided a look back to the beginning of China's civil nuclear power story. In 1970, he said, during China's Cultural Revolution, when normal industrial activities had been suspended, the leadership of Shanghai, at that time the primary economic engine of China, traveled to Beijing to ask Premier Zhou Enlai to expedite the delivery of coal from western China to Shanghai, which is on the country's east coast. With only three days of coal reserves remaining in Shanghai, the premier agreed to a special measure to ensure that Shanghai would receive its coal supply on a timely basis, and he also suggested that Shanghai leaders look into nuclear energy as a solution to securing its power. The ultimate result was the 300-MWe Qinshan I Unit-1 reactor near Shanghai.

This, however, did not initiate a major nuclear construction program based on Chinese technology, Jiang explained, mainly because the large-scale production of domestic oil began in the 1970s, with the mistaken belief that it would continue to meet the country's energy needs. Only when the leadership realized that domestic oil production would not meet future demand did the country begin developing a nuclear program, but it was based on technology imported from Canada, France, and Russia.

Although U.S. nuclear technology was not brought into China's nuclear program until 10 years ago with the signing of agreements for the construction of four Westinghouse AP1000s, China recognized the role of the United States as a world leader in nuclear technology, Jiang said. He noted that the United States remains the largest nuclear power producer in the world, de-

Meeting session coverage:

- *Perspectives on the U.S. role in the nuclear industry worldwide*
- *Sixty years of ANS history*
- *Issues in plutonium disposition*
- *Power reactor construction worldwide*
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spite 35 years of challenging commercial conditions and public misgivings.

Jiang also noted the U.S. nuclear industry's continued focus on improving safety and on the operation of existing nuclear plants after the Three Mile Island-2 accident in 1979, as well as on developing advanced technologies to maximize reactor safety and reduce financial risk. He said that he considers America's accomplishments in the area of safety during this period as providing the basis for the continuation of nuclear power post–Fukushima Daiichi, and that he sees U.S. technology as being in demand worldwide.

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Based on the strength of U.S. universities and national laboratories, "which are among the most active in the world," Jiang said, the United States remains the world's "heart" for innovation in nuclear energy. With private companies and other organizations actively pursuing Generation IV advanced technologies, he said, the United States can play a significant role and lead the way in nuclear power. "I very much hope that the U.S. decides to play such a role," Jiang concluded, adding that he looks forward to future collaboration.

Neil Wilmshurst, vice president of nuclear for the Electric Power Research Institute (EPRI), started his career as a nuclear submarine engineer officer in Britain's Royal Navy. He worked at nuclear power plants in the United Kingdom and in the United States before joining EPRI in 2003. The question McCarthy posed to him: Based on your experience at EPRI, what do you see as the research needs of the nuclear industry worldwide?

Wilmshurst

Over 80 percent of commercial nuclear plants worldwide are members of EPRI or participate in EPRI activities, Wilmshurst said, and this is because of the "reputation, credibility, and good work" of the U.S. nuclear industry. EPRI, therefore, has gained a perspective on its member organizations' needs, which differ by country. The United States, for example, is a mature market, he noted, while other countries are newcomers to nuclear power and are searching for the best way to proceed. Asia, he said, is a growing, vibrant region that provides a huge opportunity for R&D as countries there try to establish nuclear programs. The challenge, he added, is how to transfer the experience of U.S. research and the resulting technologies to those countries.

Wilmshurst noted a number of things that EPRI members have in common. For example, he said, all countries want to maximize the value of their assets in order to keep them running as long as possible. He mentioned "avoiding surprises" and reducing costs through technology as ways to help achieve plant longevity.

Wilmshurst said that avoiding surprises works on two levels: helping to gain public support, as people do not want to be surprised by their local nuclear plants, and maintaining the economic viability of a plant, as unexpected events—including new regulatory requirements—could necessitate multimillion-dollar unplanned investments. This, he added, drives research to understand the limitations of nuclear technologies, including areas such as materials aging, instrumentation and controls, and fuel performance, and, in the wake of the Fukushima accident, the impacts and likelihood of high-consequence external events.

Wilmshurst said he believes that there remain tremendous opportunities to improve and innovate within the naturally conservative approach taken with nuclear power, particularly in the areas of real-time plant monitoring and post-accident monitoring. One of the major problems at Fukushima, he said, was the lack of plant data available following the accident. Such monitoring will require a determination of what data are needed and how to deploy low-cost instrumentation to provide that data.

Wilmshurst also noted the following "holy grail" items that could have a profound impact in the future:

■ *Non-zirconium fuel.* "Imagine Fukushima without zirconium," he said, which, in his opinion, would have allowed more time to deal with the accident and lowered its consequences. A global effort is under way to "reinvent" nuclear fuel to make it more accident tolerant, he said.

■ *Low-dose health effects.* A globally coordinated research effort on low-dose health effects could eventually foster greater public acceptance of nuclear power, according to Wilmshurst, and the ability to explain low-dose effects to a doubtful public is needed. During the audience Q&A part of the session, Wilmshurst acknowledged that the industry will always be considered biased. He recommended a coordinated effort under the leadership of an independent international organization to carry out such a program—although he expressed the thought that such an undertaking "might even be too big" for the International Atomic Energy Agency.

■ *Decommissioning technology.* Nuclear decommissioning is becoming a growth industry, and more research is needed to develop better technologies and techniques for decontamination and decommissioning projects, according to Wilmshurst.

McCarthy's next question was for Ron Lewis, Westinghouse Electric Company's vice president of new plant product strategy and development: Given the recent liability lawsuit brought against General Electric in Japan and the nuclear liability laws passed in India, what risks do you see in building reactors in other countries?

Lewis

He said that he was not particularly familiar with the lawsuit, but he noted that the amounts of money that have been mentioned related to it would mean bankruptcy for most companies. "That's something that should scare all of us," he added. Lewis focused his response on the challenge that liability issues present to innovation, as well as to the supply base for nuclear projects. With the need to deploy better and safer technologies and to create a sustainable industry, it is vital for the industry to address the rules related to liability, he said.

Regarding the possible consequences for the supply base, Lewis said that Westinghouse's suppliers cannot withstand the kind of financial "shock" that would result from these types of lawsuits. That is why channeling liability directly to the operator is critical, he said. If companies can expect to be confronted by a liability challenge similar to the one that GE is facing, they will simply not put themselves at risk. The issue is not new, of course, and it is why various international conventions and other liabil-

ity protocols exist. The industry must continue to address this issue together, he declared, and he suggested that a global funding pool might be needed to provide protection to vendors/suppliers.

Lewis also put the question another way: Where will innovation be—and where will the accomplishments of U.S. scientists and engineers be—if the right legal system is not in place to protect companies and ensure that they can continue to create the next layer of innovation for the nuclear industry?

David McAlees, executive vice president of TerraPower, is part of the team that is developing a new type of reactor technology. The question put to him: What are the challenges to developing a nuclear energy technology in the United States with the intent to export?

McAlees

McAlees started by explaining that TerraPower is focused on developing the technology of the traveling wave reactor (TWR), which is a fast reactor system designed to "breed and burn" its own fuel. A conceptual design for a 600-MWe prototype TWR is nearing completion, and the current schedule calls for construction to begin in about 2018 for operation in 2025, if a suitable partner can be found to continue development and to own and operate the prototype.

McAlees addressed the question by noting how important it has been for TerraPower to have access to a range of expertise in the United States and how difficult it may be to maintain that availability in the future.

In developing the TWR concept, he said, a number of technological improvements were needed in areas such as fuel burnup and material radiation damage performance. Since the company began operating in 2008, it has engaged dozens of specialists and suppliers, including Argonne National Laboratory (model development and performance of analyses); INL (fuel development and testing); Los Alamos National Laboratory and Pacific Northwest National Laboratory (study of irradiation samples); and the University of Michigan (ion irradiation testing). On the plant component side, Carpenter Steel is manufacturing custom alloys, and Curtiss-Wright is providing the design and supply of some unique components. TerraPower is also building a metallic fuel fabrication process development facility in Idaho.

TerraPower, however, has had to go outside the United States in a few cases. In particular, to gather materials and fuel data under fast reactor conditions, the company turned to Russia, where 2,000 materials samples are currently under irradiation in the Bor-60 reactor at the Research Institute of Atomic Reactors in Dimitrovgrad. TerraPower is also working with Kobe Steel in Japan on the development of the HT9 specialty steel with appropriate characteristics. Of the 72 variations tested, the final four candidates are now under irradiation in the Bor-60 reactor and also in the Advanced Test Reactor at INL.

McAlees stressed that although the expertise needed to develop the TWR has largely been found in the United States, this has been possible because there are so few such innovative projects currently under way. He added, however, that this may not be the case in 10 or 15 years.

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Paul Howarth has been the managing director of the United Kingdom's National Nuclear Laboratory since January 2011 and was a cofounder of the Dalton Nuclear Institute at the University of Manchester. His question: Britain has reengaged in the development and expansion of nuclear energy. What have been the drivers of this, and what can the rest of the world learn from its experience?

Howarth

Howarth said that he thinks the United Kingdom is the most exciting place to be for nuclear new build, and he described a dynamic environment in which many foreign companies are actively pursuing new-build projects. Besides Electricité de France, which is already a nuclear plant owner in the United Kingdom, companies from Canada, China, Japan, South Korea, and the United States want to participate, and many other countries are watching to see how successful this deployment program will be.

About 10 years ago, Howarth said, the United Kingdom's nuclear program looked as if it would be phased out, as the government had basically concluded that it could rely on renewable technologies to provide needed power, as well as to fulfill the government's ambitious plan for a significant reduction in carbon emissions without building new nuclear plants. In fact, a legally binding target of an 80 percent reduction in carbon dioxide emissions by 2050 is now in place.

The no-new-nuclear-plants scenario, however, did not pan out. In fact, Howarth said, the country's energy position experienced "a perfect storm." The operating advanced gas-cooled power reactors were coming to the end of their lifetimes; other energy technologies had failed to penetrate the grid as expected; and the country was running out of natural gas from its North Sea reserves, which meant having to rely on importing more natural gas from Russia.

For the past few years, Howarth continued, he has worked with the government and a number of influential stakeholders to examine how to solve the energy problem and, in particular, to determine the best energy mix that can significantly decarbonize the country's electricity production. Among other efforts, a computer platform was developed that allows anyone with an energy mix strategy to input a particular choice of technologies and other key elements of an energy policy designed to constrain consumption. The bottom line, he said, is that it was not possible to get close to a solution without including nuclear power.

"It was only by introducing nuclear into the equation that we could get to an 80 percent reduction in CO_2 emissions," Howarth said. The result was a mix of about 130 GWe of fossil fuel (with carbon sequestration), 130 GWe of renewables, and 130 GWe of nuclear, and of those, only nuclear is likely to reach its target. And so, he said, the conclusion was clear: The United Kingdom would have to expand its nuclear program.

Another part of the challenge was to convince the government that a significant amount of investment in research—in areas such as fuel and reprocessing, reactor systems (including fast reactors and small modular reactors), and other advanced technologies—was needed to help understand the consequences of various nuclear scenarios. Over the past 10 years, Howarth

said, virtually no public investment had been made in nuclear fission research, and a significant ramp-up was needed. The government also agreed to reestablish its involvement in Generation IV activities to regain the United Kingdom's previous position as one of the leading nations in the area of nuclear research.

Regarding the lessons that may be relevant to other countries, Howarth admitted to being hard on renewables and fossil fuels. In fact, he said, in Britain, "We actually [ended] the debate of nuclear versus renewables versus sequestration versus shale gas. [It] doesn't matter, it is an irrelevance. You need everything."

Furthermore, the U.K. government realized that the framework that was in place for siting, approving, and licensing nuclear and other major infrastructure projects discouraged investors from risking their money. To encourage investment in nuclear, Howarth said, investors need clarity on the decision-making processes and assurance that they will see a return on investment in a reasonable time frame. He noted three actions that have now been instituted: Simplify the licensing system; provide some level of off-take guarantee to reduce investment risks; and clarify the long-term spent fuel and waste management policy.

During the audience Q&A period, Howarth was asked why Germany— which decided to phase out nuclear power after the Fukushima Daiichi accident—and the United Kingdom have such different views on their future energy mix. Howarth described the German decision as purely political and noted that Britain's situation is unique in that all the main political parties were able to take a long-term view of energy requirements and saw the need for nuclear expansion. This, he said, makes the nuclear issue in the United Kingdom "apolitical": It is no longer the subject of a politically charged debate.

Howarth also said that if it is not possible to take the politics out of energy decision making, the result will be as in Germany, which he believes will not be able to meet its energy policy goals under its now largely renewables program.

Plenary redux

The Chairman's Plenary Session carried over the format and theme from the opening plenary session, but with different speakers. The session began with each speaker answering a question from the moderator, John Carmack, national technical director of the advanced fuels campaign under the Department of Energy's Fuel Cycle Research and Development program. The speakers were clearly prepared to speak on these topics, although there were no presentation slides. Most of the remainder of the session consisted of audience questions sent to the dais on cards and filtered by the moderator.

On the panel were Nathan Faith, manager of nuclear fleet cybersecurity at Exelon Corporation; Joachim Knebel, chief science officer at Karlsruhe Institute of Technology in Germany; John Kotek, managing partner of Gallatin Public Affairs, who had served as staff director of the Blue Ribbon Commission on America's Nuclear Future (BRC); Lara Pierpoint, special advisor on energy policy and systems analysis at the U.S. Department of Energy; José Reyes, chief technology officer of NuScale Power; and John Welch, president and chief executive officer of USEC Inc. What follows are some of the more significant statements that arose from the questions posed to the speakers.

Germany's ongoing nuclear phaseout has become a frequent punching bag for nuclear advocates in the United States, and Knebel was put in the unenviable position of having to address the topic, if not actually explain or defend it. Knebel said that Karlsruhe, for many years a world-class nuclear research facility, will continue to work on future nuclear energy systems and fusion energy. He added that he believes that nuclear education and training are of the utmost importance, and that students are still enrolling to study for the nuclear professions, but he added that he is not sure whether this will be the case in five years.


Knebel

As for the effect of the phaseout on the country, Knebel said that more fossil-fuel use means dependence on Russian natural gas. He said that the people of Germany will have to change their consumption behavior and will have to face honestly what a massive shift to renewable energy sources will cost.

Asked about the Quadrennial Energy Review (QER) that was established for the United States by the White House in January, Pierpoint said that it will be done in stages. The first stage is under way, with two others to be conducted in the next two years. One of those will probably be on generation. The current stage—on transmission, storage, and distribution infrastructure—is likely to include topics of immediate interest to nuclear professionals: the role of nuclear power in grid stabilization and security, and the balance between baseload electricity and intermittent sources. Pierpoint said that fresh-fuel transportation may also be addressed in this QER.


Pierpoint

Kotek was asked what would be needed to move forward the recommendations of the BRC, which was established by the energy secretary at the request of President Obama to review policies for managing the back end of the nuclear fuel cycle and to recommend a new waste management strategy. His reply: realism and courage, or at least a commitment to fixing the problem. In Kotek's view, the DOE is motivated, but the White House is not. He said that this year, Congress may take a step toward establishing one BRC-recommended item, a consent-based process to site facilities for spent fuel storage or high-level waste disposal. He said that he does not, however, see progress this year on another BRC proposal, the establishment of a separate federal agency to take responsibility for high-level waste.


Kotek

Knebel was asked how Germany will maintain its nuclear safety culture and expertise in the nine years until the phaseout is complete. As it happens, he heads Germany's Alliance of Competence in Nuclear Engineering. There are eight universities with full nuclear curricula, along with the network of laboratories. He said that he believes that about 500 people will be maintained in key roles for the next five years.

On the question of whether nuclear power can continue to advance without resolution of the waste issue, Kotek said that there is not a clear yes or no answer. Decisions such as these are local, he said, and economics matter more than waste. Even so, he said that he believes some progress needs to be made on the BRC's recommendations.

Pierpoint responded to a question on investment in energy storage, noting that it is being addressed in the QER, and that there is not a complete database on how much storage there is, and how much it is used. There are technology costs and performance issues, she said, and added that storage does not seem to be valued very highly, nor is it well compensated.

Also somewhat related to storage was Knebel's reply to a question on whether France will tax the (mostly nuclear generated) electricity it exports to Germany. He said that currently, Germany is a net exporter of electricity from wind turbines and solar photovoltaics. Knebel conceded that storage is the real challenge for this amount of intermittent electricity, and added that old fossil-fired plants will be kept running and new ones will be added. Also, more

costs will add up because of the need to make improvements to the grid.

On a general question challenging whether governments should subsidize wind power and storage, Pierpoint said that solutions will depend on regions, especially where storage can provide grid stability. Underscoring the regional aspect of this, Knebel told of a Greek island where photovoltaics and electrochemical storage are being phased in this year and are expected to be cheaper than the only other option, the burning of oil.

It seemed that only a few minutes ever passed without questions or statements on whether the United States still has influence in nuclear power worldwide, and if not, what could be done to regain influence. Reyes said something to suggest that it helps not only to innovate, but to take responsibility. He recalled that at many conferences on small modular reactors that have been held in recent years, he sat on panels with other SMR developers and fielded questions from several people, some of them from other countries. When he was asked whether his NuScale reactor would be built first in his own country, he said yes. From that point on, he said, all further questions and expressions of interest were directed at him.

Past perspectives

In recognition of ANS's 60th anniversary later this year (the society was founded in December 1954), the President's Special Session at this year's Annual Meeting looked back at the past. The session, "60 Years of ANS—A Retrospective," was organized and chaired by 2013–2014 President Donald Hoffman and featured a panel of four ANS past presidents—Ronald Stinson (1987–1988), Ted Quinn (1998–1999), James Lake (2000–2001), and Eric Loewen (2011–2012)—representing four decades of ANS leadership.

Hoffman began the session by expressing gratitude for his own year as ANS president, a position he characterized as both demanding and rewarding. "It gives you a chance to be a part of influencing the things that mean so much to you," he said, "and I'm honestly sorry that it has to come to an end. I have thoroughly enjoyed working with the ANS staff, the membership, the leaders, the volunteers—all those individuals who are so committed and dedicated. I was trying to petition [incoming ANS President Mikey Brady Raap] to let me have a couple more years, but she reminded me that I had to run as a petition candidate, so I was lucky to get the year I had."

Hoffman

Before introducing the panel, Hoffman touched on a number of highlights from the first 60 years of ANS, including the society's first Annual Meeting (held at Penn State University) and the first student branch (at the University of Michigan) in 1955; the first ANS journal (*Nuclear Science and Engineering*) and the first local section (in Pittsburgh, Pa.) in 1956; the first issue of *Nuclear News* in 1959; the second ANS journal (*Nuclear Applications*, now *Nuclear Technology*) in 1965; the first overseas local sections in 1970; the first ANS public policy statement ("High-Level Radioactive Waste Disposal") in 1979; the third ANS journal (*Nuclear Technology/Fusion*, now *Fusion Science and Technology*) in 1981; the first plant branch (at Diablo Canyon) in 1988; the first strategic plan in 1997; the Seaborg Congressional Fellow Program in 2000; the Special Committee for Government Relations in 2001; the Young Members Group in 2005; and the Center for Nuclear Science and Technology Information in 2010.

The session's first speaker, representing the decade of the 1980s, was Stinson, who recounted a number of his experiences in the nuclear field, from his years with General Electric at Hanford and elsewhere to his many years of involvement with ANS, which included work on the society's code committees and trips to China for the Sixth Pacific Basin Nuclear Conference and to Moscow following the 1986 Chernobyl disaster. "At the time, Chernobyl was behind the Iron Curtain, and we had no way of getting real information regarding what caused the accident," Stinson said. "Four of us were invited to go to Moscow in December of that year—Bertram Wolfe [the 1986–1987 ANS president], myself, and two other ANS members. We met with some of the top Russian scientists there. Bert Wolfe negotiated an agreement with the Russians at that meeting, a memorandum of understanding, which was blessed by our State Department. Bert and I often discussed whether or not Chernobyl initiated the opening up of Russia. I think it had a lot to do with it. The American Nuclear Society truly has been active in more than just building nuclear. We have been active on a political basis throughout much of the world."

Stinson

Speaking next was Quinn, representing the 1990s. On the international front during that time, he said, nuclear plant construction was taking place all over the world. As an example, he pointed to Units 6 and 7 at the Kashiwazaki Kariwa plant in Japan, "which were built by GE-Hitachi and Toshiba, on schedule and on cost." Quinn added that in the early and mid-1990s, ANS greatly expanded its agreements with nuclear-related organizations in other countries.

Quinn

The domestic nuclear situation, however, was less sanguine during much of the decade, Quinn said. He referenced the high-profile problems at Connecticut's Millstone plant that led to the permanent shutdown of Unit 1 and noted that by 1997, the budget for new nuclear research and development programs had been reduced over a period of three years to essentially zero. "We had many good people in the Department of Energy's Office of Nuclear Energy at the time," said Quinn, "but the message was coming from the top."

According to Quinn, that sorry domestic status started to improve in October 1997, when then-senator Pete Domenici, disappointed with the U.S. position on nuclear research and development, gave a speech at

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Harvard titled "A New Paradigm for Nuclear Energy." "It made a vast sea change," he said, "even affecting what we do today."

Quinn also praised the work of William Magwood (now with the Nuclear Regulatory Commission, but to become director general of the OECD Nuclear Energy Agency in September), who in 1998 became the head of the Office of Nuclear Energy, as well as the work of the Nuclear Energy Institute, formed in 1994 from other industry organizations. "NEI is a very effective institute that has partnered with us on so many occasions in which we've been successful," Quinn added.

The 1990s also saw a number of changes at ANS, Quinn noted. In addition to the passage of the society's first strategic plan in 1997, the number of ANS board and executive committee members was reduced, and the Nuclear Operations and Power divisions were combined to form the Operations and Power Division. In 1999, the ANS board passed a proposal to establish the Glenn T. Seaborg Congressional Science and Engineering Fellowship program. "Since then, as you are well aware, there have been many successful Congressional Fellows, including one ANS president, Eric Loewen," he said.

Quinn was followed by Lake, representing the first decade of the new century. "Things really started to crackle in 2000," he said. "The very pronuclear George W. Bush was elected president, and the Congress was largely pronuclear. Bill Magwood began moving away from just the Nuclear Energy Research Initiative and Nuclear Energy Plant Optimization programs, which were very small research programs, to something more broad and international called the Generation IV International Forum. If you come to these meetings often, you know that at the last one, Bill Magwood talked a lot about that program, which has been going successfully now for 10 years."


Lake

Also in 2000, Lake said, the NRC granted the first 40-year license extension at Calvert Cliffs, and California experienced a severe summer energy crisis. "It was very interesting to get a lot of the national press and even the liberal press in California interested in energy issues," he said. "It opened up a lot of opportunities for them to understand different energy sources and how nuclear fit into the picture."

Echoing Quinn, Lake praised the ANS Congressional Fellow Program for its efforts to disseminate nuclear science and technology information to Congress. "The program is also a unique opportunity to learn how Congress works and to help influence legislation, as happened with the 2005 Energy Policy Act, which promoted nuclear reactor construction," Lake noted. In addition, he said, with ANS's increased emphasis on government policy, the society formed a Special Committee on Government Relations in 2001. "Each year, the incoming president appoints a group of advisors—including past presidents—who advise the new president on issues of public policy," he said. "That committee, I think, has been quite helpful."

Also during Lake's tenure, the society continued the practice of regular visits by the ANS president and vice president with senior DOE, NRC, and administration officials and congressional leaders. "I don't know that we keep the statistics on these things, but in my year as president, I think I visited more than 40 senior government officials in the State and Energy departments, the NRC, etc., and about 30 congressional offices," he said. "I was pleased that about half of those congressional visits were with the senators or congressmen themselves and not just the staff. ANS was welcomed and actually sought after by these government offices because people wanted to know about nuclear issues." Lake also said that during his term in office, he visited 11 countries and conducted more than a dozen TV, newspaper, and magazine interviews with such major media outlets as CNBC, the *Washington Post*, the *Wall Street Journal*, *U.S. News & World Report*, and *Business Week*. "Because of the California energy crisis, we even got a pronuclear article in the *San Francisco Chronicle*," he said.

Lake also mentioned the 2005 hiring of Craig Piercy, ANS's Washington representative. "We hired Craig to upgrade our D.C. office, and I think it's been a very positive hire," he said. "Craig has taken the lead in organizing Hill visits at each meeting in Washington and working with the congressional staffs."

Throughout the decade, Lake said, ANS members worked very actively with the DOE's Magwood to rebuild the department's nuclear commitment to include greatly expanded budgets, industry programs, a strong university R&D program, and substantial laboratory R&D programs, and by decade's end, things had turned around. "The DOE nuclear energy project had recovered rather spectacularly from essentially zero to something on the order of $750 million a year," he said. "It goes up and down for a variety of reasons, but it's still in that neighborhood. A strong DOE nuclear R&D budget is, I believe, an essential part of a healthy nuclear science and technology enterprise."

Lake concluded by stating that ANS "very purposefully and diligently upped its game" in the decade, especially in the area of government policy. "I'm proud to say that this activity is continuing to make impressions," he said. "I think it's a necessary service that the society provides to help keep things going."

The session's final speaker, representing the current decade, was Loewen, who set the stage for his remarks with a quote from the book *Thinking, Fast and Slow*, by Daniel Kahneman. "Although humans are not irrational, they often need help to make more accurate judgments and better decisions, and in some cases, policies and institutions can provide that help." Loewen took issue with those who claim they "knew" that an event like the 2011 Fukushima Daiichi accident would eventually occur. "We at ANS heard, post-3/11, from organizations opposed to nuclear science and technology that they 'knew' a reactor accident was inevitable," Loewen said. "It was just a matter of time. I think we should all be worried by the word 'knew,' especially when used to describe major events. In our scientific lives, we know only what is known—what can be shown to be true. That's why we publish technical papers, conduct conferences like this one, and organize our meetings around technical tracks."


Loewen

"We at ANS heard, post-3/11, from organizations opposed to nuclear that they 'knew' a reactor accident was inevitable. I think we should all be worried by the word 'knew,' especially when used to describe major events. In our scientific lives, we know only what is known—what can be shown to be true."

Loewen called for ANS to actively resist what he referred to as the "hindsight bias" against nuclear power that has resulted from the Fukushima accident. "As Kahneman stated in his book, 'The worse the consequence, the greater the hindsight bias,'" Loewen said. "If we let this sort of hindsight bias to nuclear power go on, it will foster an attitude of risk aversion toward nuclear projects."

Loewen also spoke about a former mentor of his, ANS member Ted Rockwell, a leading critic of the linear no-threshold hypothesis (the assumption that no level of radiation exposure is safe and that risk from radiation increases proportionately with the dosage received), who passed away in March 2013. "As ANS president, I had the opportunity and privilege to work with Ted Rockwell and Dr. Jerry Cuttler on the President's Special Session on Fukushima and low-level radiation, and why much of the administratively evicted population [of the area around the Fukushima Daiichi nuclear power station] should be allowed to return safely to their homes," Loewen said. "When we look forward to the next century to advance nuclear science and technology, we must get over our theory-induced blindness regarding low-level radiation health effects, specifically the theory of linear no-threshold."

Plutonium disposition

Twenty years have passed since the publication of the National Academy of Sciences (NAS) report, "Management and Disposition of Excess Weapons Plutonium," which characterized the world's stockpiles of separated weapons-grade plutonium as a "clear and present danger to national and international security." In recognition of the anniversary, ANS's Nuclear Nonproliferation Technical Group and Fuel Cycle and Waste Management Division organized a panel discussion on the history and current state of plutonium disposition. "Plutonium Disposition—The Clear and Present Danger, 20 Years Later," featured Steve Nesbit, of Duke Energy, organizer and cochair of the session; cochair Carl Mazzola, of CB&I; Robert J. Budnitz, of Lawrence Berkeley National Laboratory; Everett Redmond, of the Nuclear Energy Institute; Ken Canady, of MOX Services; and Frederic Bailly, of AREVA.

In his introductory remarks, Nesbit reviewed the major U.S. plutonium disposition milestones, beginning at the end of the Cold War in 1991 and including the 1994 NAS report and the related 1995 report on reactor-based options for plutonium disposition, as well as the following:

Nesbit

- The Department of Energy's 1995 request that asked commercial nuclear power utilities about their interest in using plutonium-derived MOX fuel in reactors as part of the nation's nonproliferation initiative with Russia.
- The DOE's 1996 programmatic environmental impact statement that looked at plutonium disposition options.
- The DOE's 1997 nonproliferation assessment that examined how well the various disposition methods performed.
- The selection in 1999 of MOX Services as the DOE's provider for plutonium disposition services, including the development of a fabrication facility for producing commercial reactor fuel.
- The 2000 Plutonium Disposition and Management Agreement (PDMA) between the United States and Russia, which called for each nation to dispose of 34 metric tons of the material.
- The United States' decision in 2002 to dispose of plutonium via the MOX fuel route only.
- The 2005 start of both the MOX fuel lead test assembly program at Duke's Catawba nuclear power plant and MOX Services' site preparation for the MOX Fuel Fabrication Facility (MFFF) at the Savannah River Site.
- The start of safety-related construction of the MFFF in 2007.
- The 2010 amendment to the PDMA.
- The DOE's 2012 cancellation of the Pit Disassembly and Conversion Facility at SRS, a facility that was to take the surplus weapon warheads and convert them into oxide as feed for MOX fuel fabrication.
- The DOE's reassessment of the MFFF in 2013.
- The DOE's decision in 2014 to put the MFFF into "cold standby."

"There were, of course, a number of stakeholders who objected to the cold standby course of action," Nesbit said, "including the state of South Carolina, which sued the DOE over the decision. As most of you know, after the suit was filed, DOE reevaluated its actions, and they've recently announced that they are going to continue construction of the MFFF at least through the end of this fiscal year, which has led South Carolina to drop its lawsuit. Just yesterday [June 17], the Senate Appropriations Committee appropriated, I believe, $400 million for MFFF construction in the next fiscal year, and the House Appropriations Committee has already appropriated a similar sum for it. So the story is not over. Paraphrasing Mark Twain, 'The death of the MFFF has been greatly exaggerated.'"

Next, Budnitz, an expert on nuclear reactor safety and radioactive waste management, spoke on the plutonium disposition situation at the time of the NAS reports. (Budnitz was one of seven members of the panel that produced the 1995 report.) He reminded the audience that in 1994, the Soviet Union had collapsed just three years earlier, and Belarus, Kazakhstan, Russia, and Ukraine still held substantial nuclear weaponry. Between the two sides, Budnitz said, there were some 250 metric tons of plutonium for nuclear weapons, 80 to 90 metric tons in arsenal storage, and 650 metric tons of reactor plutonium (120 metric tons separated and 530 metric tons in spent fuel). "The Russians were with us on doing something about this," he said. "Yeltsin was in the Kremlin. They were willing to talk to us about this. The understanding was, 'Boy, that hasn't happened before at the top. Let's take advantage of it.'"

Budnitz

It was deemed vital to work on disposition in parallel with Russia, so that one side would not be seen at any point as having an advantage over the other. "People understood that the programs didn't have to be exactly in parallel, but they had to be roughly in parallel."

While the 1994 NAS report calculated the cost that would likely be associated with developing a disposition program to address the excess plutonium, the cost was seen as being far less important than taking action, according to Budnitz. "The costs were thought to be a few billion dollars, and we were spending way more than that every year just watching the stuff, and so were they," he said. "And we were spending a lot of money helping them watch their stuff."

Continued

At the same time, however, it was deemed vital to work on disposition in parallel with Russia, Budnitz said, so that one side would not be seen at any point as having an advantage over the other. "We weren't going to destroy any weapons unless they were," he said, "and they wouldn't unless we were. People understood that the programs didn't have to be exactly in parallel, but they had to be roughly in parallel. That was seen as a way of defusing two groups—the group in the U.S. that didn't want to do this and the group in Russia that didn't want to do it."

The NAS study determined that the endpoint for a disposition program would be ensuring that the surplus plutonium ended up with a composition that met the "spent fuel standard," Budnitz said, meaning that the plutonium in its final dispositioned form should be approximately as difficult to acquire, process, and utilize in nuclear weapons as is the plutonium in typical spent fuel in civilian power reactors. The primary goals of the spent fuel standard were to impede the material's reentry into nuclear arsenals and to deter access to it by nonstate actors, he said.

Budnitz also discussed the recommendations of the 1995 NAS report for the most promising disposition technologies: MOX in light-water reactors, and vitrification. "These technologies were selected because it was thought at the time that both could move ahead expeditiously, meaning that in a decade [they] could be going, and none of the other options we evaluated at the time were thought to be able to move that fast," he said. "Of course, it's been 20 years, and not much has happened. But that was the thinking."

The costs for each technology, Budnitz said, were evaluated in the report and judged to be comparable. "A detailed evaluation of how much it would cost to build a MOX plant determined that it would be a few billion dollars," he said. "It was thought to be $1 billion on the low side and about $5 billion on the high side—certainly not as much as $10 billion. But remember, these were 1994 dollars, and you would have to double that today. And the costs of vitrification were about the same. We also noted in the report that there was a worry, either technically or politically, that either the MOX option or the vitrification option might not work out. So we recommended working on both in parallel for the first few years."

Following Budnitz was Redmond, who provided an overview of NEI—the nuclear industry's trade association—and its nonproliferation efforts. Over the past few years, he said, NEI has endeavored to engage the nonproliferation community more actively than in the past, and is a willing participant in weapons-grade plutonium disposition. NEI also supports the MFFF, Redmond said, stating, "We view it as an investment in the future."

Regarding the current lack of customers for MOX fuel—a major criticism of the proposed facility—Redmond remains unconcerned. "The industry, I'm convinced, will use MOX fuel," he said. "There is work that needs to be done before they can use MOX in reactors, however, and there will be a cost to that. So that will have to be figured out. At the end of the day, utilities will have to be able to get MOX fuel cost-competitive with UO_2, including the cost of modification for their facilities in the license applications. But again, I'm convinced that can be done."


Redmond

The real challenge, Redmond said, is that utilities must be assured on-time delivery when purchasing fuel. "The last two years, and especially this year, have not exactly given utilities confidence in the Department of Energy," he said. "Why would you have a contract or get a contract right now to supply fuel from a MOX fuel fabrication facility?"

On that point, Redmond quoted from a letter that NEI sent to Energy Secretary Ernest Moniz: "To cancel, suspend, or simply reduce funding for the project will unfortunately validate those critics of the Department of Energy who claim it simply cannot complete complex projects, particularly those concerning nuclear materials disposition. Unfortunately, DOE's history with this and other large complex projects does not instill confidence in the commercial industry that the MOX program will be able to deliver commercial fuel to utilities on an agreed-to schedule. However, DOE can and should begin to reverse this trend and begin to restore confidence by following through with the construction and operation of the MOX facility on a set schedule."

Failure to do so, Redmond believes, will likely be viewed as a retreat from U.S. international commitments. "The industry, being a supportive partner of the government, certainly does not want that to happen," he said. "We must lead the world in nonproliferation efforts, and the industry is there to support the government. Without collaboration, the nonproliferation goals will not be met."

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The next speaker, MOX Services' Canady, also endorsed the completion of the MFFF. His presentation included a detailed look at the evolution of the project from 1994 to the present, including the April 2010 amendment to the PDMA. "The amended PDMA was important for two reasons," Canady said. "It allowed the Russians to burn MOX in their fast reactors, and it identified MOX as the only disposition option. So now, unless we go back to the Russians, there are no other options available for plutonium disposition in the United States. It's MOX."


Canady

Canady also pointed out that in March 2014, after years of hearings and other discussions, an Atomic Safety and Licensing Board issued a decision on whether or not the MFFF met Nuclear Regulatory Commission regulations for nuclear material control and accounting. "The ASLB agreed with MOX Services that the material accountability and control was excellent," he said. "The intervenors' contentions were dismissed, and a favorable decision was issued."

Among other aspects of the MOX project that Canady discussed were the highly publicized cost and delay issues. The facility, which uses NRC quality assurance processes, contains over 400,000 feet of piping, 31,000 pipe supports, 7 million feet of cable, over 1 million pounds of HVAC, 330 gloveboxes, 170,000 cubic yards of concrete, and 35,000 tons of steel, he said. "The biggest issue, which I think led to cost and schedule increases, has been the ability to find QA-qualified vendors," Canady said. "When we started this plant, the nuclear industry in the United States had essentially been dormant for 15 to 20 years. People who had a QA program had let it lapse or put it on the shelf. So when we solicited bids from vendors for gloveboxes, tanks, concrete, rebar, whatever, it was difficult to find people to bid. In many cases, MOX Services was forced to hire QA engineers on its pay-

roll to make sure that a quality product was received that would stand up to the scrutiny of NRC inspectors."

The DOE's cold standby announcement has also had an impact on the project, Canady said. "Our turnover rate has increased and our ability to attract workers, both labor and engineers, has decreased," he said. "Even though we have funding for the rest of this year, and we have bipartisan support in Congress for funding next year, it is still difficult in the current situation to attract and keep good talent for this plant."

The session's final presenter was AREVA's Bailly, whose presentation focused on the experience with plutonium disposition and MOX fuel use outside of the United States. Worldwide, he said, there are 43 reactors that use MOX fuel—39 in Europe and four in Japan—with roughly 7,000 fuel assemblies used to date. Further, according to Bailly, six countries have analyzed the use of MOX fuel and have found that it meets the same licensing standards as UO_2 fuel. "These countries have used fuel with a very high level of reliability," he said. "Very few fuel assemblies have been identified as leaking MOX fuel. Plus, none of the leaking or other failures was attributed to the fact that it was MOX inside the tubes. It was actually fuel assemblies with some particles in the primary that led to the failed fuel. There has been no impact on operation. And there have been no early outages subsequent to the detection of the leaking fuel assemblies."

Bailly

In addition, Bailly said that the burning of plutonium in MOX fuel contributes to nonproliferation objectives, as it consumes approximately one-third of the plutonium and controls overall plutonium inventory. "It also significantly degrades the isotopic composition of the remaining plutonium and thus the potential attractiveness for nonpeaceful usage," he said.

Reactor construction worldwide

The panel session titled "New Nuclear Construction Around the World" was the first joint session of the ANS Operations and Power Division and the ANS International Committee. The session was co-chaired by ANS past president Ted Quinn and Corey McDaniel, chair of the International Committee.

The first speaker was Sal Golub, associate deputy assistant secretary for nuclear reactor technologies at the Department of Energy. Golub began by noting the role that nuclear power can play in ensuring a secure and diverse energy supply. As a non-carbon-emitting source of electricity, nuclear power is an important element in President Obama's climate action plan released last year, he said. The plan includes cutting carbon emissions, preparing for climate change, and leading international climate change efforts. Under this plan, he said, the United States will not only continue to promote nuclear power worldwide but will also expand those efforts.

Nuclear expansion will require dealing with the fundamental issues of public confidence in the safety of nuclear plants, finding a long-term solution to nuclear waste, and providing protection from the risk of nuclear weapons proliferation and from terrorism.

Nuclear expansion, Golub said, will certainly require dealing with the fundamental issues of public confidence in the safety of nuclear plants, finding a long-term solution to nuclear waste, and providing protection from the risk of nuclear weapons proliferation and from terrorism. In addition to all of these things, he said, the economics must be right. On this point, he focused on the "historical cost drivers" of high capital costs, high financing costs, and the lack of standardization. The particular issues associated with these that must be addressed include the cost of commodities, long and delayed schedules, quality problems, and design changes.

The 1979 accident at Three Mile Island had particularly profound effects on the nuclear enterprise, Golub said. It initiated many significant changes to plant structures, systems, and components, to the safety basis, and to regulatory review processes, which led to extended construction schedules, higher costs, and project cancellations. Today, with the first new plants being built in the United States in 30 years, it is essential, he said, that good cost and schedule performance are achieved for the Vogtle-3 and -4 and the Summer-2 and -3 AP1000 projects. So far, he noted, both construction projects are performing reasonably well.

Modern construction techniques have significantly improved construction times and quality, Golub said, while new technologies, such as small modular reactors (SMR), offer a potential new model for nuclear expansion, overcoming some of the obstacles to deployment. The potential economic benefits of SMRs include a smaller financial commitment for utilities, shorter construction schedules due to modular construction, and improved quality and costs due to replication in a factory setting.

To jump-start an SMR capability, the DOE established the SMR Licensing Technical Support Program to support first-of-a-kind SMR certification and licensing activities through cost-shared partnerships with industry. The DOE has now signed two partnership agreements.

Looking to the future, Golub said, the DOE's research and development program is pursuing various opportunities to reduce capital costs through, for example, design simplification and improved materials, the use of advanced high-performance computing, modeling, and simulation, and advanced energy conversion technologies. Regarding this last item, Golub said that the DOE sees great promise in a supercritical CO_2 Brayton energy conversion cycle to replace the conventional steam Rankine cycle, potentially improving efficiency by up to 50 percent, as well as reducing the size of mechanical equipment and the plant footprint.

On the policy front, Golub noted that incentives for promoting nuclear deployment, such as loan guarantees and tax credits, were included in the Energy Policy Act of 2005, and that the DOE will be exploring other possible incentives with stakeholders.

Golub also stressed that the expansion of global nuclear energy cannot occur without effective international collaboration. The United States no longer has a suite of facilities in which to conduct needed research, nor does it have a monopoly on the technical expertise needed to address the challenges facing the long-term sustainability of nuclear power. In this regard, Golub said, the United States also needs to be engaged as a player in the global nuclear industry if it is to have any meaningful influence over safety and proliferation norms.

The next speaker, Larry Burkhart, of the Division of New Reactor Licensing in the Nuclear Regulatory Commission's Office of New Reactors, had spoken on this topic at the 2012 ANS Winter Meeting, but he said

that he has noticed changes since then. There are more reactors under construction now, he said, and many more are being licensed and designs are being reviewed, although the activity is distributed unevenly around the globe. He also noted that in some countries, such as Canada, the Czech Republic, and France, politics and finance have become important factors, causing these countries to put expansion activities on hold.

Among new reactor trends, Burkhart noted that the pursuit of standard designs has provided unique opportunities for international cooperation. He pointed to the formation of the World Nuclear Association's Cooperation in Reactor Design Evaluation and Licensing Working Group, the Multinational Design Evaluation Program (MDEP), and the OECD Nuclear Energy Agency's (NEA) Working Group for the Regulation of New Reactors (WGRNR).

The MDEP was established in 2006 with 10 countries (it now includes 14) to cooperate on new reactor design reviews and to explore opportunities for harmonization and convergence on approaches to licensing and safety reviews, Burkhart said. The MDEP created design working groups and issues working groups that are intended to develop common positions. The regulators in the MDEP invite stakeholders, including vendors, operators, standards development organizations, and others, to attend meetings and help them understand the designs and the reasons for differences among them. At the NEA, the WGRNR looks at other issues, such as siting and construction regulations.

Regarding new reactor issues, Burkhart started with Fukushima, which "everyone has to address." It is clear at the MDEP, he said, that all countries are focused on the same concerns that came out of the Fukushima Daiichi accident, such as the loss of heat sink and the continued loss of off-site power. Individual countries, however, may address these issues differently.

As for trends in the United States, Burkhart said that after the Office of New Reactors was established, 18 combined construction and operating license applications were submitted to the NRC under 10 CFR Part 52. Currently, only eight are actively under review. The others were suspended, but none for regulatory reasons. In any case, the NRC will not issue any new licenses or license renewals until the waste confidence issue is resolved, which should be later this year. In the meantime, Burkhart said, experience with the procedure for introducing changes to the design/licensing basis during construction is being gained at Summer and Vogtle. He added that the applications for design amendments that have been processed so far have not had a negative impact on project schedules.

The view from a newcomer country was given by Bill Travers, director general of the United Arab Emirate's Federal Authority for Nuclear Regulation (FANR), which is responsible for planning and implementing nuclear regulations. Travers was previously the executive director of operations at the NRC.

When the Emirates Nuclear Energy Corporation received its first construction license in July 2012, Travers said, the UAE became the first new country to begin building a nuclear power plant since China some 30 years ago. When asked why the nuclear program of the UAE, a country with no history in nuclear technology, has been so successful over such a short time, he answered that the UAE "really did its homework." This included undertaking an extensive review of international experience. Even before the decision was made to embark on a nuclear program, he said, a set of principles was laid out that represented best practices in a host of areas relevant to undertaking a nuclear program.

One of the earliest and most important measures was to develop the legal framework for undertaking nuclear activities. This included the establishment of an independent regulatory body with the means and resources to do an independent assessment of nuclear safety, security, and safeguards. Another important element in devising a national nuclear program, Travers said, was addressing the commitments that the world expects from a newcomer, particularly in regard to safety, nonproliferation, and transparency. The UAE now participates in all relevant international nuclear conventions, such as the Convention on Nuclear Safety and the Vienna Convention on Civil Liability for Nuclear Damage, and has signed on to other legal instruments, such as the Comprehensive Safeguards Agreement with the International Atomic Energy Agency. Currently, he said, the UAE program is viewed as a model for other countries that are interested in developing a nuclear program.

FANR has classic regulatory responsibilities, Travers explained, but as nothing existed before, the agency has had to build a regulatory regime from scratch. While making use of the work of others, he said, its regime is not a copy of the NRC's or anyone else's. It draws upon the 50 years of world experience, using the IAEA's safety standards and its security regime. FANR, however, has adopted regulatory guidance available from the NRC and other regulators, rather than writing its own. "If it exists and is good enough," FANR will not try to reinvent it, he said.

The strategy applied was to create a team within FANR with enough expertise across a broad spectrum of technical areas that FANR could confidently take ownership and responsibility for its work, Travers said. Technical support organizations in other countries, including two in the United States, were contracted to carry out detailed reviews of parts of the construction license application. He noted, however, that all of the decisions based on the reviews are "owned exclusively by FANR."

FANR has signed up for every one of the IAEA's review services, which provide an independent assessment and recommendations for improvement. An independent advisory group, headed by former NRC chairman Richard Meserve, advises the FANR Board of Management, which is made up of nine Emirate citizens who make all final decisions. Another important activity is the development of Emiratis to work in this area. The goal is that over time, FANR will become an Emirati-led organization.

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Kannan Iyer, of the Indian Institute of Technology in Bombay, gave a presentation on India's nuclear program. He is the chair of the ANS India Section and a member of the ANS International Committee. Iyer started by noting two important considerations: Because of the international nuclear industry's concerns over third-party liability legislation, reactor projects involving foreign vendors are in limbo, and a new government was elected just a few weeks prior to the ANS Annual Meeting.

As originally conceived, Iyer said, energy security was the priority for India's nuclear program, which was to be self-contained and independent from outside forces. A three-stage program was subsequently developed, based on India's lack of uranium resources but extensive deposits of thorium.

Thermal uranium-fueled reactors, he said, would be built in the first stage to generate plutonium for fueling fast reactors in the second stage. In the third stage, the fast reactors would be used to breed fissile material (U-233) from the country's thorium reserves to create a thorium fuel cycle. India expects its prototype fast breeder reactor to be ready to start operation by the end of this year, he noted.

Iyer explained that the first nuclear units built in India were General Electric boiling water reactors (Tarapur-1 and -2). However, as light-water reactors require enriched fuel, the decision was made to develop natural uranium–fueled systems, and a contract was signed with Atomic Energy of Canada Limited for two CANDU pressurized heavy-water reactor units (Rajasthan -1 and -2). In 1974, he continued, India exploded a nuclear device, which led Canada to halt its support of India's program. This meant that India had to develop the capability to build PHWRs completely indigenously. While this took a long time, he said, India eventually created a complete nuclear design and construction capability along with the fuel cycle.

As India's regional grids were developed, it became possible to increase reactor capacity from 220 to 540 MWe (gross), Iyer said. This was soon uprated to 700 MWe, which is the size of the PHWR that is now being built by Nuclear Power Corporation of India Limited (NPCIL). Because of the country's lack of uranium reserves, the government decided to import reactors and the necessary fuel. Iyer noted that India already had an arrangement with Russia for the construction of two VVER units at the Kalpakkam site, with more expected. The possibility of using other foreign designs was opened up once India concluded a high-level nuclear cooperation agreement with the United States in 2008. This led to the start of negotiations between NPCIL and General Electric, Westinghouse, and AREVA, while NPCIL also identified specific greenfield sites for foreign units.

According to Iyer, all of these projects have been subject to varying degrees of opposition from a number of factions in India, which became even more contentious after the Fukushima Daiichi accident. Little progress has been made since then, he added.

Following the May election of a new government, a presidential address before India's parliament on June 9 included a promise to implement the international civil nuclear agreements. Because the new prime minister, Narendra Modi, had successfully delivered large infrastructure projects when he was the chief minister of the state of Gujarat, there is an expectation in the nuclear industry that the projects may soon be moving forward.

The title of the presentation by T. Jay Harrison, of Oak Ridge National Laboratory, was "The New Opportunity for Nuclear," which, he said, would offer an optimistic look at the future economics of nuclear power. While the nuclear renaissance in the United States has not panned out as hoped, he said, the Environmental Protection Agency's recently announced goal to reduce carbon emissions by 30 percent by 2030 may turn market forces in nuclear's favor. Nuclear has tough competition, he said, but it has a unique advantage in providing emission-free baseload generation.

In the early 2000s, electricity demand was increasing significantly—by about 1.8 percent annually. Since 2008, annual power production has dropped by about 100 TWh, and at the same time, cheap natural gas started coming on the market. At the moment, according to Harrison, the current CO_2 reduction figures are on track to hit the EPA target, thanks in part to natural gas, which produces about half the emissions that coal generation does.

Looking a bit deeper into this situation, Harrison said, he found some encouraging signs. Since 2008, coal's share of total electricity production is down from 50 percent to 40 percent. The lost coal-generated power has been made up mainly by natural gas and wind generation. He said that he believes that in the future, however, the EPA's carbon reduction goal will constrain the growth in the use of natural gas for electricity production.

To reach the 30 percent target, Harrison said, the United States is going to have to replace 10 percent of coal-produced electricity, which equates to about 400 TWh. Harrison said he expects that carbon-emitting production will not be used and that other options to replace the lost coal electricity production—notably wind, solar photovoltaic, and nuclear generation, which he lists as the three cheapest—will have a good opportunity to expand. In his opinion, however, it is unlikely that the renewable options can provide the amount and the necessary level of secure generation needed to fill the gap, while nuclear power, as a major baseload carbon-free source, can. Harrison further calculated that to replace 400 TWh with nuclear by 2030 means bringing about 50 GW of additional nuclear capacity on line, which he said is certainly possible.

Finally, Harrison argued that the EPA proposal provides an opportunity for the U.S. nuclear industry to reestablish capacities, capabilities, and supply chains. And because the world nuclear market considers NRC-licensed plants to be the "gold standard," a growth in the nuclear industry in the United States will likely extend beyond its borders. This, therefore, is a chance for a global nuclear renaissance, with the United States as a prime mover.

Small modular reactors

The session on small modular reactors showed that even designs that have gained approval for federal support are still subject to hard looks and revisions by their creators. Both José Reyes, of NuScale Power, and Sandra Sloan, of Babcock & Wilcox's Generation mPower, said that their companies' integral pressurized water reactors (iPWR) have recently gone through "optimization" processes, in the case of NuScale with the intent to cut the cost of the reactor and perhaps improve safety, and in the case of mPower to improve "cost and constructability." Whatever benefits there may be in having the Department of Energy share the cost of design certification and licensing, it appears that SMR vendors are also trying to pursue customers.

Reyes, chief technology officer of NuScale Power, summarized recent developments on the NuScale 45-MWe iPWR. Under the current plan, the first NuScale-based application for combined construction and operating licenses would come from Utah Associated Municipal Power Systems (UAMPS), although the operator would be Energy Northwest (which owns and operates the Columbia power reactor in Washington state), and the site would be in Idaho, most likely on the property of Ida-

Reyes

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ho National Laboratory. This involvement of organizations or facilities in four western states (Utah, Washington, Idaho, and Oregon, where NuScale Power is headquartered) seems to be in keeping with the larger regional effort for NuScale deployment, the Western Initiative for Nuclear. There are potentially as many as six projects, which could be located in the previously mentioned four states, Arizona, or perhaps Montana or New Mexico.

Reyes said that the current low price of natural gas that potentially affects nuclear economics in the eastern and central parts of the country is not a significant factor in the Northwest, because of gas transport costs. But while this may give the NuScale reactor a chance to be economically viable for UAMPS, there is a time frame in which NuScale would be of the greatest value. UAMPS wants to begin retiring its coal-fired generation in 2023, Reyes noted, and NuScale reactors would have to be ready by then to become the replacements.

As a company established to develop a reactor concept, NuScale Power does not have an existing industrial base from which to develop a full infrastructure, Reyes said. With Fluor now its parent company, NuScale has access to expertise in areas such as balance-of-plant, but a NuScale plant will need some hardware from elsewhere. Reyes said that the company is establishing specifications for a skid-mounted turbine generator but will not manufacture it. NuScale Power is working with vendors who will produce the qualified hardware.

Having the smallest of the small modular reactors currently in development in the United States makes possible some practices that even other SMRs might not adopt. Reyes said that when a NuScale reactor needs to be refueled, the reactor itself will be moved to a refueling station within the plant structure, and then back to its operational base.

According to Reyes, the optimization study led to a number of design changes, including reduction in the tube length and overall height of the helical coil steam generator, integration of the steam generator steam header into the pressurizer baffle plate, and revision of the generator's tube support structure. These changes have made it possible for the reactor module height and pool depth to be reduced by about 7 feet. The reactor building wings have also been eliminated, and the control room, technical support center, and related systems are now to be housed in a building physically separate from the reactor building. Reyes said that the NRC staff was briefed on these changes during a meeting in May and that he did not expect them to affect the agency's regulation of the reactor.

The critical heat flux test has been completed, Reyes added, and testing of the full-scale helical-coil steam generator will begin in January. An eddy current probe for steam generator inspection has also been tested.

As he looked ahead to the certification process, Reyes noted the difficulty in getting nontechnical people to understand low core damage frequency, and he said that he would like ANS to help show how low the consequences of an accident in a NuScale reactor would be. He wants to be able to tell the public that no accident in a NuScale plant would ever lead to the permanent evacuation of any residents near the plant or anywhere else.

Sloan, manager of design integration and licensing for mPower, filled in as the mPower speaker in addition to her role as chair of the session. Babcock & Wilcox and its partners in Generation mPower have been developing the mPower reactor (a 180-MWe iPWR) for a while longer than NuScale Power has worked on its own SMR, so the main recent developments with the mPower have been in the testing program. Sloan provided an update on the work that has been completed and work that is under way.


Sloan

For the reactor coolant pump, hydraulic confirmation has been completed, and cold and hot design verification tests are planned; critical heat flux testing has been completed, and correlation development is in progress; planning and fabrication are under way for vessel model flow testing of reactor internals and control rod drive mechanism feed-through penetrations; fuel assembly mechanical tests are ongoing; cold static tests of fuel and control rod drop time and drag coefficient are done, cold flow fuel assembly tests are in progress, and hot flow tests are yet to be conducted. The company's Integrated Systems Test Facility in Virginia has been used for steady-state steam generator and plant performance tests, and loss-of-inventory transient testing is under way; further transient tests are planned to validate safety analysis methods.

Sloan noted the announcement in April that the development of the mPower reactor was being slowed down, and her presentation referred to this as "restructuring" intended to "revalidate market requirements and market timing." This could be taken as a belief that the market for mPower does not exist now or in the immediate future. Sloan said that the company is focusing on the preparation of the design certification application, for which there is not currently a target date for submittal.

The NRC side of SMR development was presented by Stewart Magruder, chief of SMR Licensing Branch 1 in the Office of New Reactors. He stated the established NRC position that designs that are not light-water reactors are not considered near-term prospects. Nonetheless, Magruder said, the NRC is open to non-LWRs and has reviewed them to some extent in the past. In his presentation, he noted that non-LWRs would be addressed in a two-phase strategy. In the first phase, the Department of Energy would oversee research and deliver technical reports to the NRC. In the second phase, the NRC would develop the necessary regulatory process.

As for the LWRs that the NRC is already examining through pre-application meetings and reviews, Magruder noted that a NuScale plant, as envisioned by the company, would have fewer control room operators than reactors at critical mass. He said that while this would not be in keeping with current NRC regulations, it is "not incredible" and could perhaps be worked out. He also conceded that no SMR plant could operate economically with a security guard force of 300 people.

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Many of the issues that have been raised about SMRs for about the past five years have yet to be resolved. Magruder said that in order for SMRs to be allowed to have smaller or less demanding emergency planning zones than those used for current LWRs, there will have to be agreement on the source term and the dose to an individual at the site boundary in the event of an accident. He also noted that plant components that have hitherto been in different locations are often inside the SMR reactor

vessel, raising questions about ASME code case applicability.

What seemed to be a recurring bullet point at this ANS meeting was the United Kingdom's effort to revitalize its nuclear power program, at least to the extent of bringing in foreign-developed reactors (and generally foreign-based plant owners or investors). This carried over even to the SMR session, with a presentation by Fiona Rayment, director of fuel cycle solutions at the United Kingdom's National Nuclear Laboratory. She said that while the near-term work is focused on Generation III+ LWRs, an assessment of SMRs is also in progress. The draft report has not yet been released, so she declined to go into specifics. She did say that perhaps 10 reactor designs will be explored in the full review, perhaps starting in September.

One key difference between the United Kingdom's new nuclear program and the one that gave rise to the power reactors that are now within a few years of closure is that very little of the design, development, and funding for new reactors is British in origin. Rayment hinted that this may change if the United Kingdom introduces SMRs. One prospect that is being explored is whether British interests might buy shares of selected SMR vendors.

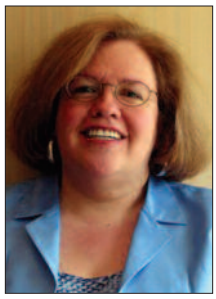
During the question-and-answer session, responses from Reyes suggested that NuScale Power has had to pull back from what might be possible with SMRs, with the optimization process perhaps addressing some of these issues. He said that the NuScale design now calls for one control panel and one turbine generator per reactor, even though multiplexing could be done. Customers, he said, prefer to have one turbine hooked up to one reactor.

Reyes and Magruder were also cordial when asked about the NRC's preference to slow down the development of the NuScale draft design-specific review standard (DSRS), because the company had deferred the submittal of its design certification application to 2016. Reyes maintained that the design is now essentially finished and the draft DSRS would make it possible for the company to address the standard in its application. Magruder said that there would probably be more design changes, which would then feed in to the DSRS. The two men, in effect, agreed to disagree.

Getting the message out

ANS's Education, Training, and Workforce Development Division sponsored two back-to-back panel sessions on communicating the benefits of nuclear energy, both of which were organized and chaired by Mimi Limbach, of Potomac Communications Group.

The first session, "Focus on Communications: Communicating with Communities," explored strategies and tactics that can be used to build support in local and regional communities for nuclear facilities and operations. The session kicked off with a presentation by Chip Cameron, of the Zero Gravity Group, a former assistant general counsel and conflict resolution specialist with the Nuclear Regulatory Commission, on the National Environmental Policy Act (NEPA)—the 1970 legislation that created the environmental impact statement (EIS)—and how the act's public participation requirements can be a resource for both communities and policymakers.



Limbach

Cameron

The two fundamental objectives of NEPA, according to Cameron, are to analyze, consider, and disclose environmental information as criteria for agency decision makers and to inform the public of the alternatives considered in NEPA analyses of EISs and the potential impact of those choices. "I believe NEPA can serve as a foundation for launching innovative public engagement efforts in communities," he said. "NEPA can be particularly useful because it applies to a broad range of federal activities, including construction, financial assistance, licensing of facilities, legislation, etc."

NEPA encourages public engagement and collaboration through the Council on Environmental Quality's (CEQ) regulations for implementing the act's provisions, Cameron explained, specifically 40 CFR 1506.6, which calls on agencies to make diligent efforts to involve the public in NEPA's implementation and to provide public notice of NEPA-related hearings, public meetings, and the availability of environmental documents to help inform interested parties. "That's the minimum that NEPA requires," he said. "But there is also something fairly new—it's probably about seven years old now—which I call 'aspirational': an Office of Management and Budget and CEQ memorandum on environmental conflict resolution that encourages agencies to engage in collaborative problem solving with the public, in an attempt to achieve better outcomes by working together with effective and interested parties in seeking information and ideas for agreement."

These collaborations can occur at any stage in the NEPA process, Cameron said, such as when determining the proper methodology to be used to gather and analyze data or when determining the alternatives to be examined. He said that he had participated in a number of collaborative events while at the NRC. "We'd get a group of representatives of the affected interests together around a table and try to establish new rules or policies," he said. "It's always amazing what you can accomplish when you have people sit down and talk with one another. You often might find the activist community agreeing with the industry on a particular issue. So even if you don't get agreement, it's worth doing."

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Cameron listed a number of other ways to involve communities, such as conducting interviews with local and state government agencies as part of the basis for the NEPA-mandated environmental analysis, establishing advisory committees or *ad hoc* collaborative processes, and designating a local government as a "cooperating agency" in the preparation of an EIS. "There is something called a 'cooperating agency agreement,' where a local government or another federal agency or state agency might have some particular expertise or knowledge that will help the lead federal agency in developing an EIS," he said. "So in that event, a cooperating agency agreement might be signed. It's another thing for an

agency to explore under NEPA in getting the community involved."

Cameron also mentioned "state-of-the-science" workshops that explain to interested stakeholders "what's known, what's not known, and what can be easily studied," focused workshops, which can offer detailed information and discussion, and town hall meetings. "The town hall meeting tends not to be about discussion or information sharing, but it does serve two important purposes," he said. "One is a forum for people in the community to come out and comment. Although that might not be helpful to the agency in preparing the EIS, it does provide a forum. The second thing—and this is what I really think is important—is that it's a context for building relationships among the agency staff and the people in the community so that there is contact that can be followed up on in terms of a phone call, an e-mail, an address. It can often lead to what I like to do a lot, and that is meeting with individual groups to explain the agency process to them. You sit down with them for a few hours—there might be 10 or 15 people in attendance—and you just talk about what the agency process is. It gives them a much better understanding of it than they could get in a public meeting."

Following Cameron was Nicole Stricker, senior science writer and nuclear communications lead at Idaho National Laboratory, who spoke on the potential benefits of taking an "informal approach" to communicating with communities, as opposed to a legally obligated one. "If you can communicate when you want to and because you want to rather than because you have to, that can help a lot in building relationships with the community," she said. "It helps the company or agency to be seen as more approachable. They're getting out there voluntarily and are willing to communicate with people. This voluntary sharing of information can help build credibility, transparency, and awareness."


Stricker

As one example, Stricker pointed to INL's practice of inviting the media to the lab every few years in order to provide them with information on emergency response procedures. "We do this a few months in advance of fire season just to help familiarize them with how it works and how we respond," she said, "so that if and when a wildfire does occur, they will be a little less frustrated with the speed at which we are able to provide them with information. It tends to make the emergency communications go a little bit more smoothly."

Stricker also mentioned that the DOE's Idaho Operations Office puts together a summary of its occurrence reports approximately every other month and sends it out to stakeholders and the media in an effort to increase transparency. "When it's done in that way, it really helps to build trust and credibility," she said.

Stricker described proactive communication efforts undertaken by INL in the aftermath of the Fukushima Daiichi accident as well, including organizing a series of open houses both at the state level and in neighboring communities to answer questions from the public. "At these open houses, we had experts available to answer questions," she said. "We had displays and handouts. It was very much an informal situation, which I think helps build a lot of credibility. It almost immediately took a lot of the vitriol out of people saying, 'This could happen here.' It also demonstrated openness and a desire to communicate the fact that we're doing this because we want to."

In Stricker's view, informal communication practices often provide the public with a greater sense of participation than do legally mandated meetings. "Some of these public town hall forums or some of the stuff required by NEPA can end up with a giant room full of people, with someone giving them some talking points, but not much of a sense of a conversation," she said. "The mandated meetings can also arm your opponents, making it easier for them to claim that this is just the bureaucracy trying to push something down peoples' throats. One of the new things we've been hearing about is antinuclear groups that have been showing up at NRC meetings with laugh tracks. Every time the NRC person says something, they hit the recorded laugh track. It creates quite an adversarial situation."

Stricker noted the importance of working with community organizations that can act as foils to antinuclear groups. "INL works with the Partnership for Science and Technology, a group created specifically to counter antinuclear rhetoric, especially the nonfactual, unscientific stuff," she said. "They are a group that advocates for science-based decision making, technology advancement, and sound energy policies." Stricker also stressed the importance of INL's efforts to provide its employees with factual information in order to make them, in effect, community ambassadors. "There are a lot of 'friends and neighbors' discussions that go on," she said. "A lot of community members who might be on the fence or looking for more information are more likely to ask someone they know. That can be really effective for us as well."

The session's final speaker was John Kotek, a partner with Gallatin Public Affairs and former deputy manager for the DOE's Idaho Operations Office, who began his talk with a reference to Princeton's Peter Sandman, creator of the "risk equals hazard plus outrage" formula for risk communication strategies. While the nuclear industry may like to characterize itself as low hazard, he said, it nonetheless creates a substantial amount of outrage, and as a result, it needs to be mindful of that unfortunate fact when attempting to communicate.


Kotek

"Don't rely on NEPA as the only way to communicate with the public," Kotek said. "It can sometimes be a platform for people to stand up on a soapbox and take a shot at you. You have other opportunities before that. My firm does a lot of work with energy companies, utilities, transmission companies, natural resources companies, and the like, and there is an advantage to being a project proponent: You know what you want to do and where you want to do it. Maybe the people who will be your opponents are not going to like what you want to do, but they might not have that information yet. You've got an opportunity to get out there and tell your story first—if you take it. You need to talk to your congressional delegation, your state officials, your governor, the media as you see fit, and certainly interested communities. You have an opportunity to get out there and tell your story in your words before somebody tries to tell it for you. You need to take advantage of that."

Having a credible spokesperson is also extremely important, Kotek noted, as the public tends to trust people rather than institutions. "I see we have John Grossenbacher here, the director of INL," he said. "I'll never forget when his team first came out to the lab 10 years ago. We were at a public presentation introducing the new team when I was at DOE. My wife came to the presentation, and afterward she said, 'You know, I don't know all of what you guys do out there, but after listening to him speak, I don't worry about it, because he won't let them screw it up.' Having a credible spokesperson like that can mean a world of difference."

Policy support

The second communications session, "Building Policy Maker Support for Nuclear Facilities," followed after a short break, with the addition of two panelists, Harsh Desai, previously a senior nuclear engineer with Knolls Atomic Power Laboratory and currently the ANS Congressional Fellow, working in the office of Sen. Dianne Feinstein (D., Calif.), and ANS's Washington representative, Craig Piercy, of Bose Public Affairs Group.

In his opening remarks, Desai described a communication method that he has found to be effective when dealing with policymakers on Capitol Hill. "A lot of these folks don't have time to know everything about


Desai


Piercy

anything," Desai said. "They just need to know enough to be able to get by, make the decisions they need to make, and leave all of the details to their staffers. So a quick thing I've developed is a 30-second approach to communication: In the first 10 seconds, state the problem; in the next 10 seconds, tell them why they should care; and in the last 10 seconds, tell them what you propose. You have about 30 seconds of their time—and that's if they're actually interested in the first 10 seconds. Otherwise, forget it. That is one of the things I picked up very quickly working on the Hill."

"I've developed a 30-second approach to communication: In the first 10 seconds, state the problem; in the next 10 seconds, tell them why they should care; and in the last 10 seconds, tell them what you propose."

Desai added that in order for nuclear energy proponents to communicate effectively in Washington, they need to be cognizant of the fact that the nuclear industry is often in competition with itself. "We're always saying that we should be focusing on this or on that, but if I were to take a poll here, I would get a wide variety of answers as to what the industry should be focusing on," he said. "It's very hard to get everything passed through and pushed through. For example, with DOE funding, if you give funding to one program, that money has to come out of some other program. Policymakers hear all sorts of answers, and trying to figure out what is most important can be difficult. If you recognize that, you can start prioritizing things better."

Piercy centered his opening comments on the "noise and polarization" of today's Washington, which force policy advocates to be more creative in their communication techniques. According to Piercy, the noise is in large part the result of the advent of social media and the 24-hour news cycle. "I know when I was on the Hill 20 years ago, postcards and phone calls were the way people communicated," he said. "Generally, as a House member, you had two years to make your case. You would go back out to the voters and present your case—'this is what I did during my last term in Congress, please reelect me.' Now, however, a vote happens in committee, groups follow it, it goes up on Twitter. The news outlets pick it up. The bloggers pick it up. In two hours, you have constituents calling and asking why you voted for or against a particular project. The response is almost instantaneous."

As for the polarization in Washington, Piercy said, it is probably more intense now than it has ever been. "When you have 85 percent of House members in the 2012 election win their general election by more than 10 points, the only real election that matters, as Eric Cantor can tell you, no doubt, is the primary," he said. "As long as you win the primary, you're in for another two years. And since 85 percent of House members don't care about the general election, they may well not care about listening to the other side of the aisle. You walk into any Republican office and they'll have Fox News on a flat screen in the corner. You walk into any Democratic office and they have MSNBC on in the corner. It's like there are parallel universes. You have to recognize that whatever message you bring up there, you're bringing to a very polarized environment. In many ways, you have to tailor your proposal to the ears upon which your message will fall."

Piercy stressed the value of building and maintaining relationships with members of Congress and their staffs. "Relationships are still everything in D.C."

Piercy also pointed out the importance of "knowing your reach." "If you're not a constituent, you'd better be an expert. You've got to bring something to the table. Are you a donor? Are you a volunteer for the campaign? If you're none of those things, then nobody up there really cares what you think. It's crass, but it's true."

In addition, Piercy stressed the value of building and maintaining relationships with members of Congress and their staffs. "Relationships are still everything in D.C.," he said. "There's an old saying in Washington that you don't make a friend when you need one. You always have to be up there maintaining those relationships with people who have an impact on the policies that affect your industry or your concern." According to Piercy, there are three important aspects of relationship maintenance: being knowledgeable, being credible, and being available. "You need to be willing to go out and find that piece of information they need and get it back to them in a couple of hours," he said. "That is the currency of the relationship in D.C."

An extensive question-and-answer period followed Piercy's remarks, engaging panelists from both sessions. In response to a query regarding communication efforts targeting groups less disposed to be automatically pronuclear, INL's Stricker said that as a member of the National Association of Science Writers, she strives to build relationships with those members on the other side. "While a lot of them are really adamant about the science behind climate change, listening to and believing those scientists, when you talk about nuclear, it kind of goes the other way," Stricker said. "Not all of them, obviously, but a lot of them. They tend to disbelieve the pronuclear scientists as some sort of biased group. But whenever I'm at those meetings, I am trying to talk to them. And I think that is what everyone in this room can do."

Limbach agreed with Stricker, noting that Westinghouse Electric Company has begun investing more of its communication dollars in such activities. "They looked at their budget a couple of years ago and decided they were spending a lot of money speaking to the converted, and if they were going to sell more plants in this country, they would need to help change public opinion," she said. "Southern Company also does a really good job of going into forums that might not be particularly comfortable. This is important. It's important that all of us talk to those friends and neighbors who may be skeptics about nuclear energy. You can change minds."—*E. Michael Blake, Dick Kovan, and Michael McQueen*