ANS WINTER MEETING

Nuclear power: Attracting notice, a brighter outlook

WITH ITS STELLAR performance indicators and clean safety record for more than two decades now, the nuclear industry has been attracting more notice from the public than it has in years. As general chair Michael Sellman noted during the opening plenary session of the ANS Annual Meeting, "It's probably the best time in 22 years to talk about nuclear power."

Rising prices of competing energy sources, rolling blackouts in the country's most populous state, and an executive branch that is unafraid to utter the word "nuclear" on national television have all contributed to the country's rethinking of nuclear energy.

"The state of the U.S. nuclear industry is very sound and . . . the outlook for nuclear power is the brightest it's been in several decades," said Jeffrey Merrifield, a commissioner with the Nuclear Regulatory Commission (see article by him, this issue). "By almost any safety, reliability, or economic performance indicator, the 103 operating nuclear power plants in the U.S. are operating better today than ever before."

The performance has improved so much over the years, in fact, that the equivalent of 23 new 1000-MW plants have been added to the existing fleet of nuclear power reactors, Merrifield noted.

But the window of opportunity for the industry may not last long. Administrations can change in four years. Senators can roll out of the other side of the bed one morning, switch parties, and affect where the nation will store its radioactive uranium for the next geologic era or so—as evidenced by the newly empowered Senate Democratic majority leader's recent announcement that the senate will not support Yucca Mountain.

The whims of the nation's leaders aside, the speakers at the plenary session agreed that the best way to ensure a robust future for nuclear power is to focus on safety. "We better be safe, or the bright future appearing for nuclear power could quickly go down," warned Richard Abdoo, chief executive officer of Wisconsin Electric Company.

More than 900 paid registrants gathered in Milwaukee in mid-June to attend *Safety Culture and Its Relationship to Economic Value in a Competitive Market,* the ANS Annual Meeting.

And just how optimistic these times are for the nuclear industry was a question on everybody's mind. Indeed, speakers throughout the week's sessions sidled into their presentations their take on how hopeful the industry should be. And the musings—by turns gleeful, dismissive, and cautious—of registrants could be heard in hallways, hotel elevators, and nearby restaurants.

As assistant general chair Tom Lewis, of Nuclear Management Company, wondered, "Is American society taking nuclear power to the prom and viewing it as the homecoming king or queen? Or is it viewing it as the cousin you're stuck taking because you couldn't get another date?"

Major themes of the plenary:

- *The state of the U.S. nuclear industry is very sound.*
- *A focus on safety is necessary for a robust nuclear power future.*
- *ANS is being sought out for information and perspective.*
- *There is a grave need to support university nuclear engineering programs.*
- *Nuclear power will not sell itself—it will have to be sold.*

ANS doings

In his comments, 2000–01 outgoing ANS President Jim Lake noted several hopeful developments at ANS over the past year. The number of new student members grew by more than 100 percent in the past three years. Also, for the first time "in a long, long time," ANS received in April an invitation to testify before Congress, he said. And, the Society has made headway toward becoming a credible and respected source of public information.

"At this time last year, ANS was unable to break through the national press to get information out to the public," Lake said. "Today, as America has awakened to energy supply and energy cost issues, ANS is being actively sought out for information and interviews."

Lake noted that just in the past few months, several current and past ANS officers have responded to calls for interviews for media outlets such as CNBC, *The Washington Post, The Wall Street Journal,* and even *National Geographic.*

"I believe ANS is on the map now as a source of credible information with some of the national press," Lake said.

Public trust in Japan

Shunsuke Kondo, a professor and director of the Research Center for Nuclear Science and Technology at the University of Tokyo, provided an overview of current issues facing the nuclear industry in Japan.

In order to prevent several years of economic stagnation owing to reduced carbon dioxide emission standards mandated in the Kyoto Protocol, the majority of Japan's Advisory Committee on Energy to the Ministry of Economy, Trade, and Industry (METI), agree that Japan should steadily increase its nuclear power supply in the coming decades, Kondo said.

To do this, Japan must, in the short term, maintain the credibility of the safety regulators


Kondo

and operators and promote the site selection for geological disposal of high-level radioactive waste, Kondo said. In the middle term, new types of reactors that are competitive with other forms of power generation must be demonstrated and deployed. And, in the long term, R&D of fast breeder reactors and related fuel cycle technologies must be promoted.

The accident at JCO Tokai Works in September 1999, however, has damaged the public's trust in the nuclear community, Kondo noted. Shortly after the accident, more than 70 percent of the people asked expressed uneasiness toward nuclear power, up from around 60 percent the year before. In 2000, the number of people favoring the reduction of nuclear power was about 5 percent higher than those favoring its continued use.

Kondo said that to win the public's trust, it is "extremely important" to inform the public of the merits of nuclear technology and its "irreplaceable role." He said a prerequisite for success is "to recover the public trust in operators, regulators, and policies, as various opinion surveys indicate that the public trust mainly comes from . . . their belief in the safety and controllability of nuclear technology."

'Tough issues'

Even though the nuclear community is on the threshold of a rebirth, noted Nuclear Management Company president Michael Sellman, "there are some hard things we have to do" if the industry is to succeed. In his presentation, Sellman provided a down-to-earth assessment of the difficult issues yet facing the industry.

"It's absolutely critical that science decide whether or not Yucca Mountain is an acceptable repository," he said. "And then we hear, unfortunately, that there is a chance that the decision will be made based on politics. If that happens I can tell you there won't be a rebirth of nuclear power. It's up to us in the room to talk to our senators and make sure that science is used to make the decision."


Sellman

Sellman said there is a grave need to support university nuclear engineering programs and encourage young people to join the industry. "In the next decade a lot of nuclear workers at the plants and a lot of us in this room will be retiring. We know that. And even knowing that, we haven't helped our universities. We haven't gotten to the point where we've revitalized nuclear engineering programs at universities. We haven't persuaded youth that this is a good industry to go into."

He said it is likely not possible to entice young people to enter the nuclear industry until a new nuclear plant is ordered—the most difficult prospect of all.

"I would love, before I retire, to build another nuclear plant. But I've got to go to investors and say, 'Would you lend me a couple billion dollars? But you won't get any return for at least five years. And during that five years there's going to be another election. Maybe there will be a different administration. Maybe that administration won't support nuclear power. Also during that five years something's going to happen to natural gas prices: Are they going to go up? Are they going to go down? What happens if they go down?' And all of a sudden what looks economical today or two years from now isn't economical." Sellman said.

"These are very tough issues. It's hard to convince someone to invest a couple billion dollars."

First, operate safely

Early in his presentation, NRC commissioner Merrifield said he believes that the future of the nuclear industry hinges not on corporate decisions about new plants, but on the safety of the existing fleet of reactors: "Neither the NRC nor the industry can allow the headlines about new plants to distract us from maintaining the safety of the current fleet, nor can we permit ourselves to lose momentum on the important regulatory improvement ini-

tiatives that are under way." Merrifield suggested some initiatives that can maintain safety while enhancing the economic value of plants, and then discussed the threats to a plant's safety culture and the economic value of public confidence.

License renewal is "clearly" at the forefront of the industry's efforts to enhance the economic value of its plants, Merrifield said. "My message to licensees considering license renewal is that the recipe for success is quite clear: Develop sound programs for managing plant aging, submit renewal applications that are of the highest quality, and ensure that license renewal does not distract your staff from maintaining the operational performance and safety of your plants."


Merrifield

Plants can also enhance economic value through power uprates, which are the least costly means of increasing power generation. The NRC has approved approximately 2000 MWe of power uprates, Merrifield said. Based on information provided by the industry, he noted, the NRC anticipates that licensees will pursue uprates totaling 8000 to 12 000 megawatts in the coming years.

"In your quest to get more value from your generating assets, don't jeopardize their future," Merrifield cautioned. "You must ensure that engineering analyses are sound, safety margins are well understood, and plant reliability is not challenged. . . . Anything short of this amounts to false economics."

In the area of threats to a plant's safety culture, Merrifield identified complacency as one danger to a plant's safety culture. "We cannot allow ourselves to forget about the Davis-Besse feedwater event, the fire at Browns Ferry, the Millstone saga, and the extended shutdowns of the '80s and '90s. . . . Complacency is simply this industry's worst enemy."

Merrifield also identified ineffective corrective action programs as a threat to a plant's safety culture. "The fact is, the history of this industry is marred with plants that have paid a heavy price because management failed in its responsibility to foster a robust corrective-action program. . . . Should the NRC staff lose confidence that a licensee's program is robust enough to maintain plant safety, I assure you our regulatory response will be swift and it will be severe. . . . I would expect that the competitive market will be an equally swift regulator."

As consolidation in the ownership of nuclear plants continues, the few large companies operating these plants must not become insular, another growing threat to the safety culture of the nuclear industry, Merrifield said. Plant managers must never become comfortable benchmarking themselves only against their organizational peers. "As I have said on many occasions, for those who are so bold as to believe that *all* of the nuclear industry's solutions, *all* of its best practices, and *all* of its operating experience lie within your organization, I ask you this: Are you bold enough to stake your assets on it? I hope and expect the answer is no."

Merrifield closed his remarks with comments on the economic value of public confidence. He said he found it intriguing that some plants have public communication as a high priority, while others do not, perhaps mistakenly believing that public confidence has no economic value. "It is difficult to quantify the economic value of public confidence. However, as those plants that have lost it can attest, the economic impacts associated with restoring lost public confidence are real, they are quantifiable, and they can be staggering."

A new image

If there is an industry with an image problem, it is certainly the nuclear power industry. In fact, with safety and performance well in hand, it could be said that the public's perception of nuclear power remains the greatest challenge for the industry.

Image also remains among the least-addressed ingredients of success for the industry, which is why the comments of David Bersoff, who provided a makeshift seminar on the marketing of nuclear energy, were particularly welcome. An industry outsider, Bersoff bluntly put forth unconventional ideas that, given the range of reactions from meeting participants—from laughter to rapt silence—and the proportion of ensuing questions from the audience addressed to him, proved compelling.


Bersoff

"The essence of marketing is selling. And seldom do things sell themselves. And I can tell you right now, nuclear power will not sell itself," Bersoff said. "It will have to be sold."

Will consumers' fears of and aggravation with rolling blackouts and high electricity bills trump their concerns about nuclear accidents and spent-fuel storage? Bersoff asked. "Nuclear power investors are being asked to stake a lot of money that this question will be answered in the affirmative. The likelihood of that happening will depend on three things: how well nuclear power markets itself, how well the antinuclear forces market themselves, and how well other energy alternatives market themselves. In other words . . . marketing is going to play a very large role in the future success of nuclear power."

Bersoff is director of Yankelovich MONITOR, an annual consumer behavior–tracking study performed since 1971. Based on 2500 in-home interviews, the MONITOR studies provide insight into the lifestyles, values, and attitudes of consumers, Bersoff said. The data are nationally representative of persons aged 16 and older.

He addressed consumer ambivalence toward technology, the decline in consumer trust of big business, and the current state of environmental activism.

Bersoff told a story of a community that was preparing to vote on a referendum on whether to fluoridate the town's water. Proponents of the referendum brought in experts who presented data on how the fluoridation would be safe and could decrease cavity levels in the community. Opponents of the fluoridation distributed leaflets with a picture of a rat on the cover, with the words "Don't let them put rat poison in your water supply."

Used in large quantities, fluoride, in fact, is rat poison. The amount used in a water supply, however, is minute by comparison. "Unfortunately, this was a nuance that was apparently lost on the public. And that referendum was soundly defeated," Bersoff said. "Basically, we saw that fear triumphed over research, authority, and data."

The nuclear industry is vulnerable to a similar "rat poison" attack. "One of the very first things to go is the public's ability to appreciate nuance," he said.

More troublesome, Bersoff explained, is consumers' reluctance to take the perceived risks associated with nuclear power. "The real enemy, the real [consumer] attitude that you have to deal with . . . is this: 'Why take a chance if we don't have to? There are alternatives. We don't have to use nuclear power. Even if the risk is really, really small, why should we do that? Why should we take any risk at all?'

"People are very conservative. People are very uptight when it comes to the issues of the basic safety of their family and neighborhoods and community."

Nuclear power, as Bersoff had said, needs to be sold to consumers. And a critical question that the industry will have to address is who is going to be the pitchman? Who is going to sell nuclear power and all its advantages to a skeptical American public?

What makes this question difficult to answer these days, Bersoff pointed out, is that the American public is not in a very trusting mood. Only 12 percent of people say that they have a great deal of confidence in consumer information provided by major corporations, Bersoff said. Only 6 percent of people say that they have a great deal of confidence in statements made by major corporations explaining their viewpoint on major issues.

"This does not bode well for the nuclear industry spearheading the renaissance of nuclear power" he said. "It doesn't bode well for the nuclear industry selling itself to the public. As a matter of fact, anybody who has anything to gain by the resurgence in nuclear power is not going to be believed or trusted. Anything said by those kinds of people is going to be viewed with a very jaundiced eye by the public.... [Consumers] are too smart for that these days."

Bersoff observed, "If a utility tries to say, 'Trust us. Go with nuclear power. It's safe, it's wonderful, it's cheap.' People are going to think, 'What's in it for them? Why do they want me to do this?'"

Bersoff then listed some very precise and compelling, if not mind-bending, examples of potentially credible spokespersons for nuclear

energy. "What you need is someone . . . who goes against type. An example? The Sierra Club. Or Ralph Nader. Or people who live near Three Mile Island. Alaskan caribou lovers. Oregonians in plaid shirts would also be a good choice." There was chuckling among the audience, but his point was clear.

"The information that is believed the most is information that goes against personal interest. . . . You're really going to have to get people that are not suspect, people that you would never expect to influence nuclear power. And it's really going to have to come from a source that traditionally hasn't been associated with the industry, or maybe even an institution that has traditionally been somewhat negative toward the industry."

What can be done to maximize the chances of nuclear power's succeeding over competing energy sources? Brand it, Bersoff said. "If you do not brand yourself, someone is going to brand you. And they're not going to brand you in a very flattering manner."

The key to successful branding is conjuring a distinctive image in consumers' minds. "When they hear 'nuclear power,' or the name of a specific nuclear company, you want a certain image to immediately pop into their minds. And you want that image to be sharp, you want that image to be clear, and you want that image to be something important to them."

Bersoff mentioned several examples of viable and clear brand images available for electricity: assurance of reliability ("We have the most reliable source of power"), assurance of cleanliness ("We're the cleanest source of power"), assurance of a good deal ("We give you the best price of what's available"), or assurance of safety ("We're the safest form of power").

"What you want is to be the most of something. . . . You need to have a clear image. You have to be the best at something. You have to decide what that something is. You have to hope that that something is going to resonate with consumers. And then you have to deliver that something 100 percent. It's clarity. It's branding. It's standing for something."

When people think of nuclear power, "you want them to think of pristine wilderness," he said, showing an image of the Grand Canyon. "You want them to say, 'This is the power source that protects my environment. This is not the power source that perverts my frogs and creates forms of life that God never intended,'" he said, jokingly, after revealing an image of a four-legged frog.

From the sudden silence in the audience following his next comment, however, it was clear the joke was over: "And it's just that simple that you could be [associated with] the waterfall and the Grand Canyon as you could be cornered into being considered the electric power that is going to potentially cause frogs to have extra legs."

Bersoff ended by commenting, "You guys have a really big job ahead of you. It's certainly an exciting time, it's certainly a heady time. It's quite possible—perhaps even probable—that you're going to win out over this. But, it's going to be a tough uphill job. You're going to need to be marketing focused. You're going to need to be consumer focused."

Advanced reactor safety

The ANS President's Special Session was devoted to discussion of *Safety Considerations for Advanced Reactors.* As the world's population grows and the demands increase for sources of energy, a new generation of nuclear reactors will need to be more economical, more proliferation resistant, safer, and cleaner than its predecessors. Public acceptance, too, will be increased only through the perception of greater safety of nuclear plants.

"Certainly as we think about public acceptance of nuclear energy, safety is the first issue that comes to mind," outgoing ANS President James Lake commented in opening the session. "I think we have a good story today for the public about how safely nuclear power plants are being operated around the world. But I believe we all recognize that we are held to extremely high standards for continued safe operation."

Lake

These standards present a challenge for the future, Lake noted, as the industry strives to improve the safety of the next generation of reactors. Questions that must be addressed include: Is safety strictly a matter of decreasing the probability of a reactor accident? Would the public understand decreased probability? What is the role of making reactor technology more robust? "There are a number of issues like these that we should be discussing now," said Lake, "because we want to be able to convince the public that as they accept nuclear energy in different places around the world, it will be safer and safer as we go forward. I think that is really our goal."

Gail Marcus, incoming ANS President and principal deputy director of the Department of Energy's Office of Nuclear Energy, Science and Technology (NE), talked about NE's goals for Generation IV reactors. These reactors will be constructed "two to three decades out," according to Marcus. (Generation III designs, which are the ABWR [Advanced Boiling Water Reactor], System 80+, AP600, and EPR [European Pressurized water Reactor], are more likely to be constructed in the 2000–2010 time frame, with Generation III+ designs—those offering improved economics—being built from 2010 to 2030.)

A technology road map is being prepared by NE to identify, assess, and develop advanced reactor technologies that can compete in all markets with the most cost-efficient energy alternatives. The road map will establish internationally recognized goals on sustainability, safety, reliability, proliferation-resistance, and economics for Generation IV nuclear plants.

Continued

Goals for next-generation nuclear power systems are broad rather than specific, Marcus noted. "They are goals, not commandments," she stressed, "and they are not applicable to near-term deployment." The goals are categorized into three general areas: sustainability; safety and reliability; and economics.

Sustainability, Marcus defined, is the ability to meet the needs of present generations while enhancing and not jeopardizing the ability of future generations to meet society's needs indefinitely into the future. Three goals exist for sustainability. They are:

1. Generation IV nuclear energy systems (including fuel cycles) will provide sustainable energy generation that meets clean air objectives and promotes long-term availability of systems and effective fuel utilization for worldwide energy production.
2. These systems will minimize and manage their nuclear waste and notably reduce the long-term stewardship burden in the future, thereby improving protection for the public health and the environment.
3. They will increase the assurance that they are a very unattractive and least desirable route for diversion or theft of weapons-usable materials.

Safety and reliability, Marcus continued, are essential priorities in the development and operation of nuclear energy systems. The three goals for safety and reliability are:

1. Generation IV nuclear energy systems will excel in safety and reliability.
2. They will have a very low likelihood and degree of reactor core damage.
3. They will eliminate the need for offsite emergency response.

Economics, said Marcus, is a requirement of the marketplace and essential for Generation IV nuclear energy systems. The two goals for economics are:

1. Generation IV nuclear energy systems will have a clear life-cycle advantage over other energy sources.
2. They will have a level of financial risk comparable to other energy projects.

Safety, Marcus concluded, is a key element in the consideration of future designs. In fact, she noted, of 79 projects funded by the Nuclear Engineering Research Initiative (NERI) program in the past three years, 48 of them address safety issues.

John Flack, acting chief of the Regulatory Effectiveness, Assessment, and Human Factors Branch of the Nuclear Regulatory Commission, offered a regulator's perspective on the licensing of advanced reactors. The NRC's advanced reactor policy statement was issued in the mid-1980s and updated in 1994. The policy declares that advanced reactors are expected to have, at a minimum, the same degree of protection as current generation reactors; that safety margins are expected to be enhanced; and that simplified, inherent, passive designs are to be used to accomplish safety functions. "Generally, [the policy] is less prescriptive and more performance-based," Flack said.


Flack

Some attributes that would support an application submitted to the NRC for approval of an advanced reactor are: reliable and less complex decay-heat removal systems; longer response time; simplified safety systems that would reduce the need for complicated operator action; a reduction in the amount of equipment subjected to severe accident environmental conditions; designs that minimize the potential for severe accidents; reliable balance-of-plant equipment; easily maintainable equipment and components; reduced potential for radiation exposure; and early interaction with the NRC through a pre-application process.

The NRC today, through its Office of Research, is looking at four areas where it now is or someday will be involved in reviewing reactor designs, according to Flack. A first design, the Pebble Bed Modular Reactor, is under pre-application review. A second, the GT-MHR, has had a request made by General Atomics for an NRC review of its design within the coming months. A third, IRIS, a design developed under the NERI program, should lead to an NRC meeting with lead developer Westinghouse in the next fiscal year to discuss pre-application. The fourth deals with Generation IV designs, for which the NRC is hunting for issues that would help improve its regulatory process for when a Generation IV application will be submitted.

Jean-Claude Gauthier, deputy director of nuclear development and innovation of Commissariat à l'Energie Atomique (CEA), commented that the French already are working on making nuclear plants more economical, safer, and sustainable by optimizing their existing fleet of reactors through license extensions, improving fuel burnups, minimizing the amount of long-lived radionuclides in waste, and working on management of the back end of the fuel cycle.

A French program for development of Generation IV reactors aims at mastering a technology based on a high-temperature gas-cooled reactor, an enhanced safety system, and a highly confining and temperature-resistant fuel. "Making use of gas turbines, which gave fossil fuel plants a decisive gain in efficiency and competitiveness, would endow future nuclear systems to also benefit from the same advanced conversion technologies," Gauthier said. "The hard neutron spectrum assures a highly efficient nuclear combustion capable of burning a wide variety of transuranic and fertile nuclides."

Several technologies investigated by CEA are key to R&D and physical modeling of advanced reactors, Gauthier noted. These include the testing of metallic, ceramic, and composite materials that have resistance to high temperatures and fast neutron fluences. "Fundamental research and modeling are essential for breakthroughs toward innovative concepts in the fields of fuels, structural materials, and spent fuel processing techniques," he said.

Yoshio Kani, director of the system engineering technology division of the Japan Nuclear Cycle Development Institute, offered insight into his research project involving a feasibility study for a commercialized fast breeder reactor. Kani indicated that the study is aiming at 2005 as a date for a selection of an FBR design to be studied, 2010 for the completion of a conceptual design study, and 2015 for preparation of a detailed design study and the establishment of systemized technical know-how for construction of an FBR in Japan.

Kani explained the FBR's safety objectives and safety design needs, which are similar to requirements for existing light-water reactors, before offering his personal view of nuclear power's relationship with the general public. "Nuclear energy should be recognized as a technology that is tightly connected with society," he said. "It will not be able to survive as a future energy source without societal or public acceptance. Therefore, everyone involved in nuclear engineering should have a great interest in societal acceptance now more than ever."

Regarding this matter, Kani said there must be a high safety level at the design stage of nuclear plants. It is especially important "to employ diverse measures and/or passive features into the fundamental safety functions" (power control, fuel cooling, and radioactive material containment).

In deciding to study an FBR design, Kani said his agency had "selected the way to provide mitigation measures in order to minimize and localize the consequences and to maintain the containment function against the proper range of core damage sequences, as well as prevention measures to reduce the core damage frequencies to a sufficiently low level."

Yanko Yanev, program coordinator for the Department of Nuclear Energy for the International Atomic Energy Agency, presented an overview of the IAEA's project on innovative reactors and fuel cycles, known as INPRO. The project, launched in May 2001, will bring together IAEA member states to ensure jointly that nuclear power is available to contribute, in a sustainable manner, to energy needs of this new century. "When you look at the long-term outlook for nuclear energy—probably in the next 50 years—if one wants to be optimistic, there are lots of optimistic signs, and if one wants to be pessimistic, there are also pessimistic signs," Yanev said.

The INPRO project is under way because the IAEA prefers to lean to the optimistic side, Yanev said. He warned, however, that while nuclear energy now provides about 17 percent of the world's electricity, it must upgrade its annual production by more than last year's 3 percent increase in new capacity or its share on a global basis will drop to 10 percent by 2015, according to IAEA projections. "When we are speaking about what meaningful role nuclear has to play in the world, we really have to be thinking not about [an increase of] a couple of percent, because [an increase of] 1 or 2 percent [annually] in the world's supply of energy is not a meaningful role at all," he said.

Instead, nuclear's long-term role has to be seen as substantial, and in that regard the INPRO project assumes that nuclear in the future will provide "at least above the present contribution [of about 17 percent of the world's total]," he said. To fulfill this meaningful role, he observed, innovative approaches will be required to address concerns about economic competitiveness, safety, waste, and potential proliferation risk.

Four subject areas will be studied under INPRO:

1. Economic requirements for innovative nuclear technology, which includes review of the energy market, utility structures, and generating costs; reactor fuel-cycle finance costs; technology transfer and diffusion; and consideration of supply security, supply diversity, and technology development.
2. User requirements of nuclear safety and safety technology development, which encompass the compilation of fundamentals and basic principles of nuclear safety and associated users' requirements; review of nuclear safety technology enhancement concepts and approaches for innovative reactors, fuel cycles, and waste management; and identification of R&D needs for confirmation of safety technology enhancement concepts.
3. User requirements for proliferation-resistance, including identification of the attributes for proliferation-resistance enhancements; evaluation of impacts of innovative technologies on institutional arrangements; regional safeguard arrangements; supplier arrangements; safeguards costs and effectiveness; proposals for new arrangements; and quantification of proliferation-resistance.
4. Environmental requirements, which involves environmental attributes for nuclear facilities and transport; environmental attributes for material flow and balance; and interrelation and interconnectivity for environmental attributes and requirements.

INPRO is being conducted in phases. Only the first phase is set, and it is expected to produce a comprehensive review of end user requirements for the four subject areas, including their evolution up to 2050 and beyond. It also will provide a selection of criteria, methodologies, and guidelines for assisting IAEA member states in the comparative assessment of innovative nuclear power technology. The first phase will result in production of a draft report to be released in June 2002, Yanev said.

University NE programs

The state of university nuclear engineering programs was addressed in the session *Business Challenges in the Universities.* Funding, as always, is a problem, noted session chair Andrew Klein, head of the Nuclear Engineering Department at Oregon State University. Indeed, John Lee, chair of the Nuclear Engineering and Radiological Sciences Department at the University of Michigan, reviewed the declining funding levels available for university research reactors in the United States. And Per Peterson, chair of the Nuclear Engineering Department at the University of California–Berkeley, spoke on the experience of developing an accredited program, an important step in competing for the decreased numbers of nuclear engineering students.

Lee provided a brief overview of the university research reactors in the United States. Out of the 65 university research reactors originally licensed under the Atoms for Peace program in the 1950s and '60s, 27 are currently in operation, with one in safe storage. Out of the 27 operating reactors, four have a power rating of 2 megawatts or more, and, altogether, 12 have a power rating of at least 1 MW. Three reactors, at the University of Missouri, the Massachusetts Institute of Technology, and the University of Michigan, operate 24 hours a day, seven days a week; six operate 20–40 hours each week. The disciplines that the reactors support include geology, archaeology, engineering, materials science, biotechnology, chemistry, and physics.

All is not well, however. "What really comes across as a business challenge to our community is the fact that total subsidy for these 27 operating reactors, from university administrations, amounts to somewhere around $20 to $25 million a year," Lee said. Also, Cornell University recently decided that it would likely shut down the reactor over the next several months. And both MIT and UM administrators have suggested that decommissioning plans be made, Lee said.

He mentioned the need for government funding support, particularly for the nine larger university research reactors that operate more than 20 hours per week. Lee pointed out that some national laboratory reactors each receive annual funds of $25–$44 million from the Department of Energy, compared to the $12 million for all university programs for FY 2001. The Nuclear Energy Research Advisory Committee has recommended $40 million per year for university programs, Lee said.

"Again, last December the University of Michigan announced plans to decommission the reactor unless we can come up with the federal government support, long-term support," Lee said in closing. "MIT . . . seemed to think that by July next year they may actually start going through decommissioning. They had prepared a decommissioning plan a number of years ago, and they are in the process of dusting off and upgrading the decommissioning plan right now. And, in our case, a number of us are dragging our feet with the decommissioning plans, hoping it will not happen. But, I don't know how much we can drag our feet at the moment."

Per Peterson provided insight into his program's experience with being reviewed and certified by the Accreditation Board for Engineering and Technology (ABET), a group of 31 professional engineering and technical societies. ABET accredits more than 2400 engineering, engineering technology, computing, and applied science programs at over 500 colleges and universities.

"Coming from the nuclear field, we're quite comfortable with the idea of regulation and the idea that you might want to have some independent body check and make sure that you're doing a very important job correctly," Peterson said.

He noted that other departments at his institution are less enthusiastic about the ABET program. "You might find that some of them consider this to be a useless exercise because they already clearly know what they're doing. Why have someone else come and confirm it? That sort of attitude will get them into trouble, just as we've seen in our own industry with nuclear plant operators who haven't taken regulation seriously. I expect in the longer term we'll see everybody begin to see this as a valuable process."


Peterson

He mentioned that the ABET program has led them to better serve undergraduate student needs and education, which has been necessary in order to compete for students. "We have always focused quite strongly on undergraduate student needs and education, in part because we've had to deal very aggressively with declining undergraduate student enrollment. Of course, I think that this is typical for all nuclear engineering departments, that we have had a very strong focus on meeting the needs of undergraduate students."

The foundation of the UC–Berkeley NE ABET program is a set of objectives for educating undergraduate students. The objectives that are set allow for greater focus on assessment and continuous improvement, Peterson said.

Besides the overall objectives of the program, Peterson said they developed course-by-course objectives, which are listed on the department Web site, that are designed to support the broad goals.

There are formal processes in place to document and periodically review the objectives. For example, there is a program advisory committee made up of leaders from industry, national laboratories, and academia who meet annually to provide feedback.

Then there is the process of identifying outcomes, which demonstrates whether the original goals are being met—a process Peterson has found to be valuable. The key aspect of the outcomes is that they must be measurable, Peterson said. He and his colleagues devised a list of certain abilities that students are expected to have upon completing the program. And, as a precursor, students fill out a questionnaire at the beginning of the semester asking them if they feel they have certain prerequisite skills for the course.

"It's been very interesting to do this because what you discover is that sometimes you get a crop of students that have been badly advised, and they will check off 'No, I don't have a clue about how to do this certain type of thing,' on this pre-quiz. And it alerts the instructors. Actually, our instructors really like doing this quiz at the beginning to check and make sure that students have the prerequisite knowledge, because they can discover is that in some cases the students have missed something. They can do something that's remedial

and then they can go and complain to the advisors about the advising that the students are getting or to the instructors of the previous courses. You can get things fixed."

The post-semester quiz has turned out to be useful as well, Peterson said. At the end of the course, the students are asked how well they believe they understand certain concepts. "And this has turned out to be very interesting, because most of the time the students come back and say that they got it pretty well. And every now and then there will be one, maybe two items where they'll say, 'No, this instructor never covered this. I never even saw it.' And that provides useful feedback. So, it turns out that actually making these measurements provides useful information for teaching better as well."

Peterson emphasized that the ABET program needs to be consistently tended to in order for it to work. "The most important ingredient is that after you succeed in getting your accreditation, you need to keep at it and not just quit and start up again five years later. And that's our intention at this point, to continue to make sure that we keep these processes running along. Because they turn out to be valuable anyhow. I think that they really do improve the quality of our education."

Excess Pu disposition

Herb Feinroth, of Gamma Engineering Corp., chaired the session *Progress on the U.S.-Russian Excess Weapons Plutonium Disposition Program,* which focused on the agreement, signed in September 2000, for the disposition of 34 metric tons (t) of excess weapons plutonium by each country. The United States, however, was not the first country to get involved with Russia in this area. France and Germany began working with Russia on weapons plutonium management in 1992, not long after the new Russian state was created. This cooperation led to a trilateral agreement, which was signed in June 1998. Canada, Japan, and the European Union are also involved in various projects.

In describing the Russian program, Evgeny Kudryavtsev, head of Minatom's nuclear fuel cycle division, reminded the audience that weapons plutonium disposition is primarily "a political and financial problem, not a technical one. Technically, nearly everything is possible." Kudryavtsev had described the Russian efforts in 1996 at an ANS meeting in Washington, D.C. Five years later seemed a good time, he said, to provide an update.

Kudryavtsev described the development of plutonium fuel in the Soviet Union/Russia, which never initiated a serious MOX fuel program for its power reactors. Before 1980, some MOX fuel development was undertaken with assemblies irradiated mainly in research facilities. In 1980, a new MOX fabrication facility named Paket was set up at Mayak. It had a production capacity of 350 kg of pelletized MOX fuel per year, which was used in the country's two power-producing fast reactors, BN-350 (located in Kazakhstan and now being decommissioned) and BN-600 (Beloyarsk). Since 1981, scientists at RIAR, in Dimitrovgrad, have also worked on another MOX fabrication route using a pyroelectrochemical conversion process and the production of vibropacked fuel. Paket and the RIAR facility are to produce MOX fuel for the weapons plutonium disposition program.

Kudryavtsev also outlined the Russian program. Under the U.S.-Russia bilateral agreement, Russia will convert all 34 t of plutonium to MOX fuel for use in power reactors. The two parties also agreed that some quantities of civilian plutonium can be mixed with the weapons plutonium during the conversion stage to achieve a particular isotopic composition. This differs from the United States, which plans to convert 25.6 t of plutonium to MOX and immobilize the remaining 8.4 t in a form suitable for disposal.

Kudryavtsev also provided cost estimates for the planning, construction, and operation of the plants needed to carry out the Russian disposition program, one based on a bilateral (Russia-U.S.) study and the other on a trilateral (Russia-France-Germany) study. According to these, the cost is $2.1 billion and $1.97 billion, respectively, excluding uranium fuel credit (estimated at $345 million). Only about $500 million has been committed so far, from the United States, France, Germany, and the United Kingdom. The G-8 governments were to discuss the funding issue at its Summit in Genoa, Italy in July.

The preferred long-term strategy for Russia's nuclear sector remains, explained Kudryavtsev, to close the fuel cycle and use its plutonium in a fast reactor program. It would also be interested in selling—or leasing—MOX fuel to operators in Europe, which would be useful for increasing the rate of disposition of weapons plutonium. Under the agreement with the United States, however, Russia will not reprocess civilian fuel for the time being.

The trilateral program was described by Bruno Sicard, of the French Commissariat à l'Energie Atomique. The aim, he explained, is to develop the capability to convert Russia's weapons plutonium into MOX fuel for use in its VVER-1000s and BN-600. A considerable amount of design work has already been done for the main elements of the plan: the conversion plant, known as CHEMOX, which will produce 2.3 t per year of plutonium powder; the MOX fabrication plant, referred to as DEMOX, with an output of 52 t of MOX fuel per year; and the necessary reactor modifications to support MOX operation. DEMOX is to use the redundant equipment from Siemens's MOX fabrication plant at Hanau, in Germany, which the company was forced to abandon before operations began, mainly due to political pressure.

Sicard

The MOX fuel is to be used at the Balakovo plant (four reactors) and the Kalinin station (two reactors operating and one under construction), and at the BN-600 fast reactor. These will have to be modified, as they are designed only for enriched uranium fuels. For example, using MOX fuel in BN-600 will require modifying the fuel storage facility to take MOX assemblies, replacing the radial blanket with steel and B4C subassemblies, and modifying some fuel assemblies to be substituted for fertile elements in the core. Various core strategies are being studied, including the hybrid core for BN-600 (25 percent MOX) as a stage to a full MOX core, and different loadings of the VVER pressurized water reactors.

Sicard also showed three different conversion processes, the French CHEMOX process, the American LANL process, and the Russian RIAR pyroelectrochemical process.

One route being developed by the Russians, he said, is the RIAR vibropacked fuel option to produce MOX assemblies for the BN-600. The work is being undertaken with the support of Japan, which signed a memorandum with Russia in September 2000. This option is considered a possible way to reduce the cost of the disposition program. Kiyonori Aratani, of the Japan Nuclear Cycle Development Institute (JNC), described a cost-reduction scenario using this option.

The advantage of the Russian technology, according to Aratani, is the simplicity of the processes and equipment compared with conventional aqueous conversion processes and pellet fuel fabrication technology. Three vibropacked MOX test assemblies, with about 20 kg of plutonium, are now being irradiated in the BN-600. In the next phase, the RIAR production facility is to be upgraded to supply fuel for the planned hybrid core (requiring 40–50 MOX subassemblies per year). Twenty-one lead test assemblies (LTAs) of vibropacked fuel containing a total of 120–140 kg of plutonium are to be irradiated in the BN-600 starting around 2004.

Under a cost-reduction scenario described by Aratani, Vibropack fuel would supply all the fuel for the BN-600. The CHEMEX and DEMOX plants would then need only to provide the MOX fuel for the VVER-1000 reactors. This would require an additional vibropack line, but the cost of the other facilities could be reduced—one of the two production lines planned for DEMOX could be cut and production at Paket eliminated. A full MOX core requires 250 subassemblies per year.

In February of this year, U.S. and Russian weapons plutonium began an irradiation campaign in a Canadian research reactor as part of a program to assess the potential of using Candu reactors for disposition. David Cox, of Atomic Energy of Canada Ltd., described the Canadian program.

Cox explained that Canada's interest in disposition began in 1994, when AECL took part in a feasibility study on the use of American produced plutonium in Candu reactors carried out for the DOE. In 1995, he said, there were even site studies for constructing a Candu MOX fuel plant in the United States. In 1997, the DOE published a Record of Decision on the disposition program, which retained the Candu as a backup option.

In 1995, Russia also expressed an interest,

noted Cox, and at the 1996 Moscow Summit, Canadian Prime Minister Jean Chrétien offered to proceed with a feasibility study and to undertake a small-scale test.

The test, called the Parallex project, is sponsored by DOE's National Nuclear Security Administration (NNSA), and involves three MOX fuel bundles, which will be irradiated for two to three years, Cox explained. The fuel was fabricated at the A. A. Bochvar Institute in Russia and at Los Alamos National Laboratory, and was transported to AECL's Chalk River facility for irradiation in the NRU research reactor.

According to Cox, Candu offers a number of advantages. The fuel is a simple design and the pellets are nearly the same as PWR pellets. A Candu reactor can take a full MOX core, which means that one unit can burn up some 1.5 t of plutonium a year (the analysis was based on the Bruce Candu reactors). Another advantage is that no physical modifications to the reactor core or to control and shutdown systems are needed. It also offers considerable flexibility.

It would not be difficult, said Cox, to adapt the DEMOX facility to produce Candu MOX. Minatom has looked at the economics of introducing the Candu option to complement its main disposition program, he noted, and believes it could reduce overall costs. A number of issues, however, would have to be worked through, he said. The Canadian government has said it is willing to consider a proposal for introducing a Candu MOX program, which would require a Candu operator to become involved.

NNSA's Kenneth Sprankle described what was to happen to the 34 t of American weapons plutonium. For the DOE, the project has the additional benefit of reducing its large surplus plutonium storage costs. As mentioned above, the United States opted for a hybrid—MOX and immobilization—strategy. The reasons, said Sprankle, are:

- Insurance in case one of the technologies cannot be implemented.
- A lack of consensus on the best approach.
- The cost of doing both was not perceived to be significantly larger than for one.
- Although antinuclear groups are strongly opposed to the MOX option, that route provides the best opportunity for working with the Russians on their program.

The project involves construction of three facilities—the pit disassembly and conversion facility, MOX fuel fabrication facility, and the immobilization facility—to be located at the DOE's Savannah River Site. The pits are now stored at the Pantex facility. The cost is estimated at $6.1 billion over 22 years.

Very early on, said Sprankle, the program ran into a funding problem. The original schedule was based on the assumption that the three facilities would be built at the same time. It was soon clear that this would create a peak-year funding problem, and the DOE doubted Congress would sanction the budgetary request. To meet budgetary constraints, he said, the DOE examined a number of possible actions and decided on a slightly different approach. It will focus on the MOX fuel schedule and delay the design and construction of the immobilization plant until needed. It will also push back the construction of the pit disassembly and conversion facility by two years. The DOE is also looking at other options for cutting costs, including the use of other facilities at Savannah River and dropping the immobilization strategy. It still plans to complete its disposition mission within the original time frame.

Eventually, the U.S.-produced MOX is to be irradiated in Duke Power's Catawba and McGuire reactors. Steve Nesbit, who is project manager for Duke Power's part in the program, presented the progress of the MOX fuel project.

In March 1999, the DOE contracted a consortium, Duke Cogema Stone & Webster (DCS), to provide MOX fuel-related services for the disposition program. Nesbit said that the DCS contract has three key parts:

1. Design, construct, license, and operate a MOX Fuel Fabrication Facility (MFFF) at the Savannah River Site; it is also to deactivate the plant after its closure.
2. Qualify the MOX fuel.
3. Irradiate the MOX in power reactors.

The deal with DCS also includes the design, fabrication, and certification of the shipping package.

DCS is taking advantage of European MOX experience, observed Nesbit. Framatome ANP has been given responsibility for fuel design and qualification and Electricité de France (EdF), the world's most experienced user of MOX fuel, is supporting Duke Power. The MFFF is patterned on Cogema's MELOX plant in southern France.

PROJECT MILESTONES

Begin MFFF construction:	2002
Insert MOX fuel lead test assemblies (LTAs):	2004
Begin fuel production:	2006
Initiate large-scale MOX fuel use:	2007
Complete MOX fuel loading into cores:	2020

According to Nesbit, technical and licensing activities are well under way. DCS submitted the Environmental Report to the NRC for the MFFF in December 2000, and a Construction Authorization Request (CAR) in February 2001, which was accepted for review by the NRC in March 2001.

Framatome ANP has submitted a MOX fuel qualification plan to the NRC for information. Duke Power has been preparing the fuel cycle plan, benchmarking it with European data on fuel and reactor operations. Nesbit said that the MOX fuel will undergo only two cycles to keep burnup below 50 000 MWd/t, which will simplify the licensing.

One of the issues that Nesbit discussed was the public outreach program. He explained that as the only major nuclear power initiative under way, the project has the attention of many antinuclear groups. A lot of effort is being put into stirring up public unrest over the reactors.

Nuclear security

The panel titled *U.S.-Russian Nuclear Security Cooperation: Navigating the Present Realities* took place soon after the first meeting of Presidents Bush and Putin in mid-June. During the session, Anne Harrington, of the U.S. State Department, acknowledged that the meeting was very encouraging for future relations.

According to the session chair, Nancy Hayden-Prindle, of Sandia National Laboratories, this session was organized not only around security concerns, but also on how the two countries are working together to advance nuclear technology and their nuclear power industries in light of different political realities and perceptions of how to do it.

Two members of the panel, Ambassador Thomas Graham, Jr., now executive director of the Lawyers Alliance for World Security, and Vic Alessi, head of the U.S. Industry Coalition, had participated in arms control negotiations with the Soviets over many years. When the Soviet Union collapsed in late 1991, explained Alessi, the U.S. faced a proliferation problem that was greater than ever. It was soon clear that the Soviet nuclear complex had already entered a period of steady decay. It got much worse after 1991 as the complex was divided among the various republics, most of which were unprepared to handle the responsibility.

Russia was struggling with the collapse of its economy and a disproportionate amount of the Soviet nuclear empire, including 10 closed cities, in which hundreds of thousands of people lived in isolation from the rest of the world. It had no money, no credible tax collection mechanism, very little understanding of free markets, and no idea what things cost. Minatom had complete responsibility for a million people, and knew no way of operating except under a Soviet-style command-control economy.

According to Graham, technology is a main influence shaping the new U.S.-Russian relationship, which will now be governed not by necessity, but by mutual self-interest. The nuclear industries have been at the vanguard of this revolution in relations.

Maureen McCarthy, chief scientist at the DOE's National Nuclear Security Administration (NNSA), gave the current DOE perspective on the U.S.-Russia cooperative programs. McCarthy had to speak from her office overlooking the Smithsonian Institute in Washington, D.C., as she was not allowed to leave town. For the last couple of months, McCarthy and some of her colleagues had been reflecting on DOE activities as part of the National Security Council–led review of the government's nonproliferation programs. The review should help to identify gaps in the programs, to understand where Russian and American requirements are at variance, and to develop more effective programs, she said.

McCarthy explained the reasons for supporting a policy of partnership with the Russian Federation and the fundamental values on which they are based. Those values include a desire to reduce the threat of war, a sustained commitment to democratic processes, a re-

spect for human rights and rule of law, and free and open market economies. Beyond that, she said, "what we mostly desire to have is a responsible and effective international partnership with Russia."

The NNSA programs focus on five strategic objectives:

1. Make the reconstitution of Russia's nuclear force more difficult, time-consuming, and detectable.
2. Reduce the potential for diversion of nuclear warheads to rogue states or terrorist groups.
3. Reduce the potential for diversion of weapons-usable nuclear materials.
4. Reduce the potential for diversion of nuclear weapons or dual-use expertise and technologies.
5. Enhance the safety and proliferation-resistance of civilian nuclear fuel cycles.

For the first objective, there are very specific things NNSA wants to do: reduce the weapons production capacity and the size of the work force engaged in defense work, as well as convert and eliminate excess weapons-usable materials and improve the transparency of facilities.

There are a number of programs that address some of these objectives. These include the high-enriched uranium (HEU) purchase agreement with USEC, the Nuclear Cities Initiative, and the excess weapons plutonium disposition program. The Nuclear Cities Initiative aims at converting the facilities in the closed cities to open, nonmilitary scientific and industrial uses.

The second and third objectives aim at reducing the potential for diversion of weapons and weapons-grade materials. The NNSA programs are designed to improve security and transparency at locations where material and weapons are stored; consolidate storage sites; convert materials to less attractive forms; and improve customs capabilities to detect and prevent movement of materials. NNSA is also working closely with the Russians to develop a comprehensive safeguards culture within the nuclear complex.

The particular programs covering weapons include Materials Protection Control & Accounting (MPC&A) and the Warhead Safety and Security Exchange (WSSX) for warhead dismantlement transparency. The DOE is also working with the Russians on a nuclear reactor fuel take-back program, excess weapons plutonium disposition, and second-line programs that are tied specifically to customs offices to help them develop and deploy technology useful for detecting potential movements of material at borders.

The fourth objective, which concerns weapons expertise and dual-use technologies, has been the hardest to address as a government and as a cooperative program. For example, it is difficult to determine what are dual-use technologies and what they are being used for, as is illustrated by Russia's nuclear cooperation with Iran. One of the main goals is to facilitate the creation of self-sustaining and full-time employment for nuclear scientists in nonweapons activities. Another aim is to facilitate the transition of activities in the closed cities into viable commercial enterprises outside the weapons business. There is also a need to strengthen export controls cooperation.

For objective 5, there are already many cooperative programs involving other countries and organizations. For a long time, the United States has been working closely with the Russians to improve the nuclear safety of power plants, develop capabilities to respond to nuclear accidents and emergencies, and develop more proliferation-resistant fuel cycles.

During the discussion, David Rossin, a former ANS President, commented that the programs seem to reflect the policies developed during the Carter administration. Rossin referred to the "can versus will" notion, arguing that because something *can* be done, does not mean it *will* be done. He says that this is not a valid basis for a policy. The answer to terrorists is safeguards, he added, and there are ways to safeguard the material to any assurance level needed. Several U.S. administrations refused to consider this approach, being concerned only with eliminating reprocessing, he added.

Underlying this position is the idea that the existence of any kind of plutonium is equivalent to proliferation, Rossin noted, and in the real world, this is not so. And the rest of the world recognizes that this is a weak position, and really does not take it seriously because it is basically against reprocessing, Rossin said. He expressed hope that policymakers will come to understand this, and come up with policies that provide a better basis for the development of nuclear energy.

McCarthy responded by first noting that "if we have a genuine concern about specific materials, which we have, we also have ways of developing safeguards. We can enhance the measures used to make sure the materials are not accessible." Another point, he said, is that by incorporating safeguards into new reactor designs to reduce the availability and accessibility of materials, the industry will be far better off than it is now.

A Russian view was given by Victor Mizin, who is on sabbatical at the Monterey Institute for International Studies. Mizin is concerned that his country could become a more closed society. Although the U.S. administration's recent decision to cut $100 million from the program may not seem significant, he said it sent a very wrong signal to Russia, where it has symbolic importance. Of course, he acknowledged, why should U.S. taxpayers' money be used while Russia is still spending billions on modernizing its own strategic potential—e.g., on new submarines, new ICBMs, and new weapons?

In Mizin's view, the United States is obsessed with plutonium, and "wants to ossify, classify, and immobilize it." In Russia, plutonium was gained by "blood, sweat, and tears" and probably many lives, and it is very important to the nation. Minatom would share Rossin's view, he added, believing that the United States has made some dreadful mistakes and wants Russia to follow in its path.

According to Mizin, Russian President Putin's landslide victory rode on nationalism, the nation's anger at feeling humiliation, and the lingering economic crisis. One of the messages was that Russia must maintain its nuclear potential, he noted. Many within Minatom are openly proud, he observed, that it has preserved the basic structures and spirit of this Stalinist-period organized enterprise and is very much opposed to any private ownership initiative. Minatom used to be like a state within the state, Mizin said, and now it is like an island of socialist command economy inside a country that is driving along the capitalist road.

Most Russian participants think the U.S. programs are a success, said Mizin, and were grateful for the assistance, particularly immediately after the dissolution of the Soviet Union. But as far as disarming goes, if the United States wants that, it must pay, he added, because Russians are not so interested.

The Nuclear Cities Initiative is the most seriously criticized, Mizin continued. Many citizens want Russia to continue to be a great power and will resist finding alternatives for its main military institutions, he said. Minatom does not want to lose its people, he commented, and added that the United States should help develop small and medium-sized businesses that will particularly attract younger people.

Anne Harrington noted that the Bush administration is the first one able to develop a relationship with a Russia that is no longer in transition. Psychologically, she noted, this is a very important point. The two can now move toward a normal relationship, not one governed by elaborate commissions, she said, but a relationship motivated by what most people at this meeting represent—commercial and research interests. These will become more fundamental to their relationship, rather than exceptions.

There are, of course, many sensitive technical issues, such as plutonium, said Harrington. The United States also does not agree with Russia's policy for exporting certain technologies to Iran and other countries. Not everyone agrees with the U.S. list of countries sponsoring terrorism, she added, but that, however, is the law.

Many of the issues have difficult technical and safety aspects, noted Harrington. Export controls, for example, require creating a culture that did not exist before. American industry and research organizations have a role to play here to impart that sense of responsibility that exists in the United States, she added.

Another hat worn by Graham is that of vice chairman of Radkowsky Thorium Power Corp., which is involved in a project that he describes as an emerging success story in U.S.-Russian cooperation. He said that the company has been working with the Kurchatov Institute for some eight years to develop nuclear fuel variants based on thorium. Past thorium fuel designs had questionable technical attributes and raised proliferation concerns, he noted, but the new designs appear to alleviate these concerns.

The advantages of thorium fuels address three overarching global issues, said Graham: the proliferation threat of nuclear weapons and weapons usable fissile material; the depletion of fossil fuel reserves and the implications on meeting the growth in energy demand; and growing greenhouse gas emissions.

The project has funding from the DOE, Graham said, and is managed by Brookhaven National Laboratory. The fuel is designed for

use in most current and new commercial light-water reactor plants, he said, and existing fuel fabrication lines could be easily modified to produce the fuel. This fuel should provide savings of as much as 20 percent over existing fuel and produce approximately 40 percent less volume of spent fuel, reducing the cost of spent fuel storage by approximately $1.5 million per reactor per year, he estimated. The waste generated is less radioactive and less toxic per kilowatt-hour produced than current conventional fuels, he observed, and can be made more resistant to meltdown.

Graham noted that the concept has three important nonproliferation benefits.

1. It would not be feasible to reprocess spent fuel to extract weapons-usable materials, which would be of such low volume and denatured and diluted by nonweapons-usable isotopes as to be truly unsuitable for an explosive device.
2. The fuel can be an effective method for disposing of existing stockpiles of plutonium and fissile uranium, using a variant that blends this material.
3. It would employ nuclear technicians in Russia.

He said it is hoped that the fuel will provide other breakthroughs. Fuel assemblies are being tested now in Russian reactors, he noted, and a plutonium and HEU burning variant will be tested in November.

Radkowsky Thorium Power is one of the companies taking part in DOE's Initiatives for Proliferation Prevention (IPP), which was discussed by Vic Alessi, whose organization, the U.S. Industry Coalition (USIC), represents over 100 U.S. companies involved in commercializing Russian science and technology. With a current budget of about $25 million a year, IPP now sponsors some 120 projects, he noted. Each project involves a partnership of a DOE laboratory, an institute in Russia (or another CIS country), and a company in USIC.

The effort, Alessi said, involves U.S. companies creating small high-tech businesses with a Russian partner, either as a joint venture or as a venture in which the Russians do the research and get royalties. Once a proposal is made, it is investigated by a U.S. laboratory to see if the claims of the Russians are legitimate, correct, and accurate. Then a U.S. company is nominated to work with that institute. A business review is done by USIC to ensure that it is the kind of venture that has a high probability of success in the business world. The U.S. laboratory ensures it will meet high technical standards and that the technical risk is "almost nothing," he observed. The U.S. partners also make sure that the projects do not violate export controls and proliferation concerns.

Under the IPP, once a positive decision is taken, the DOE allocates a certain amount of money to pay Russian salaries, Alessi said. The U.S. company must match that in kind and cash. Usually, for every dollar invested in Russia by the IPP, American industry invests about $1.60, he noted. This is just to take the technology from R&D, which would already have been done, and engineer it to the point where it is ready for production. It is then handed over to the company to begin capitalization and production. Alessi said that this typically involves some tens of millions of dollars or more, which the company has to finance.

The thorium fuel project is expected to generate a couple hundred million dollars a year, Alessi said, and many IPP projects have to do with isotopes. He explained that in the United States, it is almost impossible to build a reactor or accelerator now for producing supplies of isotopes, which is a growth market. Russia, on the other hand, is swimming in excess capability, he noted, and is able to produce isotopes for all sorts of medical purposes.

National labs' business role

Pete Planchon, director of Nuclear Technology at Argonne National Laboratory, introduced the panel at the session on the *National Laboratory Business Role in Energy Technology R&D*, noting that we are living in a world that is fundamentally changed from when the laboratories were created some 50 years ago. In particular, he said, the end of the Cold War left a very different set of nuclear problems than those dealt with during the Cold War. These and many other issues of today, such as energy and environmental sustainability, are global in nature. Generally, the labs' roles, responsibilities, and relationships with other organizations are having to change.

Planchon

For Ersel Evans, whose career spanned industry as well as the labs (General Electric, Battelle-Northwest, and Westinghouse Hanford) and who now is a consultant, the overriding concern is the more than a billion people living in abject poverty. "We need to do something about that. Otherwise, we are in deep trouble," he said. He said that opponents of nuclear energy are not facing up to that reality.

The future role for the labs, Evans observed, is in the development of energy resources and technologies. If nuclear energy is to be available beyond the current 70-year reserves of uranium, substantial development work will be needed. This includes improving fuel designs and fuel efficiency, developing advanced fuels and new fuels (or fuels in which there is a renewed interest, such as thorium), and researching other options, he explained.

More generally, Evans noted, national labs must supply political leaders with information and options. There are enough examples of predictions that have turned out to be totally wrong to provide proof that possibilities should never be dropped, but need to be retained, and the national labs are the vehicle for this, he said.

Steve Aumeier, associate director of the nuclear development division at Argonne National Laboratory (ANL), reminded the audience how significant the labs were in creating the construct in which a very successful industry operates today. They were crucial in initiating technology development, sharing initial deployment risk, developing policy frameworks, and setting the stage for U.S. leadership. But in the future, he wondered, will they become simply a technology assessment arm to support the industry?

Aumier

Aumeier said that there are two fundamental questions that need to be addressed to see if the labs are to have a role:

1. Is nuclear energy development vital to national security, and to economic and societal well-being?
2. If that is the case, are there sufficient market incentives to encourage the right level of private sector investment in the appropriate time frame?

There is no substitute for energy, Aumeier said. Although it can be bought and sold like any other commodity, it is not just any other commodity, but a precondition for others. This is partly why energy price shocks have such a significant impact on the economy and national security, he said. When prices are raised suddenly, it takes time for productivity and output to readjust. The structure of demand changes and with it employment patterns, having a real and often profound effect on individuals. Aumeier put up a graph of energy prices and the economy, which showed that every recession over the past 30 some years had been preceded by an energy price shock. This is why stability in energy supply and price is much more important than the level of fossil fuel reserves, he observed.

Several years ago, Aumeier noted, deregulation was supposed to be the death knell of the nuclear industry. It turned out to be one of the saving graces, as the industry effectively responded to the challenge. The markets, however, do drive companies to minimize reserve margins, he added, and utilities are less able to handle demand spikes, due, for example, to sudden increases in economic activity or weather transients. California has shown what happens if energy cannot be bought at any price—blackouts.

Despite events in California, Aumeier said, electricity supply is provided by fairly stable sources. But a third of energy demand is for transportation, and with 60 percent of oil imported, the international market is critical to prices in the United States. This vulnerability is set to grow, he observed, as energy demand shifts from economically developed to developing countries.

Next, he discussed the environment. "Recent evidence indicates that the climate impact of CO_2 is delayed by 20 to 30 years. What we see today is a function of what we did 20 to 30 years ago. . . . The market is not good at looking that far and does not really care," Aumeier said. This is where policy must take up the slack and the national labs' job is to provide technology options—and not only for this country, he added. The labs can help developing economies, where most CO_2 will be

produced in the future, to bypass the environmental insults that the West introduced in its own development process, he explained.

Whether the private sector will invest in nuclear energy is another matter, Aumeier said. Nuclear power is not like other industries with high investment risks. The pharmaceutical and computer industries have a potentially high payoff from their investments. Intel, for example, invests some $3 billion to $4 billion per year in R&D. In the energy sector, however, there are high risks, but it is not obvious what the payoff might be, or who will actually get the benefit. Aumeier argued that an investment decision is about price and risk. The price can be lowered to make the investment more attractive, and risk can be lessened. There is a potential government role here, he noted, such as ensuring through the national labs that there is a strategic reserve of technologies available for commercial development. He also reminded participants, however, that the nuclear business is more about political risk than technical risk.

Tom Sanders, manager of nuclear initiatives at Sandia National Laboratories, explained that about four years ago, Sandia began a study to examine the health of the domestic nuclear power infrastructure, covering everything from education to industry. "We were trying to establish an argument that regardless of what had happened there were severe national security implications," he said, "and that the national labs should be tasked with providing analysis and technology options to lead the world into the next nuclear era, [which] was going to occur with or without American participation."

Sanders

Over the next 20 years, Sanders said, all countries will remain dependent on the old forms of energy, and there is no way out of it. The supply of oil is a real security issue: U.S. imports will continue to grow; Asian dependence on Gulf oil will expand dramatically; and the increase in energy demand is going to take place in the developing world.

European gas supplies will be dominated by Russia, he said, and a particular irony is that while shutting down its reactors, Germany will be buying gas from Russia with the proceeds being used to maintain the Minatom nuclear complex. The United States already has a problem with natural gas infrastructure—the pipelines are full, he noted.

Nuclear energy and nuclear proliferation issues remain difficult. According to Sanders, U.S. nuclear policy has oscillated every 10 years between wanting to put the genie back in the bottle to one where the technology was on offer in exchange for transparency and security. The first Atomic Energy Act of 1946 was enacted to limit access. Then, in the 1950s, President Eisenhower said it was not working and thought it best to open up access, but to establish U.S. leadership. The result, claimed Sanders, was the evolution of the technology and the infrastructure for nuclear energy's being led by the cultural standards set by the United States, which focused on safety, security, and proliferation-resistance. It also provided commercial opportunities for U.S. industry and ensured American influence over nuclear programs worldwide.

Today, the picture seems much more complicated. At the end of the Cold War, suddenly there were thousands of tons of material available, and the mechanisms in place—notably the Non-Proliferation Treaty—were not able to handle the situation, Sanders explained. The United States went into a "buy what we can" mode—e.g., the high-enriched uranium purchase agreement with Russia; the foreign spent research reactor return fuel program; and the North Korean deal to give up its nuclear program.

Now and in the future, said Sanders, the issues of nuclear deterrence, arms control and reduction, and proliferation prevention, as well as those of energy security and environmental sustainability, are matters of national security. And there is a growing recognition that the U.S. nuclear infrastructure must be robust to deal with them. "We must revitalize nuclear energy in the U.S. and the world for energy stability," he said. "Industry, the labs, and government must work together to do that."

Sanders said that he does not think that leadership will come from the industry. He observed that nuclear energy in the United States has plateaued, and if a resurgence is left to the marketplace, nothing will happen, at least in the short term. The government has to start seriously investing in technologies that focus on "stretch" goals and a holistic approach to nuclear materials management, he noted, which means closing the fuel cycle. Near-term goals include increasing lifetimes, removing unnecessarily restrictive policies, and facilitating construction of new plants. In the long-term, Sanders said, the advantages of nuclear power must be maximized: Close the fuel cycle, reduce waste (he believes 80–90 percent reductions are possible), double energy efficiencies (e.g., using high-temperature reactors), and replace fossil fuels for transportation (one nuclear fuel pellet, he noted, could make enough hydrogen for 25 000 cars to go 100 miles). Certainly more can be done to make nuclear power safer, more proliferation-resistant, and more cost-effective, he declared.

In the second nuclear era, Sanders suggested, nuclear energy will assure energy security, provide an unlimited supply of nuclear fuel, allow environmental goals to be achieved, and reaffirm U.S. global leadership in nuclear issues.

Sanders was asked how to get the public and Congress on board. He replied that work with focus groups suggests it may not be so hard. Proliferation is not seen as a major issue, he said, but waste continues to receive bad press and is the one people focus on. A transparent nuclear fuel cycle is what is needed. He also noted that nuclear energy R&D has been treated very well in Congress. The nuclear caucus is expanding with as many Democrats as Republicans. What is needed is to develop an argument for the middle, he explained: "We have to build a coalition around the middle. I do not try to explain anything to the [antinuclear] activists. We need to quit talking to the activists and start debating them. We need to take them on." For example, he said, to eliminate nuclear weapons, "we have to show that you cannot even do that without a healthy domestic nuclear power industry."

John Ryskamp, of the Idaho National Engineering and Environmental Laboratory (INEEL), gave a rundown of the Generation IV program and the role of the national labs.

Ryskamp

The aim of the DOE's Gen IV program is to develop systems that offer significant advances in sustainability, safety and reliability, and economics, he said. The concepts address all issues, the front and back ends of the fuel cycle, and power conversion. They should be suitable, he noted, for a diversity of applications, such as hydrogen production, desalination, and process heat, and be deployable in a wide range of markets, sizes, etc.

Ryskamp noted that although some Gen IV reactors, such as the Pebble Bed Modular Reactor (PBMR), may be deployed within 10 years, most will not be available until about 2030. Their development will require collaborative, long-term, high-risk R&D. The labs' work will initially be financed through the DOE's Nuclear Energy Research Initiative (NERI) and the Laboratory Directed Research and Development (LDRD) programs (which provide internal seed money to pursue R&D), he said. The other parties in Gen IV, including universities and industry, will be able to use national labs' facilities, such as test reactors and hot cells for materials testing, safety experiments, etc.

For the period FY 1999 through FY 2001, he noted, a total of 69 NERI projects were under way, with half led by the national labs. Total funding for this period is $79 million.

To develop the program, a Roadmap group was set up, which, over about 18 months, will define what R&D will be needed over the next 10 years to move forward, said Ryskamp. INEEL and ANL are leading the Roadmap effort, which involves 50 experts from the United States and 40 from the Generation IV International Forum (GIF) made up of nine countries (Argentina, Brazil, Canada, France, Japan, Korea, South Africa, the United Kingdom, and the United States), plus observers from international organizations.

A request for proposals was issued earlier this year and some 94 concepts have been submitted, he said. These will be evaluated against a set of goals and whittled down to four to eight concepts that will receive R&D funding. The final screening will take place in April 2002, he added, and the DOE will provide the initial funding, with industry gradually taking over.

Safety in a deregulated market

Deregulation in the nuclear industry has set the stage for an environment where higher levels of plant performance may be expected because of cost- and profit-based competition. A panel on *Safety of Nuclear Power Reactor Installations in a Deregulated Market* was assembled to discuss the effects of safety and economics on successful plant operations.

Session chair Thomas Esselman, president of Altran Corporation, noted that deregulation has forced the nuclear industry to reevaluate the way plants are run. Gone are the days when costs could be directly passed on to ratepayers. In today's environment, a plant must be kept in top condition within a set budget, he said, because "safe and economic operations are not independent, they are interdependent criteria."

With nuclear power expected to play an important role in the nation's energy policy going forward, Esselman commented that the industry must continue demonstrating to outside observers that its plants can be operated safely. However, he challenged, "how good, how cheap, how available can [nuclear plants] be without compromising" safety?

Stephen Floyd, senior director of Regulatory Reform and Strategy for the Nuclear Energy Institute, argued that the industry always has strived for safety perfection, regardless of the operating market. "[NEI doesn't] see a disconnect between a regulated environment, a deregulated environment, and safety performance," he said. "We think all three go hand in hand together."

Performance measures released annually by the World Association of Nuclear Operators show the industry on an improvement track, even as it travels farther into a deregulated world, Floyd noted. Recent statistics for the nation's nuclear power plants reveal that unplanned automatic scrams are down, safety system performance has increased, license event reports have declined, and capacity factors have risen (*NN,* May 2001, p. 38). In short, Floyd reported, nuclear has never performed better or been a safer industry.

With the advent of deregulation, 90 license transfer requests since 1998 have been submitted to the Nuclear Regulatory Commission, according to Herbert Berkow, project director for the NRC's Office of Nuclear Regulatory Regulation. These requests have been made to accommodate proposed mergers, acquisitions, formations of operating and holding companies, and alliances. "Deregulation has been the driving force largely for nuclear industry consolidation," he said.

The potential effects of deregulation on the NRC have been assessed by the agency in its role as regulator. In addition to consolidation, the NRC also is expecting an increase in the number of license-renewal applications submitted by the industry, plus the possibility of requests for construction permits to build new reactors. As industry statistics reflect safer plants, so does the NRC's own self-assessment indicate it is prepared for effective regulation in a restructured environment. "The bottom line is, with our limited experience to date and our own preliminary assessment, we've identified no need for any near-term major changes in what we're doing or how we're organized," Berkow said.

The self-assessment has reviewed the NRC's activities related to plant operational safety (such as possible cost-cutting initiatives, technology-related issues, and emergency preparedness); licensing; inspection, enforcement, and assessment; decommissioning; financing issues (such as foreign ownership); and non-NRC considerations (such as grid stability).

For some of the assessed areas, the NRC's staff has recommended that the agency take "no further action at this time," Berkow said. Other areas will continue to be monitored because not enough information has been collected to make a thorough assessment of their impacts on safety. Even in these areas, he concluded, "the existing regulatory infrastructure seems to be adequate for the time being."

Ted Quinn, vice president of MDM Services and a past President of ANS, noted that in many cases those plants in deregulated markets that record the highest grades in safety are also the most economical. "Safety is the highest priority because of the impact on cost that would result from an NRC-forced shutdown," Quinn said. There is now, he added, "actually a higher focus on safety than before."

Twenty-four states have, through legislation, regulation, or a combination of both, acted to restructure their electric power industries, Quinn said. Of those states, 17 are home to nuclear sites, totaling 60 nuclear units that are now in deregulated markets.

Quinn

With restructuring comes challenges for plant operators and regulators, Quinn continued. These challenges for operators include management focus on economics, not safety; pressure on workers to keep the plants operating (because of volatility of electricity prices); pressure to reduce preventative maintenance; deferral of equipment replacements; and less investment for safety backfits. For the regulator, these include increased workload (because of mergers, license transfers, etc.); pressure to avoid requiring shutdowns of plants; and increased political pressure to reduce the regulatory burden. Challenged also is the nuclear technology infrastructure. According to Quinn, there is less cooperation among competing nuclear utilities, and less safety research and technical support for the plants.

These challenges have pushed utilities to act more like for-profit organizations. "Plants have adjusted cost structure to focus more on business operations for both O&M [operations and maintenance] and capital expenditures," Quinn said.

But even in deregulation, he continued, nuclear plants are seen as valuable electricity generators. They have been sold for increased prices—Entergy purchased the James A. FitzPatrick and Indian Point-3 plants in February 2000 for $536/kW, compared with the sale of the Clinton plant to AmerGen in April 1999 for $21/kW. And, agreeing with earlier comments by NEI's Stephen Floyd, Quinn said that statistics for 1999 from the Department of Energy show nuclear plants in the United States making leaps forward since 1973 in the amount of electricity generated (more than 700 billion kWh for the first time) and capacity utilization (85.5 percent, the highest level ever).

Ronald Hagen, energy specialist for the DOE's Energy Information Administration, emphasized that nuclear plants in the United States are safe while being profitable. In the new world of deregulation, however, to optimize either safety or economics would mean a tradeoff on the other.

Hagen explained that there is a balance of safety and economics that each nuclear utility must control. Because profits are no longer guaranteed, the balance would be upset by spending more on safety, such as by adding another redundant system, for example, which would reduce the profit of the plant. On the other side of the scale, cutting costs to achieve greater profits might risk safety of the plant.

Hagen advised there are ways to safely cut costs at plants, such as by abolishing redundant rules or bringing in improved technologies. But until these methods are realized, safety and economics cannot both be improved. "Eventually," he said, "you get to the point where there will be a tradeoff somewhere."

Generation IV safeguards

Protecting advanced nuclear systems from proliferation risks was the topic of the session *Safeguards for Generation IV Reactors.* The goal on a worldwide basis is to create safeguards that will increase assurances that advanced systems and fuel cycles will be unattractive targets for proliferators who want to divert or steal weapons-usable materials.

Proliferation-resistance, as defined by Per Peterson, is the ability to detect and stop the diversion, theft, misuse, and sabotage of nuclear materials, facilities, and technologies. Peterson, professor and chair of the Nuclear Engineering Department at the University of California–Berkeley, works currently with an international "evaluation and methodology group" that is focusing on safeguards for systems, fuel cycles, and the complete life-cycle of materials. "We want to make sure we're not just making one part of the system extraordinarily proliferation-resistant while ignoring or neglecting another part," he said. "We want to have a fairly uniform level."

The first task, though, is "figuring out what proliferation-resistance really should be," he added. Ultimately, Peterson's group wants to do a complete assessment of the entire fuel cycle and all facilities used in that cycle, a task that for now "is completely impractical, because the concepts we're working with have large uncertainties associated with their design and their likely performance," he explained. For example, many of the Generation IV concepts don't have fully developed fuel cycles attached to them.

Continued

What Peterson's group is focusing on, then, is identifying reactor designs that have potential to someday be built. The group is developing criteria that would be used to screen only those systems that might be the most proliferation-resistant (given that the group has knowledge of what the systems would look like when fully designed).

An area now under investigation by the group is safeguarding advanced systems through use of inherent characteristics, such as by maintaining radiation or chemical barriers to make the materials unattractive for theft or diversion. A second area concerns looking for Generation IV characteristics that would aid in the timely detection of any removal of materials or misuse of facilities.

A goal of the nascent National Nuclear Security Administration (an autonomous agency within the Department of Energy) is "not to prevent countries from producing materials through clandestine programs. The point is to prevent them from using civilian nuclear power systems to augment their [bomb producing] programs," said Jon Phillips, deputy director of the NNSA's newly named Office of Nonproliferation.

Phillips discussed a metrics that NNSA may create to measure advanced reactor safeguarding. The metrics, termed a "proliferation index," would reveal the strengths and weaknesses of those Generation IV systems that likely would be the most attractive targets of proliferators. "Somehow [we] have to be able to roll all these [strengths and weaknesses] into a very limited set of figures of merit," he said.

Comparative analysis of the advanced systems also would need to be done, which would result in a "baseline index" that would expose common proliferator pathways and misuse thresholds. "To achieve proliferation-resistance, all we would have to do is [see a] rise sufficiently above those types of thresholds, and then it would no longer be economically practical [for proliferators] to pursue misuse or diversion of [materials from] civilian [reactors]," he said.

Robert Bari, senior physicist with Brookhaven National Laboratory, explained that the DOE's Nuclear Energy Research Advisory Committee (NERAC) has performed a study on proliferation-resistance of Generation IV reactors and has formed a committee to produce a report, "The Technology Opportunities for Increasing Proliferation Resistance of Global Civilian Nuclear Power Systems" (TOPS). The report, Bari claimed, revealed that there is no universally acceptable definition of proliferation-resistance, and that the term "may actually elude succinct definition."

Kory Budlong-Sylvester, technical staff member at Los Alamos National Laboratory, offered that there is no silver bullet to the problem of proliferation risk, as evidenced by the International Nuclear Fuel Cycle Evaluation report and other analyses. Protection must be done through accounting of materials and containment or surveillance of materials, he said.

Budlong-Sylvester noted that the industry should strive to "evaluate fuel cycles for their safeguardability, incorporate low-cost design features that maximize safeguardability, and eliminate diversion scenarios and concealment opportunities whenever possible."

As a design principle, he continued, the fuel cycle "should make it intrinsically difficult for a proliferator to divert material or misuse a facility, and easy for an inspector to meet his or her objectives of timely detection and verification."

Budlong-Sylvester

While an inspector perhaps will show up unannounced at a facility and want to be convinced that no misuse has occurred, a proliferator still will want to achieve his objectives. So safeguarding must be creative and consider all misuse, diversion, and concealment opportunities available, Budlong-Sylvester challenged. Can the proliferator be driven to using only visible means? Can misuse scenarios be avoided? Can seals or tamper-indicating devices be developed? Are there relatively few diversion scenarios that would not require obvious design modifications?

"In the end," said Budlong-Sylvester, "the relative success of a fuel-cycle design . . . could be measured by the ease in which the technical objectives of safeguards can be met. It seems that a facility or fuel cycle would be more desirable if it possessed characteristics that made it inherently easy and cheap to achieve a high probability of timely detection for diversion or misuse under any credible scenario."

Andrew Kadak, a past President of ANS and professor of the practice of nuclear engineering at the Massachusetts Institute of Technology, termed the proliferation issue a "political problem." Despite the work of the TOPS committee (the Task Force on Technology Opportunities for Increasing Proliferation Resistance of Global Civilian Nuclear Power Systems—which was a subcommittee of the DOE's NERAC) in seeking to find a technology that can assure that no nation can make nuclear weapons, "we can make designs of plants so complex and costly to avoid diversion that we will have missed the real threat—the need or desire to build nuclear weapons by a nation."

Kadak

Kadak declared that the nuclear industry could design fuel cycles that are more proliferation-resistant but are uneconomical, and it could develop accelerator-driven systems to eliminate plutonium or other higher actinides. But what would have been accomplished? "We will have made these nuclear energy systems much more complex, costly, and probably not ever used, and not stopped the making of nuclear weapons by those nations that choose to do so."

India and Pakistan, Kadak continued, through building their nuclear arsenals, have not helped the deployment of nuclear energy on a global scale. "Instead, they have reinforced the belief that there is a relationship between nuclear-generated electricity and nuclear bombs," he said. By establishing clandestine programs using research reactors and commercial plants, India and Pakistan "have shown that you can, if you want, make a nuclear bomb."

The bottom line, Kadak said, is that the industry's focus should be only on developing and deploying naturally safe nuclear plants. This may mean international standards, training, and front- and back-end fuel support. "Whatever we can do in the intrinsic and extrinsic design areas to make nuclear plant systems less proliferation-prone and easier to safeguard, we should do," he said. "But we should not be obsessed by nonproliferation technical fixes since they will not deter a nation from building such a weapon if the national need or will is there to do so."

The only true safeguard, Kadak concluded, is one in which the desire to build a nuclear bomb does not exist.

Recruitment challenges

The session *Business Challenges for the Young Generation–I* brought in perspectives from national laboratories, universities, and the military on how to attract young people to the nuclear industry. Although it is a bit easier now than even a few years ago, endeavoring to appeal to young engineers remains a difficult task.

"Just two or three years ago, people were actually very worried about internships [as a way to introduce students to the industry], because the interns would come in and the first thing the experienced people in the industry would do was run up and say, 'Change your major! Quick, get out!'" quipped session chair Robert Margolis, of Dominion Generation Co.

"But now, with the changing times . . . people are realizing, even with no new plants on the civilian side, that there are another 30, 40 years left of this business, not even counting decommissioning. And where are those people going to come from?"

The nuclear industry has trouble attracting young people, in part, because the on-campus recruitment strategies of many companies in the field often pale in comparison to those of other industries, said Dale Klein, vice chancellor of the University of Texas system. "I can assure you, as a former associate dean for research, where I was looking at other departments, the microelectronics companies are very aggressive, very financially sound, and provide a lot of resources to the students," Klein said. "It's just a tremendous difference to see the

Klein

kinds of programs that some of the very active oil and gas companies have. And we're not even close to doing the same thing in the nuclear profession. We're just light-years behind that in terms of utility companies coming on campus, the national labs coming on campus, the Nuclear Regulatory Commission coming on campus. It's just a stark contrast. . . .

"One of my favorite recruiting stories that shows what happens when we do it right was done by Sandia National Laboratories. They had a recruiter who was assigned to the University of Texas at Austin. He would meet with the master's and Ph.D. students in the nuclear program every semester. So, when they graduated, they knew him, he knew them, they knew about Sandia. And one semester, Sandia recruited six Ph.D.'s from our academic program."

The lack of university funding for nuclear engineering programs also makes it difficult to keep some departments afloat—especially given that within the next five years, about 80 percent of university reactors will need to be relicensed, Klein noted. "One of the things that we should expect over the next few years is we will see more nuclear programs decreased. And the reason for that is simple economics," Klein said. "When you are in a dean's office or a president's office and you see the very high demand for electrical and computer engineering [graduates], you see the very high demand for chemical engineering [graduates], and you have X dollars and you have to look at where you put those dollars—that's one of reasons that some reactors are being seriously challenged now as they look at relicensing."

Steve Trautman, director of external affairs for Naval Reactors, described the recruitment activities of his organization, which provides nuclear reactor propulsion plants for the United States Navy.

The success of the Naval Reactors program has been a strong selling point for young people. "We've been successful in keeping naval nuclear propulsion out there and doing what it's supposed to do," Trautman said. "We've steamed over 122 million miles. We've steamed over 5200 reactor years of safe operations—that's a little bit more than twice what commercial nuclear power has done in this country. And, over the years, we've put out over 50 unique reactor core designs."

Among its hires each year, Naval Reactors recruits more than 900 people for technical positions, Trautman explained. About 500 of those hires are officers who are going into the navy to become nuclear plant operators. The other 400 will eventually work for the organization's laboratories, shipyards, and vendor base. All new hires are trained extensively, so that they are on equal footing with everyone else, Trautman pointed out. "For those of us who come to headquarters, we spend about 600 hours in the first two years just training. At the shipyard, it's about the same—maybe 700 hours. At the laboratories, it's an extended training period over their entire career. But, up front, to get everyone on the same playing field, they'll go through a training period of quite a few hundred hours."

Trautman said that the training is expensive, but that it is necessary because there are not enough graduates coming out of the universities with the necessary backgrounds. The training also becomes a potential means of retaining personnel, however. "This is the investment that we put up front, so that hopefully a large percentage of them will end up staying."

Naval Reactors attracts young people to its program because enlisted personnel can receive more than 70 college credits for their work. "Boy, what a deal," Trautman said. "They're actually getting credit for what they're doing in the military. And, frankly, they've got an associate's degree when they get out. . . . And we're working down the same path for the officers, where they get very close to a master's degree."

The Naval Reactors program has not been suffering from a gradual industry slowdown like the nuclear commercial power industry has, and so can more easily draw enterprising young minds. Every new ship class that comes out requires a new reactor plant design, Trautman said. "And, in fact, in existing reactor plant designs, we may put a new core design in it to get more lifetime out of it. So we are continually and constantly working on new plant designs. . . . We're able to lay out in front of folks that this is not a stagnant organization, that we've got new business coming down the road. And it's an exciting business, because we also are trying to be on the cutting edge of technology."

The greatest selling point of the Naval Reactors program is something that no utility can offer. "I'm not trying to demean anyone else's business here, but national security still sells with the young folks," Trautman said. "There are an awful lot of patriotic folks out there. And giving them the mission of driving these 88 warships around and doing the President's bidding is a very good selling tool in getting them into the program."

A good portion of today's engineers will be retiring within the next decade, said John Sackett, deputy associate lab director at Argonne National Laboratory–West, who presented the viewpoint of the national laboratories. At the core of the need for new nuclear engineers is the need for aging staff to pass along knowledge to their incoming counterparts.

"I think we have a very limited window here to transfer information and experience," Sackett remarked. "There are too many of us who have been around a long time, who won't be around much longer, who need to be working with people coming into the field to share what has been a great wealth of knowledge and understanding in these technologies—not all of it written down."

Sackett

The need for nuclear engineers is rapidly outpacing the supply, Sackett said. Undergraduate enrollment has declined substantially, decreasing by about 72 percent in the last 10 years. And enrollment in master's programs has dropped 50 percent over the past decade.

There are several reasons for this, Sackett explained. First, the nuclear industry has a bad image. It is perceived by many to be a stagnant and fading field, and it has been criticized as being antienvironmental. It also has been lacking excitement. "Effectively what happened in this last decade is the growing edge of nuclear power and nuclear technology has stopped. And what we hear most about is cleanup—dealing with the problems of the past. There is a lack of excitement in the field," he said.

Also, as with many other industries, nuclear companies have been downsizing and promoting from within their organizations for the past decade, reducing the need for nuclear engineers. And there has been intense competition from other technologies. "We all understand the allure of computer science and the Internet and biotechnology and bioengineering. A lot of excitement has been developing in technologies other than nuclear, and that's drawn a lot of people away from this field," Sackett said.

The situation is not entirely negative, though, Sackett said. "The downsizing is over. Companies are looking to hire people. There is the possibility that we may be able to reestablish advanced reactor and advanced nuclear technology programs, going forward.

"And what is this creating? It's creating a significant difference between supply and demand. The estimates are that we will be short by about 100 nuclear engineering undergraduates each year for the next three to five years. Projections are always dangerous, but it certainly says that there are great and growing opportunities ahead for people coming into the field."

The industry can attract young engineers by "describing the vision for nuclear power," Sackett said. "Energy supply is a national and global challenge of immense proportions. I can't think of a greater challenge. To me, it's even greater than putting a man on the moon. It affects the economics of all nations and it is fundamental to the quality of life. It has potentially very large and adverse effects on the environment. And it has been and will be the source of conflicts and wars between nations," Sackett said.

"In my view, nuclear power is the only realistic sustainable energy source, going forward. If we are really going to have an impact on our environment beneficially, with CO_2 initiatives, for example, we need to look at much greater use of nuclear power. . . . It is truly inevitable, in my view.

"Our challenge, and what we have to challenge the younger generation to do and make known to them, is that we have to do better with this technology. And there are great opportunities out there to do so."

Sackett closed by saying, "While we have significant challenges ahead, I think we are as

an industry developing a vision for the long-term future, for developing a description for the near-term things that need to be done. There is increasing cooperation within the technical community to help draw people in a coherent way and deal with these adverse issues that have plagued us for the last 10 years or so.

"So, I'm optimistic. I'm also feeling a sense of urgency about doing this because, unless we can move through this period successfully, I think we're going to see another long hiatus before we really get back to significant nuclear power development beyond the systems that we currently have."

PI programs

A panel discussion on *Innovative Public Information Programs* featured overviews of several efforts to improve education of the public about nuclear energy and enhance communications. "Often, I've found, our idea in the industry of what the public thinks is not, in fact, what we find out when we conduct a really well-constructed survey," remarked session chair Barbara Newsom in her opening comments. "So, as scientists, and social scientists as well, I think we have a lot to learn in this area."

Included in the discussion were a preview of a new Web site, an overview of a utility's energy information center, and a review of the ANS teacher workshop program.

Emmy Roos, chair of the ANS Public Information Committee, provided a sneak preview of an upcoming Web site that provides information about nuclear sciences to the general public. The Web site, which is scheduled to go on line this month, will have a separate address from the ANS Web site, but will be linked to it. (The Web address was unavailable.)

As it stood in mid-June, the site was about 85 percent finished, Roos said. Tentatively titled "Nuclear Science and Technology and How it Influences Your Life," the site is divided into five sections: food, industry, medicine, space, and electricity. And, in the food irradiation section, for instance, there will be subsections on process, types of food that are being irradiated, benefits/effects, safety, worldwide application, and U.S. status.


Roos

Roos said the plans to separate the site from the ANS Web site were in place because the ANS Web site is geared more toward members and less toward the general public. "We wanted to have something that, when they go to the Web site, they wouldn't have scroll through to find where the public information is," Roos explained. She also mentioned that work will be done to have the site pop up at the top of Internet search engine lists, in order to increase its accessibility.

The information on the Web site is to be reviewed for technical accuracy in the coming months by members of several ANS professional divisions. Roos said some problems are anticipated in determining the correct level of detail in which to present the information.

"What the [Public Information] committee has been trying to do is start with all the technical information available—with way too many details—and bring it down to a level that's comfortable to read but is still technically accurate," Roos said. "That's the thing we're very much struggling with, to come to a compromise. . . . We don't want to overload [readers] with all the technical details, or they won't get the point."

There will, however, be links throughout to sites providing more complete and technical information, Roos said. "The point of this is to give information to people in a very short and precise way."

Lauretta Kerchma-Olson provided an overview of public information programs at the Point Beach Energy Center, one of the country's newest public information facilities sponsored by a nuclear utility, Wisconsin Electric.

The nuclear energy public information program at the Point Beach nuclear power plant has existed since 1969, but has only recently moved into a new building. Kerchma-Olson, supervisor of the center, said that approximately 28 000 people tour the center each year, and nearly 800 000 people have visited over the last 32 years.

While the center has information on other energy sources, at least half of the space is dedicated to nuclear science. Exhibits include a model of the containment structure, as well as other hands-on and multimedia displays.

The following programs are among those sponsored by the center:

- The Super Science Bowl, an annual event in which 14 teams from local high schools compete by answering energy- and science-based questions.
- Atomic merit badge program for boy scouts, which brings approximately 100 scouts to the center each year.
- Various free, non-energy-related family events, such as a model train show and a farm toy show, which help bring people to the facility who would not otherwise come.
- Energy educator workshops, which are scheduled during outages at Point Beach so that teachers can be taken into the containment.

Kerchma-Olson is particularly enthusiastic about the plant tours that are offered for the general public. "I can't say enough about this. . . . We opened up the opportunity for people to come and tour the plant about six years ago because we wanted people to see where we stored our used fuel." Even though the tours are not overly booked, she feels the opportunity for the public to tour the plant on the second and fourth Wednesdays of each month "has been a wonderful opportunity for us."

ANS communications administrator Chuck Vincent reviewed the society efforts to educate science teachers about nuclear energy.

ANS conducts educator workshops of two different lengths, a 75–90 minute session, which is aimed at national science teachers' meetings, and a day-long session. Teachers walk away from the sessions with a handbook that includes a variety of information on nuclear science, examples of classroom activities, overhead projection masters, and a list of equipment suppliers and relevant Web sites. Various brochures, bookmarks, and stickers are also provided.

The linchpin of the program, however, has been the Geiger counters that are given to teachers who attend the workshops. "Teachers are always eager for any new equipment they can use in their classroom," Vincent said. "Many schools have limited budgets and buying a Geiger counter is not on the top of their list. But getting one of these analog instruments is a strong motivator [to attend the workshops]."

A thorium source sealed in a plastic bag is given to the teachers along with the devices, which were rescued from several states that were preparing to dump them because they could no longer store or maintain them.

"We conducted a workshop on the first morning of the science teachers' convention that was held in Tulsa about a year and a half ago. We began the session before the meeting itself even began," Vincent explained. "We said, 'How are we going to recruit people to come and attend our workshops?' So we simply mailed out several hundred invitations on a postcard telling them when the session would be held and that they would get a free Geiger counter. And at 8:00 in the morning, 50 teachers showed up, before the sessions even began at the convention.

"And then in Reno, a little later that fall, we had a room set up for 95 people. That was our limit. They filled the room and sat on the floor. Our final count was 180 teachers.

"So, my point here is to let you know that this yellow box is a strong motivator for teachers."

Vincent said about 40 workshops were conducted last year, which more than 1000 teachers attended. The workshops present a tremendous opportunity to reach students, as the average middle or high school teacher has anywhere from 60 to 125 students. "As a former teacher, I know that it tends toward the higher end," Vincent said. "Let's assume that each one affects 100 students. Well, that would mean in one year 100 000 students have the potential to be impacted. That's one year. And if those teachers are going to be in the profession, say, two, three, four, five, six, seven, eight, 10 years? Think of the impact that has over the long term.

"We need to keep feeding those teachers new ideas to keep their enthusiasm up . . . . But it's an ongoing impact that lasts for years. So, if you say, 'We trained 1000 teachers. One hundred thousand students were impacted in one year.' Multiply that by 10 years. The potential is enormous."

Currently, 36 ANS teacher workshops have taken place or are scheduled to take place this year. And the workshop schedule typically builds at the end of the summer, as people begin planning their fall activities. "We anticipate conducting well over 40 workshops in the year ahead," Vincent said.

He then explained a tactic a local section in Ohio uses to improve attendance at the ANS teacher workshops. Rather than simply announce they're going to hold a workshop, they approach the leaders of each school district to sell them the idea. "They use the angle that the content of these workshops is not covered in the curriculum of any school system," Vincent said. "And then by presenting that information to the curriculum specialist or for the superintendent, they get their blessing, their endorsement, their agreement to support that kind of a workshop in their school system. The result being, instead of getting one or two or three teachers who already have an interest in nuclear and will come to a workshop, they get large numbers of teachers from school systems."

Near the end of the session, an audience member offered a comment to Vincent that underlined the importance of the teacher workshops. "What you've said about the influence that the schools have, I can really appreciate that. In my case, one day in seventh grade there happened to be a seminar after school. And who in the seventh grade wants to stay after school? But for some reason I went to that seminar—it was on nuclear energy, nuclear power—and it grabbed me. And somehow I'm still here."—*Dick Kovan, Rick Michal, and Patrick Sinco*

TOPICAL MEETING

The Department of Energy's safety culture

A REVIEW OF INTEGRATED safety management was presented at the opening plenary of the *Eleventh Annual EFCOG/SAWG Workshop.* This was the first time the Department of Energy's Facility Contractors Group/Safety Analysis Working Group conference was held in conjunction with an ANS annual meeting—this time as an embedded topical meeting.

The EFCOG/SAWG workshop, an annual get-together of DOE personnel, contractors, and stakeholders, emphasizes safe operation and utilization of existing DOE facilities, new programs within the DOE complex, R&D operations, consolidation of strategic infrastructure, and dispositioning of older facilities.

The opening plenary, *Promoting and Assessing an Improved Safety Culture for DOE Facilities,* touched upon what likely was one of the most misunderstood phrases in the DOE lexicon—"changing culture"—if only because it meant different things to different people, according to Michael Hitchler, the workshop's general chair and principal of Westinghouse Safety Management Solutions LLC, a subsidiary of Westinghouse Savannah River Company, which manages the Savannah River Site in South Carolina. "Unless you were working with petri dishes, no one really could define what [changing culture] meant," Hitchler said.

In the past few years, however, safety culture has evolved within the DOE through two philosophies that have helped define it. The first is a set of core values established to map out where the DOE complex should be headed. "Our first philosophy is that we will not start up anything until we have demonstrated to ourselves and are satisfied that it's truly safe to do an operation," Hitchler said. This differs from the past, when the prevailing attitude toward performing a task was "it's safe because we've done it for 40 years and nothing major has happened," he added.

While the new core values are meant to change the way an organization thinks, they aren't effective unless DOE people believe in them. This has led to the second philosophy, which is the introduction of "missionaries" who go out into the DOE world to promote safe operations. In the end, Hitchler concluded, "the key purpose of this conference is that we work together [to] develop concepts and ideas . . . and that we as missionaries go back . . . and develop those [concepts and ideas] in our own organizations."

Discussing implementation of new philosophies was Richard Black, a main driver in developing the Nuclear Safety Management Rule (10 CFR 830). Black is director of the DOE's Office of Nuclear Safety Policy and Standards.

The safety rule, 10 CFR 830, was defined by Black as a regulation that explains *how* to achieve safety in the DOE nuclear arena. It is complemented by what is known as Integrated Safety Management (ISM), developed by the DOE about four years ago to explain *what to do* to achieve safety.

ISM is not a safety assessment, but is "an intuitive thing," according to Black, and it means only to stop, think, and plan before approaching a job. "You define the scope of work you're going to do, you analyze the hazards, you identify your requirements for control, you perform work safely, and you have feedback and an improvement. It's very, very intuitive," he said.

What ISM does is get creative juices flowing, Black continued. "ISM is a good way of looking at things from a different perspective," he said.

But it does have its shortcomings, Black admitted, such as it must be transcended from paper to practice, and it does not provide tools to analyze hazards methodically and systematically.

Providing a field perspective on ISM was Beverly Cook, manager of the DOE's Idaho Operations Office. "What ISM has done is allow us to turn [group decisions on risk] back to people who know what to do," she said. "We don't have to *instill* a safety culture, we have to *allow* a safety culture."

Cook noted that ISM came to Idaho at a good time, following the death of a worker there in the late 1990s. Although the workforce at Idaho numbers 7000, it is close knit, and the worker's death was seen as a loss of a family member. "So putting in ISM, which defines how you do work and how you help each other and how you protect each other, was very, very important to that workforce," she said.

The workforce at Idaho is independent, responsible, and driven, Cook explained. "They are extremely interested in getting things

Major points from the session:

- *"Changing culture" means different things to different people.*
- *Safety culture has evolved within the DOE through two philosophies.*
- *Integrated Safety Management has driven improvements at numerous DOE sites.*

done. But you can destroy that attitude if you take away from a workforce the ability to make decisions on how work gets done," she said.

Once ISM was implemented at Idaho—an 890-square-mile site—workers found they could travel around the site and find work procedures the same for each task to be performed.

What ISM means to Cook is that every single worker believes that he or she has a right to do a job safely. "I believe this is the case" at Idaho, she said. "I have been in more than one meeting where someone has stopped" the meeting to fix a faulty piece of equipment, whether it's a chair with a loose part, a smoking speaker system, or some frayed wiring.

The bottom line at Idaho, according to Cook, is that if something is wrong, the worker has the responsibility to fix it, not wait for approval or a work order to get it done. "I really believe that this attitude can change the safety culture, and that personal responsibility can spread throughout the whole workforce," she said. She related a conversation she had with a contract worker at Idaho. What the worker said, according to Cook, was: "We can't afford *not* to do ISM. Doing it right the first time is cheaper than having to do it over and over again until it is done right."

Gail Marcus, new ANS President and principal deputy director of the DOE's Office of Nuclear Science, Energy and Technology (NE), explained that ISM is implemented at all NE-managed facilities, which include the Fast Flux Test Facility at Hanford; the Annular Core Research Reactor and the Hot Cell Facility at Sandia; the Brookhaven Medical Research Reactor; the RTG Assembly Facility at the Mound Site; Oak Ridge's High Flux Isotope Reactor and Radiochemical Engineering Development Center; Idaho's Advanced Test Reactor; and Argonne–West's Experimental Breeder Reactor-II, Fuel Conditioning Facility, Fuels Examination Facility, Transient Reactor Test Facility, Zero Power Physics Reactor, and Fuel Manufacturing Facility. "We get together all the managers [from these facilities] to share experiences, to give each other technical and safety feedback, lessons learned, and accomplishments," she said. "This seems to be the broad link to the ISM process."


Marcus

A philosophy similar to ISM also is practiced by the Nuclear Regulatory Commission for its regulatory activities, by the International Atomic Energy Agency, World Association of Nuclear Operators, and by nuclear operators in Japan, Marcus noted.

At Argonne National Laboratory, ISM is "a way of codifying common sense," said Adam Cohen, director of ESH/QA (environment, safety, health/quality assurance) Oversight at Argonne. Workers at Argonne have a specific "Stop Work Authority," where they have not only the authority, but the responsibility to stop a project if they determine safety has been compromised. "Employee empowerment and communicating this authority is the most important aspect of ISM implementation," said Cohen.


Cohen

The ISM program at Argonne provides a structured approach to hazard assessment. There is a formal checklist to ensure that all hazards have been addressed; a pre-job briefing to answer questions; procedural compliance for protection; a post-job briefing to improve the process; and discussion of lessons learned to improve from others' experiences.

Jeffrey Allison, assistant manager for health, safety, and technical support at the Savannah River Site, called ISM "an evolutionary process" and "a journey" at SRS. The site, since 1989, has been run by Westinghouse, the first management change at SRS since 1950, so the transition was "in and of itself a culture change," Allison said.

ISM was implemented at SRS in the late 1990s. "One of the things we've found that's really important is senior management's commitment to safety programs throughout the site," Allison noted. Senior boards were put in place. On the Westinghouse side, an ISM executive steering committee is made up of senior line and environmental safety and health management, and chaired by the company's executive vice president. So important is it to the company that Westinghouse's chief executive officer sits on the steering committee board. On the DOE side, an ISM board is made up of the site's executive technical manager and other senior managers. It is chaired by a DOE deputy manager.


Allison

"These boards are there to look at ISM across the [SRS site], look at opportunities for lessons learned, take the work that's being done at the staff level and provide direction to those missions," Allison said. "It's helped to have senior management involvement in ISM, as well as participation at the work level, to break that middle-management layer that sometimes results in conflicting guidance. We now have a clear relationship and seamless transition between people who are doing the work and the senior management."—*Rick Michal*

TOPICAL MEETING

Overviews of safety goals and safety culture

The Embedded Topical Meeting on *Safety Goals and Safety Culture* was organized jointly by ANS and the Atomic Energy Society of Japan. The opening plenary session chairman Edward D. Fuller, of Associated Project Analysts (who was also meeting Technical Program Co-chair), explained the session's aim, which was to explore the relationship between safety goals and safety culture, and how to implement them in a complementary fashion.

Nuclear Regulatory Commission Chairman Richard Meserve noted that these two topics are sometimes treated as independent, but really are intimately connected, and influence each other. Safety goals refer to objectives established by a regulatory agency. They reflect the agency's regulatory philosophy and the approach it takes to the consideration of risk, he noted, especially the concept of acceptable risk. Safety culture also involves an element of regulatory philosophy, but can encompass a broader range of issues. While there are clearly aspects of safety goals and culture that do not bear on one another, he said, the way that safety goals influence regulatory activities can have an impact on the development and maintenance of the appropriate safety culture.

The NRC safety goals are described in the Safety Goal Policy Statement of August 1986. Its development began in the wake of the accident at Three Mile Island-2. At the time, probabilistic techniques were being developed, and, explained Meserve, this was a first attempt by the Commission "to come explicitly to grips with the integration of quantitative assessment of risk into the regulatory system."


Meserve

The primary issue for the NRC in developing safety goals was to use these techniques to help articulate a level of acceptable risk—in other words, "to define how safe is safe enough."

The Commission established goals to address both individual risks and societal risks, noted Meserve. In both cases, the Commission based its acceptable level of risk on a comparison to other types of risks in society from other causes, applying the rule that the consequences of nuclear plant operation should not result in significant additional risk to life and health. The goals, he said, were expressed in qualitative terms and were to be easily understood.

The Commission also expressed the qualitative goals in terms of individual and societal "quantitative health objectives," or QHOs—which were established at 1/1000 of the risk arising from other causes presenting the same types of risks. These, however, were never directly reflected in NRC regulations, Meserve said. They were promulgated to provide guidance to designers and operators as to the level of safety they should strive to achieve and to NRC staff to use in regulatory decision-making. But the Commission made clear that the safety goals were not meant to serve as the sole basis for licensing decisions.

In fact, he said, the practical implementation of the Commission's guidance proved to be difficult because of the wide uncertainties involved in the mathematical calculation of risks. Instead, the NRC developed "surrogate objectives" based on the frequency of core damage accidents and large releases of radioactivity, which were easier to calculate. The numerical value of 1 in 10 000 years for core damage frequency (CDF), in particular, was cited as "a very useful subsidiary benchmark." There is a downside, however, in that the surrogate quantitative goals tend to skew the focus of attention to severe reactor accidents.

Another issue is that while the societal risk is dominated by accidents that have low frequencies and high consequences, the perception of risk by the public is influenced by events of low consequences in terms of radioactive releases, but which have much higher frequencies. Meserve pointed to the reaction to the steam generator tube failure at the Indian Point-2 station in February 2000. This was widely reported to involve a release of activity to the environment, although the release was so slight that the monitoring equipment could not detect it. Nonetheless, said Meserve, "there was intense public reaction to the event, which continued for several months and only recently tended to subside."

Nevertheless, risk is now used as a tool helping the NRC focus on risk-significant activities, he noted, thereby enhancing safety and reducing needless regulatory burden. The NRC is clearly moving in the direction of more reliance on quantitative tools and goals.

Safety culture is a much broader and, perhaps, less clearly defined concept. Meserve pointed out that the elements of safety culture include management emphasis on safety as the highest priority; training of all staff at all levels to ensure that each employee understands his or her responsibilities for ensuring safe operation; conservative, safety-conscious decision-making; a philosophy of continuous improvement, including critical self-assessment and a questioning attitude; and, when a problem arises, willingness to address it promptly and effectively. Most important, perhaps, is the fostering of a safety-conscious work environment, one in which plant staff feel they can (and do) raise concerns without fear of adverse consequences, he added. All of these attributes work together to establish a climate that nurtures high safety performance.

The NRC's own safety culture can have an impact on a licensee safety culture, according to Meserve. Overregulation has the potential of robbing the licensee of a sense of ownership of safety performance of the plant, which can degrade licensee performance. Underregulation has its own obvious set of perils.

During questioning, Meserve spoke about the original hopes tied to safety goals. "The goals set in the 1986 policy statement were clearly aimed at trying to tell the public what we were aspiring to do," he said. But, he continued, what had started out as a goal to provide a philosophy to enable the public to understand what the regulator was about has turned into an analytical tool applied by experts. It seems that the public is not so much concerned with the overall accident performance, but of the reduction in the margins. Slight slipups get reported, he said, and the NRC soon thereafter receives congressional letters of concern. Expectations are higher. The adage "no good deed goes unpunished" is relevant here, noted Meserve. As performance improves, expectations grow. "There is a risk trade-off that the public does not appreciate," he said.

Shojiro Matsuura, chairman of Japan's Nuclear Safety Commission, and also General Co-chair of the meeting, said that his country is 15 years behind the NRC in setting formal safety goals. But a lot has changed since the JCO criticality accident in 1999, which greatly damaged the public's trust in nuclear activities.

Japan became interested in setting safety goals soon after the NRC did, said Matsuura, but without early results. Following the JCO accident, however, a nuclear safety white paper was published, he said, indicating that safety goals should be "the ultimate objective of safety assurance activities" and required the Commission to formulate a general "safety goal," which considered worldwide trends and takes account of PSA studies in the international community. The NSC also examined the importance of the "image" of the safety goal to public attitudes, Matsuura noted, and added that NSC believes that the safety goal will contribute to developing a comprehensive nuclear regulatory system and encourage discussions on safety based on the concept of risk.

In September 2000, NSC decided to establish a Special Safety Goal Committee, which started up in January with Prof. Shunsuke Kondo, of the University of Tokyo, its first chairman. According to Matsuura, the 21 members nominated cover a wide range of activities, including specialists (in reactor engineering, environmental engineering, biology, human science, and jurisprudence), as well as the news media, consumers groups, labor unions, etc. This was done because the safety goal must be widely accepted by Japanese society.

The implementation of the safety goal will be quite comprehensive, he observed, requiring changes in the regulations and guidelines and the use of additional measures, including PSAs, particularly in developing new designs.

Continued

Major points from the session:

- *Safety goals and safety culture influence each other.*
- *Japan is 15 years behind the U.S. NRC in setting safety goals.*
- *Even the best operated plants can learn from a peer review.*
- *Russian licensing procedures began just in 1993.*
- *An ongoing plant risk profile contributes to safety culture.*

Matsuura focused on two particular issues that he considered the most important for establishing the safety goal. The first is the social acceptance of the concept of risk. This includes risk perception, which is an issue of public knowledge and understanding, and risk acceptance, which is an issue of public confidence. The second issue concerns safety assurance and safety culture.

Safety culture is dependent on the cultural background of society and is based on history, environment, customs, etc. Human organization in Japan developed what Matsuura called a "shame culture," over-conformity to the group, and a homogeneous, paternalistic, and exclusive community. He pointed to the landscape of Japan, which he said was created by more than 2000 years of rice paddy farming, as being the result of this organization. Characteristics such as selfless devotion and solidarity can have a positive effect on safety, but there are also negative effects, such as systematic violation of rules and concealing of problems. Stark examples include the Monju fast reactor fire of 1995, which was not a major accident, but the ethos of the culture at the plant led to the concealing of information, while the JCO criticality accident, which killed two workers, demonstrated a systematic violation of rules. The national culture has an important influence on safety culture, said Matsuura: "We have to create a good combination of positive aspects of the Japanese ethos, then we can have a strong safety culture."

When the World Association of Nuclear Operators (WANO) was formed in 1989, many operators had no contact with plants in other regions of the world, and often little meaningful exchange with plants in their own region. While focusing particularly on helping operators in Eastern Europe gain from the experience of the West, few would have predicted the extensive level of sharing that takes place today among nuclear utilities throughout the world. Ryosuke Tsutsumi, director of the Tokyo Center of WANO, described two particular programs of the organization that help in maintaining and improving safety and safety culture: Operating Experience and Peer Review.

The Operating Experience program alerts members to events that have occurred at other plants, enabling them to take appropriate actions to prevent event recurrence. By the end of 2000, more than 1500 event reports were posted on the WANO Web site. The program has identified human performance as a key issue, and WANO has developed a training course on Improving Human Performance that has been conducted at many utilities. "The human can dismantle all or many of the defenses or barriers leading to incidents," said Tsutsumi. "Therefore, this is one of the steps, which help improve the safety culture in plants."

He noted that experience has shown that even the best operated plants can learn from a Peer Review, which has the added benefit of passing on experience to the team members themselves to take back to their own companies. With some 100 Peer Reviews completed, the two management issues identified as needing action were that managers do not spend sufficient time in their plants, and when they are there, do not correct improper practices; and that management expectations are not clearly established, communicated, understood, or reinforced.

A general lesson learned, Tsutsumi noted, is that safety culture is very vulnerable. No matter how hard plant people work, he said, once they think their plant is safe, in that instant, the safety of the plant starts decaying. "Let me remind you that safety culture is a daily thing, and can never be completed," he observed.

A contribution from Russia was presented by Alexander Gutsalov, the State Secretary, First Deputy Chairman of Gosatomnadzor (GAN), the country's nuclear safety regulator. Since coming into existence following the disintegration of the Soviet Union, GAN has had to develop and improve regulatory and legal documentation for nuclear activities, establish licensing and inspection procedures, and create an oversight capability. Licensing procedures began just in 1993, he said, and will take many years to implement at all sites. GAN works to international standards, following safety concepts such as the separation of responsibility, openness, and transparency. A strong safety culture is also an important element.

Various policy statements have been issued dealing with regulation, licensing, safety goals, and other issues, Gutsalov added. The last policy statement stated that the regulatory requirements for the use of PSAs should be established. He noted that the U.S. Nuclear Regulatory Commission is assisting.

The final talk was given by Harold Ray, executive vice president, generation, at Southern California Edison Co. To approach the topic, he posed the following question: Is it possible to have a successful safety culture without providing visibility to the achievement of safety goals?

With a sufficient number of prescriptive and deterministic requirements, he noted, safety can be maintained in most instances, as it has been over the last 25 years. Few people, however, had any idea how much such requirements actually contributed to safety, "and even fewer cared," he mused. The results were periodic, and sometimes spectacular, lapses. This also meant a significant waste of resources, he observed.

Ray

Ray expressed his belief that this approach also results in a mindless (or even cynical) "compliance with requirements" culture. This is not to say compliance is not important. The management of SCE's San Onofre Nuclear Generating Station strives to make clear its high nuclear safety expectations, which include compliance as a top priority. One reason for that, he said, is that the public cannot be expected to understand that some amount of noncompliance may be okay because it is not safety significant.

But the question posed is what value the visibility of the achievement of safety goals has in the safety culture being promoted, Ray noted.

Quantitative nuclear safety goals are important in this respect, he said. Core damage frequency is used most often, although other measures are applied as well. At San Onofre, the use of quantitative safety goals in the day-to-day operation of the plant is pervasive. According to Ray, since 1994 when this approach started, the goals have changed as more and more features are included in the monitoring of safety performance. In 1997, only internal event initiators were included. In 1998, shutdown and transition-to-shutdown modes were added, and since 1999, external events, including seismic and fire, have been included. "These quantitative goals represented an assessment of how well we were doing in operating the plant from a safety perspective," he said.

Keeping track of "how well we are doing" in meeting safety goals and carrying out other assessment procedures (such as IPEs) led to changes in plant design, configuration, and work processes that have been beneficial to safety. None, Ray said, were driven by regulatory requirements.

It has also been possible to reduce unnecessary requirements, Ray continued, when it could be shown that they are very small contributors to safety. The plant has also increased allowed outage time for some maintenance activities where it made sense. He noted that with more reasonable outage times, applied on the basis of safety significance, a much healthier attitude toward safety develops among the workers, resulting in the identification and resolution of more potential problems.

San Onofre has been using a safety monitoring tool since 1994, said Ray. It provides a risk profile over any interval of time for different plant configurations and has a lot of triggering mechanisms to indicate high risks. It is a very informative tool and helps make the safety goal achievements visible, he noted, contributing strongly to safety culture as a result.

Ray showed an actual risk profile taken during a refueling outage that was followed by a forced outage at Unit 3 due to a breaker failure and fire, resulting in considerable damage and a long outage. There was a loss of offsite power during the fire, which is the highest risk of all. As the levels of risk drive the company's worker reward system, it had an impact on their earnings. Workers do not need any other measure to be aware of the implications of safety, and this has become very much an embedded part of the culture as a result.

Ray said that overall, there has been an 85 percent reduction in the calculated core damage frequency at San Onofre over the years, which have come about as a result of measures the plant was motivated to take by looking at the risk profile. None of them, he pointed out, resulted from any regulatory requirements imposed on the plant.—*Dick Kovan* NN