A new era for nuclear

NUCLEAR REPRESENTS THE ultimate holy grail, declared Neal Blue during the opening plenary of the American Nuclear Society Annual Meeting, held June 4–8 in San Diego, Calif. Unlike the search for the grail of legend, however, the nuclear industry's quest for a viable future should be fulfilled.

Blue, the meeting's honorary chair, was the first speaker of the plenary, titled *Nuclear Science and Technology: Beginning a New Era.* Noting the industry's future will be linked to a time of unequaled safety and economics for the next generations of nuclear power plants, he said, "I think the topic of this session is entirely appropriate."

Blue

Blue is president of General Atomics, a company involved in fusion research, fission reactors, remediation, and uranium mining. While other companies were heading for the nuclear-power exits some years ago, General Atomics made "a conscious decision to become involved in this industry," he said, because of the environmental and financial benefits that could result from it.

The benefits will be realized once the industry introduces a power plant "that is as safe as any other power generation technology, like coal, and as economically attractive as scrubbed coal plants," he added. If those two criteria can be fulfilled, the results will be an environmentally preferable technology [nuclear fission] and a viable commercial future. With that future in mind, he said, "I think there is room for some measure of real excitement."

Blue tempered his optimism by recognizing a hurdle in nuclear's path: Regulatory involvement. "Regulatory lag [in approving construction of a new nuclear plant] causes a delay of something resembling 15 years in this country," he said. "Regulatory delay alone is enough to devastate, from an economic point of view, the deployment of a new power plant that is based on fission technology."

Which is why, he stressed, there is the need to develop a reactor "that is so safe that it can't melt down and therefore does not involve evacuation-of-plant requirements, and that is so economically interesting that it can be an alternative to a coal plant." A nuclear plant meeting these requirements would not have to jump over years of regulatory hurdles, he concluded, and would receive approval in less than 15 years.

Andy Kadak, ANS immediate past president and vice president previous to that, followed Blue on stage to recap his term. ANS accomplishments in the past two years, in the vein of ushering in a new era for nuclear, included electing student members to the ANS board of directors, opening an office in Washington, D.C., to serve as an advocate for nuclear science and technology, and restructuring ANS meetings to make attendance "a professional necessity and a valuable educational experience," Kadak said.

Major themes of the meeting:

- *The NRC expects to receive more than 20 applications for plant license extension in the next 3–5 years.*
- *A coalition of organizations has been formed to give irradiation technology a higher profile vis à vis government and consumers.*
- *Nuclear power could sustain life on Mars and nuclear propulsion provides the means to get us there.*

Kadak

These improvements and others, termed the "infrastructure change process" that started under past presidents, "have made ANS an organization that is capable of responding to the issues of the day," Kadak said. His own agenda as president included making ANS an active contributor to public policy in debates affecting the nuclear industry, putting nuclear energy back on the "building" track, globalizing ANS to work with sister societies in other countries on research and applications, and opening a dialogue with "those who should be our natural allies," the environmentalists. Not all of his goals were realized, Kadak admitted, but a good start was made on many, and he hoped that his successors will continue them on to completion.

His "crown jewel" as president, Kadak said, was ANS's advocacy for such programs as the Nuclear Energy Research Initiative and Nuclear Energy Plant Optimization, funded by the Department of Energy. "People are actually thinking about a future for nuclear energy," he concluded.

Rep. Ron Packard (R., Calif.), following Kadak, called himself "a seedling among a forest of giant redwoods" regarding his knowledge of nuclear technology. His first exposure to nuclear issues was 18 years ago, upon his initial election to Congress, when he served on a science committee. Nuclear, he recalled, was designed as and was supposed to be a competitive source of power. But the antinuclear atmosphere that then existed, and still exists, led to an overload of requirements that have accelerated the cost of building a new nuclear plant in the United States to "almost beyond the ability to compete."

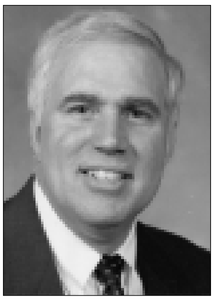
Packard

That is why, Packard announced, he was pleased to be part of the opening plenary when there was mention, as Blue and Kadak had, of the possibility of building a new plant. "I would be so elated if we could build one new nuclear plant in this country, because I believe it would then start a new trend that could proliferate where nuclear could become what it ought to be, one of our major sources of power," he said.

Packard then turned his attention to U.S. regulators. He saluted the Nuclear Regulatory Commission as "one of the few regulatory agencies of the federal government that has the correct perspective on what its role and job ought to be." But he had ire for other federal agencies, specifically the Occupational Safety and Health Administration (OSHA) and Environmental Protection Agency (EPA). These renegade agencies, Packard claimed, "find ways to entrap and destroy and imprison and ruin." The inference was that anyone applying to build a new nuclear power plant would find OSHA and EPA waiting to pounce from behind the NRC. The role of a regulator is not to destroy a business or industry, Packard advised, but to ask, "What can we do to help you to comply?"

Packard concluded by calling nuclear power a bipartisan political issue in the House, but that the new U.S. president's position on the technology will be "crucial to where we go with our nuclear efforts. I would hope that whoever is elected president will emphasize that as a priority. If he does, then it doesn't matter if he's a Democratic or Republican president." If the technology is backed by the White House, said Packard, who is retiring from Congress after this term, "we're going to see the nuclear process move forward. And if we don't, it's going to languish."

NRC chairman Richard Meserve called the theme of the meeting—*Beginning a New Era*—particularly timely for his agency. "As we move into the 21st century, the agency is facing many changes and challenges," he said. Among them are restructuring of the electric utility industry, revamping of the NRC's regulatory processes, and license renewal of nuclear power plants.



Meserve

Regarding license renewal, Meserve announced that the NRC expects to receive more than 20 applications for life extension of U.S. nuclear plants within the next three to five years. "We understand," he continued, "that up to 85 percent of our current operating plants may ultimately seek to renew their licenses." Other countries, he added, are watching license renewal in the United States as those countries begin dealing with their own aging plants.

Meserve noted also the NRC's "common enterprise with other nations." Among them are frequent interactions of regulators on policy matters, leveraging of research money for joint international activities, and foreign ownership of plants.

However, Meserve cautioned, the nations of the world are linked in an even more fundamental way, and that is the safe operation of nuclear plants worldwide. "A nuclear accident can have consequences that transcend national borders and will assuredly affect public attitudes everywhere," he said.

Meserve placed the goal of safety on the shoulders of the entire industry—utilities, vendors, researchers, regulators, and policy makers. Assurances must be guaranteed by the industry that necessary resources and technical capabilities will exist to achieve the safety goal, he explained.

In the United States, Meserve said, the trend has been consolidation of ownership, and the NRC expects this trend to continue, resulting in "a few large nuclear operators, which may be either single companies, partnerships, or operating consortia." The NRC, however, views these developments with cautious optimism. The companies that are acquiring plants "are generally good performers," he added, but there must be assurances that the purchasers devote adequate resources to fixing plant problems.

With the changes in ownership of some plants, a new era for nuclear regulation exists, Meserve continued. Four strategic objectives for the NRC have been established in the past few years: Maintain safety, increase effectiveness and efficiency, reduce unnecessary regulatory burden, and increase public confidence. The last objective may be the most challenging, Meserve concluded. "It is essential that our regulatory actions both be fair and be perceived as fair," he said.

Offering an international perspective was Abel Gonzalez, director of radiation and waste safety at the International Atomic Energy Agency. Gonzalez announced that there is a general recognition around the world that the huge increase in energy production anticipated for the 21st century could lead to damaging health and environmental impacts. "This is bringing about some political awareness of nuclear power's potential role in the sustainable management of energy as it delivers large quantities of energy without releasing common atmospheric pollutants and greenhouse gases," he said.

Today, non-greenhouse energy sources are a significant factor in avoiding carbon dioxide emissions. Countries with large nuclear and hydroelectric capacity have markedly lower CO_2 emissions per unit of energy than countries with high fossil fuel shares. "With nuclear power," Gonzalez said, "France has over the past 30 years lowered electricity sector emissions by more than 80 percent."

Yet public concerns continue to be roadblocks to nuclear's advance. Three major concerns exist, according to Gonzalez: nuclear safety, nuclear proliferation, and fear of radiation and radioactive residues and wastes.

Regarding the first, the public has the belief that a nuclear power plant constitutes a kind of bomb. "This concern must be dealt with by distinguishing the future from the past," Gonzalez said. "Certainly it is useful to point out that the human and environmental damage done even by the Chernobyl accident pales against the continuing onslaught against man and nature caused by the extraction and burning of fossil fuel."

Regarding the second, that nuclear power plants breed proliferation, the claim has little foundation in the current direction of international affairs, Gonzalez assured.

For the third, fear of radiation, Gonzalez called it "the most intractable public concern about nuclear energy." People are not concerned with the "relatively high radiation doses delivered by nature," he said, but "they are hysterical with the minute doses from nuclear power."

The real or perceived problems, Gonzalez continued, of regulating radioactive residues that deliver relatively low radiation doses have exacerbated an academic controversy about the linearity between radiation doses and biological response—the so-called linear no-threshold hypothesis. "An undesired outcome of the controversy between radiobiologists, regulators, and others has been a general loss of public confidence," he said.

Gonzalez concluded by recalling from Greek mythology the tale of the Gordian knot. According to the myth, anyone who could untie the knot would rule all of Asia. Alexander the Great, the legend goes, simply cut the knot with his sword and proceeded to the glory that had been foretold. "If we are to take control of our destiny and guide ourselves rationally in meeting the urgent imperative of producing more and cleaner energy, we will not do so by slicing through the current impasse," he said. "We must untie the Gordian knot, carefully and painstakingly, using all of our resources and democratic institutions wisely and well."

David Baldwin, senior vice president of General Atomics, wrapped up the session by talking about the recent progress made in fusion research. The good news, Baldwin said, is the degree to which the fusion community,

Baldwin

as it looks to a new era, is becoming involved in determining its own future. By setting priorities and objectives, the community "no longer has the tendency to circle the wagons, which has been the characteristic of the fusion program over the years," Baldwin said.

The program on magnetic fusion, which relies on charged plasma particles tied to magnetic lines that are wrapped in a torus—a doughnut-shaped component—has made substantial progress in the past decade in research and development, but large issues remain that have not been addressed, Baldwin said. These include how this fusion can interact with the external world—that is, issues of activation and production.

Fusion research has gone through three identifiable stages, according to Baldwin. The first occurred in the 1970s with the emergence of tokamaks, when there was optimism that a demonstration project would exist by the year 2000 at a cost of about $1 billion per year. That was followed by the second stage, in the 1980s, when large tokamaks were introduced and ITER was started, but the demonstration project was pushed back to the year 2025 at an annual cost of about $800 million per year. The third stage, starting in the 1990s and continuing today, has led to advanced tokamaks and optimization, where fusion researchers no longer have a target date for a demonstration project but, Baldwin ended, "are working on the notion of a knowledge base so that if and when the nations of the world move to fusion power, we will have the scientific base to do so with a superior product."

Food irradiation

There is an old saying among produce farmers: "The garbage can is the best customer." That old saying, according to Brian Folkerts, may be a reason why not everyone has jumped on the food irradiation bandwagon. After all, he offered rhetorically, why would a farmer support something that keeps his fresh vegetables on the store shelves longer? Folkerts, vice president of government affairs for the National Food Processors Association (NFPA), was a panelist during the special session *Food irradiation: Is it finally here?*

The NFPA, the nation's largest scientific and technical trade association representing the food industry, promotes government policies that encourage food irradiation's use and availability. That encouragement is needed, Folkerts said, because the federal government has erected barriers that have delayed irradiation's use. Examples of these barriers include Congress's Food, Drug & Cosmetic Act, which defines "radiation" as a food additive, meaning that all new food irradiation uses must be approved as food additives; lengthy review times that discourage new-use petitions—red meat irradiation, for example, took more than five years for Food and Drug Administration/U.S. Department of Agriculture approval, which finally came in December 1999; and consumers' perception of the FDA-required labeling statement—"Treated with irradiation"—that is seen as a "warning," Folkerts said, discouraging consumer acceptance of irradiated foods. Further, a pending USDA rule would prohibit use of irradiation in production of foods labeled as organic.

Folkerts

There are, however, positive signs coming from the government, Folkerts indicated. Congress, he said, has recently directed the FDA to consider revising its labeling requirements, and the FDA itself has approved a food-holding package to be used during electron beam irradiation.

To promote food irradiation, a coalition of organizations has been formed to give the technology a stronger showing in the eyes of government and consumers, according to Folkerts. More than 30 organizations have joined the coalition, including the American Association of Meat Processors, American Bakers Association, American Meat Institute, Grocery Manufacturers of America, National Chicken Council, National Fisheries Council, National Meat Association, National Restaurant Association, and Snack Food Association.

The group, called the Food Irradiation Coalition, has pushed for irradiation of refrigerated ready-to-eat foods, with maximum dosage up to 4.5 kGy, and frozen or dried ready-to-eat foods, with maximum dosage up to 10.0 kGy. Foods promoted by the coalition for treatment include frankfurters, cooked sausages, luncheon meats, precooked beef patties, marinated chicken, frozen fried chicken, beef and turkey jerky, cut and packaged salads, orange juice, sprouts, broccoli, peas, strawberries, tomatoes, and bananas.

In arguing for use of the technology, the NFPA has reviewed literature concerning vitamin loss of certain irradiated foods (specifically for thiamin, vitamin C, carotene, and vitamin E) and found that "it is unlikely irradiation of ready-to-eat foods will have a significant impact on the diet of the elderly or the population in general," Folkerts noted. Further, he said, the NFPA has found that any radiolytic products formed during the irradiation of ready-to-eat foods would not pose any danger to human health.

Folkerts stressed that three steps must be taken by the federal government to move food irradiation forward: FDA and USDA need to accelerate new-use approvals; government health officials need to speak out about its benefits; and FDA and USDA need to prescribe an alternate label to "Treated with irradiation," possibly something along the lines of "Treated for contamination," he concluded.

The session's chairman, Raymond Durante, president of the Food Safeguards Council, offered his own version for food irradiation's slow acceptance—"organized resistance," which has been formed to stop the use and commercialization of the technology. Fighting back with education is the key to winning this battle, he urged, because projections for the coming decades show the world's population growth climbing into the unknown billions. "It is an obligation for us to find ways to feed the people on this planet and make sure that the food is of the highest quality," Durante said. "I believe this is the justification for all of us to help educate people and promote the use of food irradiation."

Durante

Donald Thayer, research leader for food safety at the Department of Agriculture, with the Agriculture Research Service in Pennsylvania, offered statistics showing the numbers of people getting sick and dying from contaminated food in the United States. Using estimates from the Center for Disease Control, Thayer revealed that 76 million illnesses, 325 000 hospitalizations, and 5200 deaths are associated with the *known* foodborne pathogens each year in the United States. There are also other kinds of *unknown* pathogens that contaminate food products, he indicated, but most laboratories aren't equipped to look for them.

Despite these alarming figures, Thayer said the good news is that the United States, even without widespread use of irradiation, has "the safest food supply in the world." The bad news, though, is that more than 1.8 million pounds of ground beef contaminated with *E. coli* O157:H7 and more than 36.5 million pounds of hot dogs and various luncheon meats contaminated with *Listeria monocytogenes* were recalled in 1998, the latest year for which Thayer had statistics. In addition, 97 percent of turkey carcasses were found to have been contaminated with at least one pathogen. There also were numerous types of contaminated raw vegetables: artichokes, beet leaves, cabbage, carrots, cauliflower, celery, cucumbers, eggplants, endive, fennel, onions, mustard cress, lettuce, mushrooms, parsley, pepper, potatoes, prepared salads, salad vegetables, spinach, sprouts, and tomatoes. Contaminated fruits and fruit products included cantaloupe, raspberries, strawberries, watermelon, apple cider, and orange juice.

All of these foods could be made safer for human consumption through greater use of irradiation, Thayer stated. Approval of the technology by government agencies goes back to 1963 for wheat flour and more recently for red meats and poultry. However, one of the things that Thayer's research group is concerned about, he said, "is that there are not many irradiators being built or even contemplated" to handle the amount of food that needs to be irradiated.

Joseph Shepherd, a manufacturer of machines for irradiating, followed Thayer's presentation. Shepherd's company, J. L. Shepherd & Associates, has provided irradiation systems and radiation detection instrument calibration systems since 1967. Although the company spent little time working on irradiation machines until recently because the market wasn't there, "I believe food irradiation's time has come," Shepherd said.

Shepherd speculated that widespread food irradiation won't necessarily come today or tomorrow, but somewhere in the near future. "I don't believe the opposition will be able to stop it," he said, "strictly based on the safety factors that are involved."

Shepherd's company currently has in the works three different types of systems that have applications for irradiation of food and various nonfood products. The systems come in three categories, each of which is compact enough to be housed inside a larger building: Category One, for dry storage goods and dry food products, for which human access to the irradiation area is prohibited; Category Two, a modular walk-in unit; and Category Three, like Category One but made for irradiating wet storage products.

Tom Mates, vice president of IBA/SteriGenics, talked about larger irradiation systems. IBA/SteriGenics, according to Mates, is the largest irradiator in the world, offering sterilization services to other businesses and their products. The company owns 37 facilities in 14 countries, including 16 facilities in the United States.

Mates was quite frank regarding his company's position on consumer acceptance of food irradiation when he stated, "I apologize [because] in the world of contract sterilization . . . we unfortunately tried to divorce ourselves from the American Nuclear Society." He added, though, that he is a board member of a local ANS chapter in California, so "on one hand [IBA/SteriGenics and ANS] embrace each other and on the other hand, because of consumer issues, we kind of stay away from the [American] Nuclear Society."

Unlike the smaller systems produced by Shepherd's company, the IBA/SteriGenics units are full-scale facilities "where, unlike the gamma facilities that [Shepherd] was describing, have multi-million curie levels of cobalt for the processing of virtually hundreds of millions of pounds of product per year," Mates said. IBA/SteriGenics's systems include accelerators that use electron beam energy, radioisotope units using cobalt-60, and X-ray facilities.

Fire at Los Alamos

Almost exactly a month before the meeting, a tragic fire occurred around Los Alamos, destroying nearly 50 000 acres of forest, the largest fire in the history of New Mexico (*NN,* July 2000, p. 71). Damage to structures at Los Alamos National Laboratory was significant. Hundreds of homes were destroyed. It will take years for the community and the laboratory to recover.

Considering the links that many ANS members have with Los Alamos, ANS arranged a special session on the fire and its impact with speakers from the lab. The presentation, which was the first opportunity for lab personnel to describe the event to the technical community, was led by Dennis Erikson, director of LANL's Environment, Safety and Health Division, who was on duty practically the whole time as one of the emergency directors.

The county of Los Alamos contains the laboratory, the town of Los Alamos, and the community of White Rock. To the south is the Bandelier National Monument, where the fire started. The laboratory sits on a mesa 2000–2500 feet above the Rio Grande river.

On May 4, the park service began a controlled burn on the Cerro Grande in Bandelier to thin out several hundred acres. The fire team lost control of the fire the next day. For the following four days, the fire sat in this area. Over the next day and a half, however, the fire spread rapidly, burning about 25 000 acres, including laboratory property.

As the fire spread, more than 18 000 residents of Los Alamos and White Rock had to be evacuated.

Eventually, some 48 000 acres, forming a band 10 miles long by 5–6 miles wide, burned. The fire stripped out the watershed that feeds the canyon leading to the lab and town site. This could have severe consequences to the town and laboratory when the rains come in late summer.

As the fire spread, more than 18 000 residents of Los Alamos and White Rock had to be evacuated. There were no lives lost and no serious injuries. About 240 home structures involving over 400 living units were affected. It took about a week to get people home.

About 9000 acres—30 percent—of the laboratory site burned. No damage occurred to the major hazardous materials facilities, including the plutonium, tritium, and high explosives processing and storage facilities; neither the radioactive waste storage area nor the liquid waste treatment facilities was damaged. There was no release of hazardous materials, nuclear, chemical, or other. The laboratory stood down for two weeks.

In answer to the question "Was the community ready?", Erikson said "yes."

After a fire in 1996, an Interagency Wildfire Management team was set up as all agencies involved realized there was a need to share responsibilities and decision-making as the nature of the threat changed. The local fire department is trained to a man to do wildfire fighting, which is usually left to specialist organizations.

Since 1996, there has also been a growing commitment to fire prevention, which was the purpose of the controlled burn. The lab and the municipality have also been tree thinning to knock back the density of the forest—every place where this was done was successfully protected. "We saved at least two major facilities by doing that," noted Erikson.

Last year, LANL reissued its Site-Wide Environmental Impact Statement, which was approved by the Secretary of Energy in late 1999. The EIS included a worst-case wildfire scenario. "We lived through parts of that scenario," said Erikson. Another coincidence was that earlier this winter Los Alamos county had put together an emergency evacuation plan and actually practiced it. Ironically, on April 26, the laboratory held a public meeting on wildfires at which the plan was walked through. "This certainly helped," he noted.

The public is naturally worried about materials released by the fire and spread with the smoke. Air quality measurements and assessments are being made with assistance from the state, the EPA, and various emergency arms of the DOE. As soon as possible, reported Craig Eberhart, the air quality group began to check the state of monitoring equipment and to take samples. These and other measurements made it possible to track the impact of the fire on air quality, and assess the possibility that laboratory-derived contaminants had become airborne. The measurements indicated that concentrations of alpha and beta radiation increased, but this would have been expected during any such wildfire, as radioactive materials left behind from the decay of naturally occurring radon accumulate on forest vegetation over the years. Scientists also looked at concentrations of uranium and other radio-elements. Measurements did not indicate that there were releases from lab facilities.

In general, the data available did not reveal any surprises, nor a suggestion that anyone would have been exposed to any significant additional health risk from laboratory contaminants as a result of the fire.

David Rogers, of the lab's water quality and hydrology group, described the damage to the watershed and what to expect in the future. Vast areas of the watershed leading to the site has been denuded of trees, shrubs, and other vegetation on the forest floor, which means that rain water will just run off. This can lead to serious flooding and increased erosion. And, as a large portion of rain falls during the late summer, there would not be much time to take action.

Previous fires have allowed scientists to predict what problems may arise. For example, in the first year, peak runoff flows of 160 times the rates experienced before the fire can be expected. This means that peak flow from a major (25-year) storm could be higher than the average flow of the Rio Grande there of 1500 ft^3/s. At that level, roads, utility lines, houses, and other structures are at risk.

A burned area emergency rehabilitation team assembled by the forest service looked at consequences and suggested mitigating measures. Seeding of ground cover will help reduce runoff in the short term and provide a long-term environmental benefit. On hill slopes, measures include contour raking (breaking up soil to be receptive to moisture and seeding), placement of logs as erosion barriers, and contour felling of trees to slow down water. Protecting water channels involves constructing check dams, improving catchment basins, and enlarging culverts. Measures to protect roads are also needed.

Because of the possibility of flooding, the lab has stopped operation at one facility located at the bottom of Los Alamos Canyon to ensure no one could be endangered. Actions are also being taken to protect facilities at canyon bottoms.

The laboratory's present assessment is that the radioactive contaminants in sediments will be very small and will not present a health risk. Nevertheless, it will take actions to prevent any significant contamination from leaving the laboratory property.

Erikson closed the session with a look at other challenges. Replacing lost homes and businesses will take many years and cost hundreds of millions of dollars, he estimated. The same is true of the laboratory.

The government and its agencies have accepted responsibility for the fire. How well the government fulfills this responsibility, which will require legislation to make available the resources needed to rebuild the towns and lab, will be "interesting," observed Erikson. He said there are many examples where the federal government has accepted responsibility but took many years to deliver. This will not be of much use to many of his colleagues and friends, he commented. Alternatively, there are, as expected, law firms lining up to initiate tort and class action suits against the federal government; however, these could take years, if not decades, to settle.

Last, but not least, Erikson spoke of the emotional impact of this disaster, which touched everyone, and will continue to affect many for a long time to come. There were some positive results to report, noted Erikson. Following the evacuation, outside police departments and the National Guard provided protection of the area. When residents returned, besides the devastation caused by the fire, they found no incidents of vandalism or even disturbance of property. Furthermore, help well beyond expectations was forthcoming. Besides the heroic efforts by county services, people came from all over New Mexico to help make the towns operable again. The help from outsiders has been a source of comfort to the Los Alamos people who had in the past felt isolated from the rest of the state. One resident was quoted by Erikson: "This week we became part of New Mexico. They took care of us."

Among the many examples of help being provided, ANS made a $15 000 corporate contribution to care for the needs of the people, and is also collecting donations from individuals.

Nuclear in space

A day-long series of sessions presenting an overview of space nuclear technologies (or, as the enthusiastic chair of the meeting, Robert Singleterry, amended, *aero*space nuclear technologies) drew numerous attendees. By the end of the day, enough signatures of ANS members were collected to begin the process of forming a technical working group. If that technical working group is made official during the American Nuclear Society's Winter Meeting in Washington, D.C., aerospace could be the next new division of ANS.

Six speakers made presentations in the morning, as part of the session "Overview of Space Nuclear Technology I: Concepts and Experience." After a lunch break, four speakers addressed the topic of human factors during part II of the meeting, and were followed by part III, a panel discussion including each of the day's speakers.

Singleterry spoke first, explaining that he thought aerospace was a more appropriate title because, while NASA puts just tens of people in space, millions of people fly in airplanes. The physical processes are the same in space and at aircraft altitudes, he said, and therefore cosmic radiation can be conveniently studied at aircraft altitudes to predict conditions on the Martian surface.

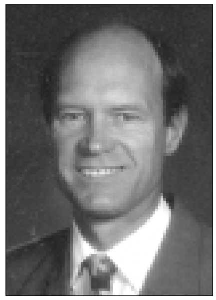

Singleterry

"How do nuclear technologies come in to play with aerospace?" he asked. Of course, nuclear power could sustain life on Mars and nuclear propulsion provides the means to get there, but that is not all, he observed. Nuclear technologies in the areas of materials, human factors, operations, and risk/cost mitigation are all important, he added. "Nuclear is the only credible power source in a nonoxygen atmosphere," Singleterry said. "Nuclear provides large and sustained thrust for propulsion. Solar power doesn't have the energy density."

Power to sustain life in space could be provided by a small reactor on the surface of Mars or the moon, he explained. Radioisotope thermoelectric generators (RTGs) could also help to support equipment. Propulsion could be provided by fission (nuclear thermal or nuclear electric) or fusion (controlled or uncontrolled). Other necessary support for the Mars mission could be provided by nuclear technology, including strong, light materials needed to build safe vehicles and provide shielding, biopharmaceuticals to repair DNA faster than it is damaged, and the know-how to design a small reactor that a nonspecialist could easily operate.

NASA creates the goals for space exploration, and Department of Energy laboratories and universities provide the relevant technology required. This cooperation could be improved, Singleterry said, if the groups could communicate in a forum such as ANS annual meetings. It is ANS, he said, that must be proactive to take advantage of the potential of aerospace.

Ron Lipinski, of Sandia National Laboratories, spoke on "The Role of Nuclear Reactors in Space Exploration and Development." Other forms of propulsion simply do not match up to what is possible with nuclear, he explained. He showed a photo of the main external tank from a space shuttle, approximately the size of a semitrailer truck, and said that the amount of energy in that tank is one-eighth of the energy contained in a kilogram of uranium-235. Solar power, he said, is useful near Earth, but near Mars the intensity of sunlight drops to 40 percent, and a large, cumbersome solar array would be necessary. "If you want to go [to Mars] without nuclear it's going to cost at least twice as much," Lipinski said. What's more, the astronaut corps is very much in favor of nuclear, according to Lipinski, because the increased speed of travel means less radiation exposure.


Lipinski

Another benefit of nuclear fission propulsion, Lipinski explained, is that the reactor is subcritical at launch, that is, it has very little radioactivity at launch. He described a direct thermal rocket concept—hydrogen is run through the core of the reactor, where it is heated to extreme temperatures and exits as a rocket plume. Another option he mentioned was nuclear electric propulsion, which could involve a high-power, low–specific-mass impulse space reactor coupled with an advanced electric thruster, or could also be a modest nuclear electric "tug" that moves a Mars transport vehicle into position in high earth orbit, where it waits for a rendezvous with the astronauts before moving on to Mars.

Both the United States and the former USSR have launched nuclear reactors into space, Lipinski reminded his audience: "We know how to do that. Let's not lose it." A revived space exploration program using nuclear technologies cannot move forward, he said, until a commitment to the technology comes from NASA and all the pros and cons of the system have been communicated to NASA. When that happens, Lipinski said during the panel session, "nuclear power, and fission power in particular, will deliver to humanity the entire solar system. It's that powerful."

David L. Black, a consultant in the Washington, D.C., area who has retired from Westinghouse Electric Company, reviewed the "History of the Development of NERVA Nuclear Rocket Engine Technology." He urged his audience to recognize that the intensive research done between 1955 and 1972 resulted in valuable knowledge about how to construct a safe and reliable nuclear rocket engine that should not be dismissed. He shared a quote by Bob Bussard from 1952 that says a lot for the determination of the researchers who still struggle today to have nuclear taken seriously: "'It seemed, from the immediate-post–WW II work, that nuclear rocketry had been effectively written off as a dead end by most of the missile and rocket people (who didn't really understand nuclear energy and liked chemical energy better anyway) and most of the reactor people (who thought the whole idea of nuclear flight of any sort was generally loony).'"

Black described in detail the testing of reactor concepts, specifically a fully enriched uranium–fueled, graphite-moderated, beryllium-reflected reactor, cooled with a monopropellent, hydrogen. Some "spectacular failures" were expected and occurred at the beginning, such as structural damage, severe corrosion, and broken fuel elements. These failures were tackled and led to some equally spectacular successes by the time the program was canceled for lack of a specific mission, according to Black.

From the total expenditure of $6–7 billion (in 1999 dollars) for the Rover/NERVA program, a lot of technical accomplishments were achieved, Black said, and the old data is easily retrievable. If the Rover/NERVA program was used as a starting point, Black believes that a full power test of an updated 1972 R-1/E-1 reactor could be made within six years. In fact, he asserted, "the Rover/NERVA technology path will provide the highest likelihood of success for a manned nuclear flight to Mars."

Robert Cataldo, of NASA's Glenn Research Center, spoke about the power requirements for human exploration missions, and explained that solar power would not be feasible because of occultation: during martian dust storms, dust would collect on the solar arrays, cutting the power output. NASA's blueprints for a mission to Mars includes a focus on using substances found on the surface of the planet to produce materials needed for the mission, such as the fuel used to power the space vehicle's ascent from Mars at the conclusion of the mission. Producing fuel (by, perhaps, extracting carbon dioxide from the atmosphere or extracting water from the subsurface) would take large amounts of power.

On the surface of Mars, the required power reactor will be located a short distance from the astronaut habitat and other vehicles, and be connected by cables. The 160-kWe reactor would have to be autonomously deployed, highly reliable, and low in cost. In Cataldo's opinion, however, any technical issues hindering the development of this technology are dwarfed by political and programmatic issues.

Terry Kammash, professor emeritus of nuclear engineering and radiological sciences at the University of Michigan, discussed two alternatives for fusion propulsion: a gas-dynamic mirror system (GDM), and a magnetically insulated inertial confinement system (MICF). "The technology is almost available and achievable if somebody's willing to spend some money and do something about it," he said.


Kammash

The GDM system uses the principle of magnetic confinement: the plasma would be confined long enough to produce fusion energy, and a portion of the plasma would escape through a magnetic nozzle, forming a rocket plume. The MICF system involves a pellet with a small hole through which a laser beam or particle beam would be directed. The inside of the pellet would be coated with fusion fuel, such as deuterium-tritium. The beam would ablate the surface inside the pellet, creating a hot plasma with a strong magnetic field. The MICF system combines the favorable aspects of inertial and magnetic fusion, Kammash said. The walls of the pellet and the strong magnetic shield provide containment and insulation, respectively. Kammash estimated that with the MICF system, a mission of 10 000 astronomical units (an astronomical unit is the distance between the Earth and Sun) could be completed in approximately 29 years, while the GDM system would take about 42 years. He conceded that fusion propulsion is a second-generation concept and would be used only after fission propulsion has been proven.

Stanley Borowski, a nuclear propulsion researcher at the Glenn Research Center, discussed "Human Exploration Mission Capabilities to the Moon, Mars, and Near Earth Asteroids Using 'Bimodal' NTR Propulsion." Borowski and his colleagues are looking at using clusters of relatively small engines to make concept testing easier. He is testing an engine with 15 000 pounds of thrust at the Idaho National Engineering and Environmental Laboratory, using a contained test facility outfitted to reduce possible exposures. Borowski stated that with these engines, a nuclear rocket could approach a specific impulse (Isp—a measure of the efficiency of a fuel) of 950 seconds.

At this time, Borowski explained, NASA's interest is in obtaining a lightweight, operational rocket quickly to demonstrate that a trip to Mars is feasible. Current engine concepts use high-temperature fuels for performance, but once the rocket concept is proven, "where you really want to operate is in lower temperatures . . . we want to be able to reuse our systems over again, because that's where the economics comes in." The engine Borowski is involved in optimizing is 4½ meters by 1.3 meters in diameter. "The beauty of these systems," Borowski says, "is that they're high thrust, low burn, rapid departure, and high Isp."

Borowski voiced his opinion on the proposed Mars mission, saying, "to think that you're going to go to Mars now after the last mission in which we left low earth orbit was in 1972 [Apollo 17], I think that's the height of arrogance." He maintained that the Moon must be used as a testbed for qualifying Mars-bound equipment. Although the Moon has, of course, been visited successfully with chemical rockets, using nuclear to travel to the Moon will mean a trip of just "a couple of days," said Borowski.

Alenka Brown-VanHoozer, from Argonne National Laboratory–West, led off the afternoon session with a thought-provoking talk on "Human Factors and Nuclear Space Technology in Long-Term Exploration." Brown-VanHoozer has only recently begun to work with NASA, and studies the "neurophysiological aspects of the human in respect to the types of systems that we would need to be looking at and designing." Even the most foolproof equipment that NASA and the DOE can engineer will be vulnerable, to some degree, to human error, she said. Brown-VanHoozer studies how best to select, train, and provide for the astronauts that would be required for a possible Mars mission of two years in duration.

Advanced voice recognition systems that could determine how each individual processes information and automatically adopt to that individual would be required, she explained. As many tasks as possible should be automated to reduce human error and the chance that physiological problems could keep an astronaut from his or her duties.

NASA's method of selecting personnel would have to change, Brown-VanHoozer said, to make sure that the group of astronauts would have compatible belief systems. People who are healthier and less sensitive to radiation would be selected over others. Training could be better conducted if the individuals' learning strategies and decision-making strategies could be taken into account, and training would include skills to minimize conflict and mismatches in communication between the astronauts.

Because of the length of a possible Mars mission, the selection of a crew is much more critical than on a two-week mission to the moon. On the shorter mission, Brown-VanHoozer said, each person understands that he or she will return home soon, conflicts are minimal, and belief systems are not challenged. On the longer mission, the astronauts would have to be carefully selected by gender and marital status, and they should have similar backgrounds and belief systems, Brown-VanHoozer said. Each astronaut headed to Mars would be required to be knowledgeable in two or three disciplines, so that the group forms "the beginnings of a highly technical society."

Singleterry spoke again, presenting a paper on protection from space radiation authored primarily by his colleague, Ron Tripathi, at NASA's Langley Research Center. NASA is paying more attention to cosmic radiation now than it has in the past. In fact, Singleterry said that NASA only recently realized that shielding would be necessary on the International

A new approach to session participation

After 20 years of attending ANS meetings, Ken Powers wants to liven up technical presentations.

As a result, a pilot project emphasizing shorter technical presentations, a professional facilitator, and more relaxed seating style is emerging.

"Our goal is to create a more interactive environment, where the expertise of the audience contributes to each presentation," said Powers, ANS Decommissioning, Decontamination and Reutilization (DD&R) Division vice chairman/chairman-elect. "We want people to have fun while they're learning. It will make their attendance at ANS meetings more enjoyable and beneficial."

Powers

The fast-paced exchange replaced traditional presentation styles during two DD&R sessions at the ANS Annual Meeting in San Diego—Decommissioning Hot Topics and Emerging Issues and Free Release Standards Governing the Release of Solid Materials.

"[The sessions] really engaged the audience and made them participants in the presentations," said Andy Kadak, who was then ANS President. "It's a great format that I believe is a trend for the future."

Instead of entering a room with theater-style seating, about 50 attendees approached cloth-covered round tables. The speakers often made their entire presentation in front of the formal speakers' table. Attendees were encouraged to ask questions throughout the presentations.

When a speaker was finished, Jack Fontaine, a professional facilitator and ANS member, used a flip chart to make suggestions about possible areas of exploration during follow-up discussions. Participants were given a few minutes to prepare questions and comments with their tablemates.

The process encouraged people to engage the speaker, and often, attendees offered valuable information about the topic—beyond the speaker's comments.

"People can be reluctant to ask questions when part of a large audience," Powers said. "The goal here is to take some of the burden off the speakers and place it on the audience."

Burden turned into participation, and participation into an engaging atmosphere.

"The DD&R sessions became almost a separate entity, an island unto themselves in an ANS sea of regular sessions," wrote Nancy Zacha, editor of *Radwaste Solutions* in the July/August issue of that magazine. "Instead of a simple question-and-answer session, a true dialogue between speakers and attendees was achieved," she wrote. "The learning curve for attendees rose exponentially, as scientists love to say."

According to Fontaine, studies show that adults learn and retain more when they are actively involved in the process. Throughout the pilot sessions, he timed speakers, presented questions for the audience to consider, and kept discussions moving. He is founder of The Fontaine Group, which provides organizational change consulting, coaching, and facilitation to a variety of nuclear organizations.

"People generally have a 20- to 25-minute threshold when sitting and listening to a presentation," Fontaine said. "By shortening our presentations and emphasizing three main points, the audience is more apt to leave the room with the information we wanted them to have."

Increasing interaction between speakers and attendees helps open everyone involved to more information. According to Fontaine, this type of session approach will make people more emotionally involved and satisfied when the presentations are over.

The approach to this pilot program began at the ANS Executive Conference in Traverse City, Mich., in June 1999. At the time, Powers was site general manager for Consumers Energy's Big Rock Point Restoration Project, which hosted the conference. Following the event, Powers and fellow Consumers Energy employee Jim Rang were invited to make a presentation on how to organize a successful conference to the ANS Executive Committee in Long Beach, Calif., in November 1999.

With the support of ANS leadership, Powers invited Fontaine to facilitate the San Diego sessions. The pilot approach was used in two of the DD&R Division's six sessions.

"In later sessions, the facilitator was gone, and the little group discussions were abandoned, but by then, the attendees had become almost a little family, and the sessions became a real information-sharing experience," Zacha wrote in *Radwaste Solutions*.

Former ANS president Ed Fuller is technical program chair for an embedded topical meeting to be held during the ANS Annual Meeting June 17–21, 2001, in Milwaukee, Wis. He said he's planning on using the new approach at his sessions. And, Powers said the DD&R Division will use the format in several of its sessions during the upcoming ANS Winter Meeting this November in Washington, D.C.

The process promotes communication, networking, and learning. And, as Zacha said, "I guess that's why we go to meetings in the first place, isn't it?"—*Janenne Irene Harrington, Big Rock Point Restoration Project*

Space Station and began to construct that shielding. The space radiation environment is easy to describe, Singleterry said: It is a complex radiation field of protons, electrons, mesons, neutrons, heavy ions, and photons that varies as a function of time and space. That said, it is not easy to understand.

He and his colleagues are attempting to determine which particles can do the most damage, and how that damage is done. Cosmic radiation cannot be stopped by any existing shield: "even a couple of miles of lead will not absorb this radiation," Singleterry said. Instead, the focus is on finding a shield that will break high energy ions into smaller particles that "are hopefully less damaging cumulatively than the original particle." The researchers are considering not only the long-term risk of an astronaut's developing cancer, but also short-term effects of radiation such as vomiting, nausea, and burns, that could be harmful or fatal and keep an astronaut from his or her duties.

Three parts of the design process have been defined: accurate risk prediction, optimization methods (ALARA), and meeting mission costs. The group at Langley is studying radiation effects at the Alternating Gradient Synchrotron at Brookhaven National Laboratory, using mouse glands to study the effect of the different components of cosmic radiation. The researchers have learned, for instance, that their data show that protons are responsible for the generation of most tumors.

The architecture of the space vehicle must be designed to minimize exposure. For instance, equipment will line the walls to provide some extra shielding, and the astronauts must be kept away from the windows as much as possible. With all the work to be done, "I'm painting a picture of doom but it's not that bad," said Singleterry. "We are doing the things we need to do." During the panel session, he estimated that from a radiological point of view, 10–15 years of preparation are needed before humans can be sent past Earth's orbit.

Mike Houts, of Los Alamos National Laboratory, in cooperation with NASA and the Marshall Space Flight Center, has worked on "Enabling the Use of Space Fission Propulsion Systems." He presented a three-phase approach to expanding space exploration.

Phase I is the first fission propulsion system, and Phase II is advanced human exploration, with a goal of developing fission propulsion to enable rapid, affordable access to any point in the solar system. Finally, Phase III, highly advanced human transportation, includes the goal of rapid solar system transport and interstellar entry. Houts commented during the panel session that "fission propulsion systems can enable a great deal of space exploration. But we won't have fission propulsion systems unless we decide to do a great deal of space exploration."

Houts is participating in the development of a propulsion concept called the safe, affordable fission engine (SAFE). The SAFE-30, a 30-kW (thermal) modular test engine, was to be ready for testing (using a nonnuclear heat source) in August 2000. Following those tests, his group planned to begin building the SAFE-300 in October. Houts stressed that to speed the development of fission propulsion, systems must operate within established radiation damage and nuclear fuel burnup limits, testing must be affordable and accurate, and the system must be safe at all times.

Jack Wheeler, of the DOE's Office of Space and Defense Power Systems, spoke on "Space Nuclear Power: Systems and Safety." He reviewed the use of DOE-developed radioisotope power generators (RPSs) and RTGs. Such systems are safe, he said; three radioisotope systems have failed, but without safety consequences. One burned up at high altitude as designed, another landed in the Pacific, was retrieved and its fuel recycled, and the last landed in the South Pacific, and, while it was not retrieved, no releases were detected. He theorized that a radioisotope power system used with a Stirling engine could provide the power needed for the NASA Pluto-Kuiper Express mission.

Wheeler also repeated what was said by several—that communication between the DOE and NASA must increase. He also stressed that safety is "of paramount importance."

Prior to a launch, information must be obtained from NASA on accident probabilities and the accident environment. Research data could then be consulted to understand how the system would react in that accident environment, and a safety analysis report would be generated using probabilistic safety analysis methods.

The report would then be independently reviewed by an interagency nuclear safety panel. Wheeler pointed out that RPSs and RTGs are highly radioactive at the time of launch and decay naturally, giving off alpha particles, while in a reactor system the fuel is unirradiated at the time of launch, and the safety focus is on protection from inadvertent criticality.

IAEA

An interesting fact about the International Atomic Energy Agency is that it is not international enough, admitted Abel Gonzalez during a session on the IAEA's radiation and waste safety activities (the first of three special sessions on the agency). Although the IAEA has a membership of 130 countries from around the world, including the United States, there are as many as 60 nonmember countries that have some form of radiation source within their boundaries. These countries have yet to join the IAEA because, in some instances, they find the paperwork too confusing, Gonzalez said. For example, one IAEA member, the Marshall Islands in the Pacific, had to hire a lawyer in Washington, D.C., to fill out IAEA membership forms.

The long and short of it, said Gonzalez, who is the IAEA's radiation and waste safety director, is that the IAEA first has "to take care of our members" before it can look at radiation issues in nonmember countries.

Headquartered in Vienna, Austria, the IAEA has a staff of 800 professionals supported by 900 general staff. Its annual budget of $800 million is supplemented by another $90 million in assistance funds. What the IAEA offers its members is technical guidance in waste management, radiation protection, reactor activities, and operational safety. The IAEA also conducts international conventions and establishes radiation safety standards.

The standards are prepared by an IAEA advisory committee, under which four technical subcommittees provide a first review. Those subcommittees deal variously with the safety issues of nuclear power, radiation, waste, and transportation. It is interesting, Gonzalez noted, that the International Labor Organization—made up of unions, employers, and governmental bodies—is one of the groups that "blesses nuclear requirements" before they become IAEA safety standards. Other non-nuclear groups represented on the advisory committee include the Food and Agriculture Organization and the World Health Organization.

Besides issuing standards, the IAEA also publishes books termed as fundamentals and guides.

The IAEA has five vehicles for applying standards: rendering services, providing technical cooperation, fostering information exchange, promoting education and training, and coordinating research and development. In this regard, the IAEA has spent in excess of

$15 million on conducting 150 technical cooperation projects on radiation safety in more than 50 countries. It has hosted six major meetings and 44 advisory meetings on the application of radiation safety standards. It offers 74 educational and training courses on radiation safety, taught in five languages, to 1500 participants each year. It has coordinated 19 R&D programs and 20 research contracts on radiation safety, and provides services for dealing with radiation sources.

The above-noted items are IAEA *functions,* Gonzalez stressed, which differ from its two distinct *thematic activities*—radiation safety and waste safety—although he thinks they are synonymous. "I believe they should be one and the same," he said, "but politicians want them separate."

Radiation safety programs include radiation protection, safety of radiation sources and security of radioactive materials, safe transport of radioactive materials, radiation emergencies, and operational services for radiation monitoring and protection. Waste safety programs include the safety of disposable radioactive waste, radioactive discharges, and radioactive residues.

One highly political issue, Gonzalez said, is the transport of radioactive materials. "Many countries make noise about this," he commented. "They say, 'If a ship carrying radioactive waste sinks near my country, no one will buy the fish we catch.'" Yet a response to that argument came during one of the most effective moments of the session, when Gonzalez showed a short videotape on the safety of transportation casks. In the video, a waste container was secured in the path of a speeding railroad locomotive. The train, following an explosive impact, was reduced to rubble. The waste container, however, remained intact. Still, Gonzalez added, sooner or later there will be a need for a convention on safe transport.

Other videotapes were played by Gonzalez. One showed IAEA activities in investigating an event that occurred in the Republic of Georgia. In 1997, nine Georgian servicemen at the Lilo training center experienced burns from radiation exposure. The source of the radiation remained from years before, when the Soviets had used the center for nuclear war training. When the Soviets left, the Georgians, uncertain of the testing that occurred there, took over the training center and worked around what was left behind. Much of Lilo is in shambles from the Soviet testing, with large chunks of concrete strewn about perhaps from conventional bombs destroying the buildings there. The IAEA investigation revealed a hot spot that measured 45 millisieverts per hour. Cesium-137 was detected. Several of the Georgian servicemen stationed at Lilo were severely burned and needed multiple operations for skin grafting. They were transported out of Georgia to a hospital that specialized in radiation burns, where they received medical services. Lilo was cleaned up of radioactive sources and IAEA's involvement "saved the lives of these Georgians," Gonzalez said. "All they got in Georgia was morphine for pain. Without our intervention, they would have died."

Another video showed IAEA work being done at the Pacific islands of Mururoa and Fangatuafa, which were once French military bases for nuclear weapons testing. Gonzalez commented he was "very proud" of the IAEA's involvement there because investigations were completed that showed no ill effects remained from the bomb testing. The islands, he said, have become the first test-bomb site "that has been released to the public domain and given back to civilians."

The IAEA has done much work in investigating the legacy of the Cold War, Gonzalez added. Statistics released by the IAEA reveal that in total, 2419 nuclear weapons have been tested around the world, having a yield of 530 megatons (one megaton equals 10^{15} calories of explosive energy). Those tests, most occurring during 1952–1962, break down to 543 atmospheric experiments yielding 440 megatons and 1876 underground experiments yielding 90 megatons. The atmospheric tests resulted in the largest man-made release of radioactive materials to the environment, Gonzalez said, with the highest world average radiation dose of 0.15 mSv occurring in 1963. (The present world average is 0.005 mSv.) IAEA investigations have occurred or are ongoing at test-bomb sites in Algeria, Australia, China, Kazakhstan, Marshall Islands, Russia, and the United States.

Much of the IAEA's work does not have the enormity of test-bomb studies. Other investigations by the IAEA have included looks into an accidental overexposure of radiotherapy patients in San Jose, Costa Rica, and an electron accelerator accident in Hanoi, Vietnam. With the advent of what Gonzalez termed as "orphan" sources, which often are radioactive scrap metals that are melted down and easily transported, the incidence of investigations in member countries leaves the IAEA with a full platter.

Special Session: IAEA activities

Other activities of the IAEA, notably regarding nonproliferation, were discussed in the last of three special sessions on the agency.

While the United States and Russia have been negotiating ways to reduce "excess" weapons-grade fissile material, the main global instrument for reducing proliferation risks, the Non-Proliferation Treaty (NPT), has been under sustained pressure throughout the 1990s. In response, the agency, which administers the NPT, has been strengthening its safeguards system. Winston Alston, of the IAEA, described these safeguards, explaining what it cannot achieve, as well as what it can.

President Eisenhower's Atoms for Peace initiative led to the creation of the IAEA as a United Nations agency in 1957. The agency's role was to aid countries to gain access to nuclear technology, but only in return for applying safeguards to ensure that the country did not misuse the technology.

The first safeguards system, set out in INFCIRC/66, goes back to 1965–67; it concerned only reactors, reprocessing, and fuel fabrication, plus materials and equipment. In 1971, the IAEA Board of Governors approved INFCIRC/153, which details safeguards for non-nuclear–weapons states (and nuclear states on a voluntary basis) based on the NPT, according to which the IAEA takes on the role as the international safeguards inspectorate—the nuclear watchdog—to verify that nuclear material is not diverted to nuclear weapons.

To fulfill this role, each country must reach an individual safeguards agreement with the agency under which the "facility operators and the state are required to report all activities involving nuclear materials," Alston explained. The job of the agency then is to verify the "correctness of material flows, material inventories, and facility operations." The way it does this will be set out in the agreements. The chief mechanism for verifying the information is onsite inspections, supplemented by technical aids, including containment measures (e.g., seals) and surveillance measures (e.g., cameras and monitors).

Alston's colleague, Richard N. Olsen, discussed the more technical and practical aspects of the IAEA's safeguards system. He described the approaches and methodologies used, the system's technical criteria, guidelines and inspection goals, the terminology of safeguards, inspection techniques and equipment, reporting schemes, and how inspections are evaluated.

The traditional tools and approaches to safeguards, however, had serious limitations, Olsen said. The "holes" in the system came to the attention of the world in the 1990s, first "when Iraq opened our eyes" to the system's dependence on the truthfulness of the state and on the limited access to facilities, he explained.

It was a chance accident that Iraq's nuclear program was discovered. To protect its clandestine activities, the Iraqis placed hostages in the facilities. Following the hostages' release, examinations of their clothes revealed traces of high-enriched uranium and plutonium.

Other incidents that revealed the weaknesses of the system were:

- The discovery in 1992 of inconsistencies in the initial report on nuclear materials in the DPRK (North Korea)—in contravention to the NPT, which it had signed.
- When South Africa signed the NPT and declared that it possessed nuclear weapons. The difference here was that the country had not been in contravention of any agreement.

In addition, the breakup of the Soviet Union led to the creation of several countries with large amounts of weapons materials.

It was clear that there was a need to strengthen the efficiency and the effectiveness of the system, Olsen said. The result was the Strengthened Safeguards System.

When it was first agreed to strengthen the system, the initial effort, now called Part 1, involved identifying measures and powers that were already possible within the present safeguards agreements, although implementing them still had to be approved by the board. This included, for example, the provision of more and better information, unannounced and short-notice inspections, and the use of new technologies (e.g., environmental sampling, digital cameras, and unattended and remote monitoring).

Part 1 exhausted the legal possibilities of the existing agreements and it was necessary to look at expanding the system. This led to Part 2, which included the creation of the Additional Protocol—INFCIRC/540—which expands the agency's mandate: It no longer simply confirms the stated existing nuclear activities, but is required to confirm the absence of undeclared nuclear activities.

Part 2 now allows access to all facilities on a site, even if the building is not declared as having nuclear uses, to confirm the correctness of information. It also requires information on other nuclear fuel cycle–related R&D activities not involving nuclear material; activities in locations outside facilities where nuclear material is used; uranium mines, thorium and uranium concentrates plants (previously safeguards started after yellowcake); and on previously exempted material (for non-nuclear use of nuclear material); and high-active waste containing plutonium or high-enriched uranium.

Additional Protocols have been concluded with 49 states and are in force in nine, including Cuba, which had never signed the NPT. Additional Protocols have also been negotiated with weapons states.

Also discussed at the session were the implications of the breakup of the Soviet Union. The new countries agreed to become non-nuclear weapons states and Russia agreed to remove all nuclear weapons. The countries, however, still retain nuclear facilities and material, and are often unable to fulfill their obligations under the NPT. In most cases, there were no nuclear laws in place nor nuclear safety commissions. The countries could not even provide adequate physical protection of materials when the Soviet armed forces left. The IAEA also discovered that there had been little in the way of material accounting in the old Soviet Union. Olsen visited a huge fuel fabrication plant that, he said, had no record books.

Western countries and the IAEA are helping them set up nuclear safety infrastructures and develop the capabilities needed to maintain safety, he said.

Relicensing research reactors

That the relatively small research reactor community benefits from the open exchange of experiences was clear as its trials, tribulations, and successes were shared at the technical session "Relicensing of Research Reactors." Representatives of three research reactors and the Nuclear Regulatory Commission were present.

Alexander Adams, Jr., a senior project manager at the NRC, attempted to clarify regulations on nonpower reactor license renewals. He discussed two methods that could possibly be used to extend the expiration date of nonpower reactors prior to license renewal: recapture of construction time and extension of the renewal license expiration date (recapture of time spent on NRC staff review). Currently, the standard fixed period of time for a nonpower reactor license is 20 years. Adams stressed that license renewal applications must be submitted by 30 days before the date of expiration.

Research reactor staff can take advantage of construction time recapture only if the initial construction permit was issued while the reactor's current license was in effect (that is, older reactors that already have undergone license renewal will not be able to recapture original construction time). NRC staff review is, of course, required, Adams explained, and the condition of various reactor facility systems is evaluated to verify safety during the time of the extension, whether it be months or years.

Adams

One licensee that Adams presented as an example obtained a construction permit, took five years to build a facility, ran the facility for five years, obtained a second construction permit for some modifications, took two years to complete the modification, and then completed the normal term of the license up to 20 years. A recapture would take those seven years of construction and add them on to the term of the license, effectively extending the term of the license to 27 years.

According to Adams, that procedure was first investigated by John Bernard of the Massachusetts Institute of Technology (who was present at the meeting as session organizer). Bernard contacted Adams and asked whether, considering that power reactors recapture construction time, research reactors can do the same.

Adams said the NRC staff determined that 9 of 36 operating nonpower reactors can likely take advantage of such extensions. The NRC has not determined, however, if nonpower licensees will be permitted to recapture time spent doing required high-enriched uranium–low-enriched uranium conversions.

Wade Richards described the transfer of ownership of the McClellan Nuclear Radiation Center (MNRC)—of which he is director—from the Air Force to the University of California at Davis (UCD), and the required change from an Air Force license to an NRC license. The MNRC was constructed by the U.S. Air Force 1988–1990, Richards explained, to inspect aircraft structures for moisture and corrosion with neutron radioscopic techniques. In 1995, the decision was made to close McClellan Air Force Base, but officials wanted to prevent the closure of what was the newest U.S. research reactor by transferring it to a new operator, UCD.

Richards

The Air Force license under which the reactor had been operating was created using American National Standards Institute standards, with the help of NRC regulation guides, which eased the transition, said Richards. At the same time, however, the TRIGA-type reactor was being upgraded from 1 MW to 2 MW. Complying with NUREG 1537 (which was being used by the NRC for the first time), cost 500 personhours and approximately $36 000. UCD began operations as owner of the facility on February 1, with a new 20-year NRC license.

Lin-Wen Hu spoke on the relicensing of the MIT research reactor (MITR), a 5-MW, light-water- cooled and heavy-water-moderated reactor. The license was due to expire in August 1999, and MIT duly submitted a relicensing application in July 1999. MIT also requested a 20 percent power upgrade from 5 MW to 6 MW. Three options had been considered: a power upgrade to 10 MW with new primary and secondary coolant system equipment and a new nuclear safety system, a power upgrade to 6 MW with the existing coolant system equipment, and license renewal at the current power level. Funding levels dictated the upgrade to 6 MW, Hu said.

Hu

The advancement of computer technology since the previous MITR renewal meant that the safety analysis could be done more efficiently and with greater assurance of accuracy. Core tank aging evaluation, neutronic analysis, thermal hydraulic analysis, and step reactivity insertion analyses were all conducted. Knowledge gained from studies of Brookhaven National Laboratory's High Flux Beam Reactor allowed the conclusion that the core tank could last for 20 years at a maximum power of 10 MW. Neutronic analysis was performed with an MCNP (Monte Carlo N-Particle) model, which produced axial power distributions for each plate. For thermal hydraulic analysis, MIT operators decided their best bet was to write a computer code in-house, named MULCH-II. The MULCH-II code models the primary and secondary cooling system of the reactor, and can model individual cooling channels, or do transient analysis. Step reactivity analyses were done with a PARET code for low-flow–low-power and forced-flow–full-power conditions.

The fully qualified, relicensed MIT research reactor is fully equipped, with a new safety system and new cooling tower, to serve the MIT community at 6 MW for 20 more years, Hu said.

William Vernetson, director of nuclear facilities at the University of Florida, spoke about his experiences with an extended, multipurpose outage at the University of Florida Training Reactor (UFTR). The UFTR is a regional facility, Vernetson said, that can serve research needs from all over the state. Safety was paramount during the outage, Vernetson says, which meant outage or maintenance work on the reactor, especially fuel handling, was done somewhat slowly. All work was limited by the age and unique construction of the reactor.

Vernetson

Beginning in early March 1998, the reactor operators began to detect "a significant shift in the critical position": The critical position would go up and down, necessitating careful attention to maintain criticality.

In May 1998, attempts were made to identify the source of the problem. After periodic NRC communication, and investigations for problems with electronics, gear position variations in the control blade drive system, movement of permanent experimental facilities, shield tank leakage, foreign material, distortion of the core geometry, and loss of physical integrity of the control blades or fuel assemblies, no specific cause was identified.

The decision was made to unstack the shield blocks and graphite intricately packed around the core. Vernetson was able to show his audience just how tricky a task that is with a diagram. "It's like a giant erector set—you've got so many pieces and they all have to go back somewhere. And a lot of the pieces aren't exactly the same length and that's another problem. If you put them in they may not fit."

The entire outage was performed with care and backed up with documentation with the goal of using the results to support the upcoming UFTR relicensing application, due to the NRC in 2002. Because the reactor was built in 1959, some components are very old, Vernetson explained, and the operators felt there was a need to measure and verify several dimensions of the reactor. The reactor was successfully restarted in August 1999 with 93 percent availability, and, although no cause for the criticality anomaly was identified, the critical positions have been consistent since, Vernetson reported.

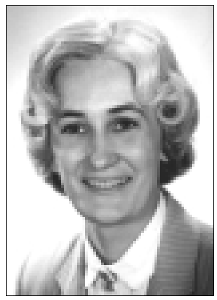
Radiation policy and science

Three of the organizers of the Bridging Radiation Policy and Science (BRPS) International Conference held December 1–5 at the Airlie House Conference Center in Warrenton, Va., chaired a session to present the final report issued after that meeting (*NN,* Feb. 2000, p. 42) and encourage discussion. The goal of the BRPS conference was "to develop strategies for formulating national and international policy based on current scientific information in the context of economic, political, and social concerns . . . with respect to radiation protection in view of the scientific uncertainties of the effects of low-level radiation (100 millisievert [mSv])."

Some session attendees questioned whether the select group of 78 BRPS attendees possessed the expertise to formulate valid conclusions and recommendations, which guaranteed a lively give and take between the audience and panelists at this session.

Kenneth L. Mossman, professor of health physics at Arizona State University, Sigurdur M. Magnusson, of the Icelandic Radiation Protection Institute, and E. Gail de Planque, of de Planque Consulting, chaired the meeting and presented different parts of the BRPS final report in turn, together with Abel Gonzalez, director of the International Atomic Energy Agency's Division of Radiation and Waste Safety, who served on the BRPS advisory committee. Often, the speakers quoted and paraphrased the words of the BRPS participants to show the ANS session attendees what exactly transpired.

Mossman



de Planque

The BRPS meeting was supported financially by several organizations, including the American Nuclear Society, the U.S. Department of Energy, the Environmental Protection Agency, and the Nuclear Regulatory Commission. The organizers released the final report January 31.

Session one of the BRPS meeting last December, "A Philosophical Overview of Policy Making," focused on "the challenges of setting policy and on what the policymakers need to know when formulating policy at the highest level." Sen. Pete Dominici was scheduled to speak during the session, but Peter Lyons, his science advisor, presented his message. "If these standards overestimate the risks," he said, "they force us to divert funds from other, potentially more worthy, national goals."

Several messages were repeated by six speakers during that session: underpinning principles should be established, policy should be based on sound science, uncertainties should be clearly delineated, processes need to be transparent, policies need to be consistent (nationally and internationally), stakeholder input is essential, citizens need to be accurately informed in language that is understandable, and relating dose limits to levels of natural background radiation and/or variations is useful.

Session two focused on "The Science Issues," specifically on epidemiological and molecular/cellular radiobiology research. The BRPS conference attendees were not attempting to resolve the linear no-threshold (LNT) debate; they simply focused on the nature of scientific uncertainties and some current research problems and future goals to clarify health effects. The participants agreed that no research breakthrough has as yet permitted a final conclusion about the shape of the dose-response at low doses.

Session three, on "Bridging to Application—Factors that Influence Policy," summarized some of the factors besides science that influence policy and regulation, such as risk, and economic, social, psychological, and ethical factors.

Risk assessment has developed to the point that regulators can make value assessments between different risks, said George Gray, of the Harvard School of Public Health, at the BRPS conference. Cost is what motivates some people who wish to abolish the LNT, because escalating requirements mean higher costs, and the misuse of collective dose also causes increase in cost, as Neville Chamberlain, of the International Nuclear Energy Academy, explained.

Lennart Sjöberg, of the Stockholm School of Economics, spoke about the psychological aspects of gaining the public's approval of nuclear and other "risky" endeavors. It is not enough any more, he had stated, for experts to seek the public's trust, because the public believes that there are unknown effects and factors that are not understood by the experts.

Abel Gonzalez presented the conclusions of *Session four* of the BRPS meeting, on "International Organizations and Policy Making." "There is a growing perception that we need an international agreement," he said. Gonzalez spoke to that issue at the BRPS conference, and summarized some of his own views during the technical session. He discussed the role of the IAEA in establishing this international agreement. The role of UNSCEAR was also discussed, because, as Golzalez said, UNSCEAR produced a new report in late May. Also represented at the session were the International Commission on Radiation Protection (ICRP), the International Radiation Protection Association (IRPA), and Friends of the Earth.

Session five focused on the development of "National and Regional Policies." Representatives from regulatory agencies from the United States, Europe, Korea, and Australia were present. The main points of discussion included the role of ICRP in determining radiation policy, international cooperation in crafting radiation regulations, and public confidence in regulations and policies. "It was clear that the ICRP has a very central role in determining the national radiation policies," said Magnusson, who presented the conclusions of session five. "It is really very impressive that a nongovernmental organization such as the ICRP is so influential."

Some session attendees had questioned this influence by suggesting it was time for the ICRP to "clean house" in order to regain confidence, or by proposing that the ICRP could be circumvented if another organization stepped up with an alternative radiation protection system. Others had said that the ICRP should present its conclusions in a more "user-friendly" document, describing results and allowing policy makers and regulators to see how conclusions are reached.

Session six involved a discussion of moving "From Science to Policy and Regulations." Three broad issues were the focus of this session: the reconciliation of science, international recommendations, and policy in the formulation of recommendations, according to Mossman, who presented the conclusions of the session.

He mentioned the various studies on dose response at low exposures, such as those now being conducted by the National Council on

Radiation Protection (NCRP) and the BEIR VII committee of the National Academy of Sciences. The NRC must wait for this new research to be incorporated into recommendations. "It becomes a vicious circle. These agencies depend upon the ICRP and the NCRP for recommendations, and until these recommendations come forth they are in a holding pattern," Mossman said.

Cooperation among stakeholders was acknowledged as important by the BRPS attendees, but had prompted a lively discussion about who, precisely, these stakeholders are. Several speakers at the December meeting noted that the policy makers and stakeholders must work together cooperatively, and all must be able to speak freely. Some of the attendees felt that unless the people affected by rulemakings are involved in making decisions, they are unlikely to accept the outcome.

Some session attendees questioned whether the select group of 78 BRPS attendees possessed the expertise to formulate valid conclusions and recommendations.

Session seven focused on "Problems and Options": the problems of implementing current radiation policy, and the possible ways that policy could be changed.

Roger Clarke, of IRPA, had proposed a simple approach to radiation protection, based on controllable dose, that would recognize that controlling the dose received by the most exposed would give an acceptable risk. Helen Garnett, of the Australian Nuclear Science and Technology Organization, said a new system should have a practical approach to declassification and exemption of material now classed as low-level waste, which under the new system could be considered clean, and should eliminate the misuse of the collective dose approach.

Maurice Tubiana, from Academie des Sciences, in France, wanted a statement that the LNT theory does not apply below 50 mSv, and advocated more research to find an alternative to the LNT.

Nils Diaz, an NRC commissioner, said he would support a system based on individual, rather than collective dose, once it was finalized, and noted that the NRC, which is undergoing a period of change, could be receptive to new approaches. Gonzalez, who presented the conclusions of the session, remarked that debates over radiation protection are more intense in the United States than internationally: "The U.S. speaks with many voices and that is the strength of the U.S., but there are too many voices," he said, referring in particular to the NRC and the EPA. Outside the United States, there is not as much pressure to find a safe dose, he said.

Magnusson, who presented the conclusions and recommendations from the conference, stressed that reaching the conclusions was a "rather complicated exercise with severe time constraints. We had an editing committee of about 80 extremely strong-willed individuals from 16 countries." In order to avoid any protests that could be made if the conclusions were edited, the conference organizers had transcribed them verbatim into the report, and presented them at the session:

■ Ionizing radiation is a well-known human carcinogen. During the past 50 years numerous epidemiological studies of adult human populations exposed to radiation from medical, occupational, or military purposes have been conducted. The lowest dose at which a statistically significant radiation risk has been shown is ~100 mSv. This does not imply the existence of a threshold.

■ The effects of low-level radiation below 1 mSv per year above background radiation cannot currently be distinguished from those of everyday natural health hazards.

■ The concept of collective dose is often misapplied, e.g., to estimate health impacts of very low average radiation doses in large populations and/or doses delivered over long time periods. Collective dose can be a useful comparative tool, for instance, in the evaluation of protection options.

■ It is essential to continue to foster international cooperation in radiation safety. In particular, international harmonization of radiation safety policies for radiation sources delivering low radiation doses should be developed. Consistent and coherent radiation policy on a national level is necessary for the effective implementation of radiation safety.

■ Economic, environmental, ethical, psychological, and scientific factors are all essential in the policy and regulatory decision-making process to assure public health and well-being. The way in which these factors are incorporated in nation-specific decision-making processes may vary.

■ Concern over low doses should not deter the public from obtaining benefits of medical procedures.

The recommendations of the BRPS attendees were similarly presented:

■ Policy discussions on the regulation of radiation sources delivering low-level radiation should include references to natural background radiation.

■ The conference supports the evolving framework of the International Atomic Energy Agency (IAEA) for the safe use of radiation.

■ The conference supports further development and evaluation of the ideas associated with the proposal on controllable dose.

■ No radiation dose is below regulatory concern but certain levels should be below regulatory action, and appropriate dose levels should be established.

■ Fundamental questions about the shape of the dose-response curve and mechanisms of effects of radiation at low doses are unlikely to be answered in the near future. Scientific research, including molecular and cellular radiobiology studies are critical in order to better understand mechanisms of radiogenic effects, and providing important information about the likely shape of the dose-response curve at low doses of radiation, and should be coordinated and continued.

■ Strongly encouraged are multinational support and analysis of human data derived from studies such as the Radiation Effects Research Foundation (RERF) Life Span Study, the Russian Mayak and Techa River studies, nuclear workers studies, and studies of populations living in high natural background areas to assist in reducing scientific uncertainties in risk and in elucidating mechanisms of radiation health effects. These data offer a unique opportunity to further quantify effects at low doses in human populations.

■ Groups involved in the development of policy and regulations, or making recommendations for such policies and regulations, should operate in an open and transparent manner, and engage in dialogue with stakeholders.

■ There is a pressing need for more effective communication by scientists with the public, politicians, policy makers, regulators, and other interested persons. The science should be clearly articulated, emphasizing what is known and what is not known, explaining the limitations in the information, and what is being done about it.

While some of these conclusions and recommendations were accepted by the audience at the ANS session, others provoked debate. Mossman succinctly expressed some of the hostility in the room by saying, "Why can't we scientists stand up and collectively say such-and-such a dose is safe? That's what you're looking for, and that's what the scientists have been unwilling to do."

De Planque, an ANS past president, closed the session by explaining that "our major motive was to get people talking to each other who normally do not connect at all. In that sense I think it was very gratifying to most of the participants." She stressed that the BRPS conference was put together by an ad hoc group of people who provided volunteer labor and begged financial support from several organizations. "If we move to further conferences like that it's got to be supported by official organizations," she said.

Nuclear societies' cooperation

Nuclear energy is driven by many concerns that are shared by most countries. While there are many existing mechanisms for international cooperation, ANS felt that its links with other nuclear societies should be strengthened. To do this, a special committee for nuclear societies cooperation was created by Andy Kadak, then the president of ANS, (and agreed upon by the board of directors in June 1999). As a special committee, its remit last-ed for only one year, but the new and current president, James Lake, wants it to continue for a second year.

A session on the committee's work was led by Octave J. Du Temple, executive director emeritus of ANS.

The committee members include the societies that have entered into cooperation agreements with ANS—there are about 25—plus the non-U.S. ANS local sections. Some international organizations, such as the Organization for Economic Cooperation and Development's Nuclear Energy Agency (OECD/NEA), also have arrangements with the committee.

The committee supports ANS international programs and promotes cooperation and communication between ANS and other nuclear societies. One condition is that the committee not duplicate the work of other international bodies, such as the International Nuclear Societies Council (INSC), which is open to all nuclear societies, or the Pacific Nuclear Council (PNC), which includes nuclear societies in the Pacific Basin.

According to Brazil's Jorge Spitalnik, who chairs the special committee, ANS wants the committee to develop common goals on a global basis, to allow a broader international spectrum of viewpoints to be aired and to foster a better understanding of the concerns and interests of the different societies. The committee offers members mutual support and cooperation on issues that arise and provides a forum for presenting views on issues of a global nature, for developing common multilateral positions and for reaching consensus where possible.

Spitalnik

Over the past year, the committee has dealt with a number of lively issues with international implications:

1. The committee addressed the challenge faced by countries from neighbors who are trying to stop their nuclear projects politically through international groups; for example, Austria tried to impose a linking of Slovakia's application to join the European Union (EU) with the closure of its nuclear plants. The committee's discussion ensured that the situation was understood by member countries (the EU dismissed the Austrian demand).
2. Although nuclear power is accepted as an option to mitigate the effects of CO_2, many countries negotiating within the climate change convention were "shy" to say so. The committee prepared a statement giving the rationale for the nuclear option and sent it to its 34 cooperative societies. The intention is that they convey this (mild) declaration to their governments.
3. The committee is working to ensure that position papers/statements covering issues that have occurred in one country are prepared so that other countries can avoid having to develop new answers when the issue comes up for them.

One of the most internationally active of the societies is the Atomic Energy Society of Japan (AESJ). Founded in 1959, five years after ANS, AESJ has a membership of around 8000 and is increasing by more than 200 per year. According to Masao Hori, the society is taking a leading position in the INSC and PNC. It also has a very active Foreign Professional Societies Coordinating Committee, which acts as the ANS Japan Local Section. With some 200 members, it is the largest non-U.S. local section.

Du Temple went through a number of ways that societies can help each other. He mentioned the effect of U.S. sanctions on Cuba and Pakistan, which isolates their nuclear scientists from their U.S. counterparts. Pakistan had wanted to come to this meeting, but its application to enter the country was rejected (in this case, Du Temple said, there was not enough time to intercede). Dialog, however, is still possible through meetings held in other countries. ANS also has access to Cuban scientists through Cuba's membership in the Latin American Nuclear Society, an ANS agreement society.

Society members, who are often the best informed on critical nuclear issues, can often act as important international sources of information when there are new developments or incidents. The criticality accident at Tokaimura provided a good example. Immediately after the incident, rumor and misinformation were rife. Japanese contacts, however, circulated limited but reliable information by e-mail, yielding some valuable results. Du Temple, for one, was able to provide a Wisconsin utility with this information to answer questions posed to it. Following a request from Brazil's Energy Minister, Spitalnik was also able to provide him with the same information, helping him answer questions posed in their country. Both agreed that this type of information has credibility that can help stop damaging speculation.—*Susan Gallier, Dick Kovan, and Rick Michal*

TOPICAL MEETING

Transportation of DOE spent nuclear fuel and fissile material

PART OF THE DOE's National Spent Nuclear Fuel Program was to develop the transportation cask system to move DOE spent nuclear fuel (SNF) canisters, which are designed to take all types of material in the department's inventory, from the sites to a national repository.

Dave Pincock, of the Idaho National Engineering and Environmental Laboratory (INEEL), described the basic design concept developed with the help of the sites, in a session about transportation at the Embedded Topical Meeting on DOE Spent Nuclear Fuel and Fissile Material Management, held during the ANS Annual Meeting, in San Diego.

The next stage, to produce draft design specifications, should be completed by the end of this year. It will be more than a decade, however, before there is a working system, because considerable time and effort will be needed to certify, procure, test, and train people to use it. According to the present schedule, the transports should begin in January 2015. The DOE expects to need eight casks.

The original concept was based on the cylindrical cask used to transport the damaged fuel from Three Mile Island to Idaho for storage. The cask is designed to be shipped on eight-axle rail cars equipped with top and bottom impact limiters; it will use lead or depleted uranium as shielding and have a maximum weight of 150 tons without impact limiters. The cask will use interchangeable baskets to take a wide variety of payloads and provide two levels of containment—a feature added to allow the shipment of failed fuel.

The shipping cask or primary containment vessel has an internal containment into which

Major points from the meeting:

- ♦ *Since the end of the Cold War, there have been attempts to build stronger institutions for arms control and nuclear material management.*
- ♦ *Under DOE's Foreign Research Reactor Program, The U.S. will take fuel from 19 countries through 2009.*

is installed an insert or basket tailored to the package to be transported. The packages include vitrified high-level waste, spent nuclear fuel from DOE facilities, multicanister overpacks (MCOs) designed for N-reactor fuels, and commercial nuclear fuel assemblies.

An example of a typical payload configuration is five vitrified HLW canisters and a DOE standard spent nuclear fuel canister set in the middle; the cask can also hold up to nine standard SNF canisters and up to 37 commercial assemblies. The internal dimensions of the cask are based on the Defense HLW DOE spent fuel disposal container designed for emplacement in a repository. This ensures that the transport package will go directly from the transportation cask into a disposal container, reducing temporary storage requirements at the repository.

Keith Morton, also of INEEL, described the development of the standardized canister for the SNF program. The DOE wanted a standard canister that can be incorporated into spent fuel storage systems, the transport system, and the waste package used at the disposal repository.

Preliminary design specifications provide the common design basis for the standard canister. The specifications satisfy a number of criteria. For example, canisters should be able to accept various storage casks now in use at many plants and have two levels of containment to be able to take high-enriched and damaged fuel.

Various drop tests were carried out on nine model canisters, including seven used for different 30-ft drops, one puncture test, and one test simulating a possible transportation accident. The tests were set up to maximize damage. All proved to meet leak-tight criteria. The computer predictions also provided good results.

Some countries outside the United States are much more familiar with the transportation of spent fuel. To give another perspective, Claude Bonnet, of SGN (a Cogema subsidiary), described the experience of shipping canisters to France's La Hague reprocessing plant. Cogema has reprocessing contracts with 28 utilities covering more than 100 reactors. Some 500 shipping casks are unloaded at La Hague each year. Cogema also returns vitrified HLW canisters to countries of origin. The only transport accident that occurred involved a crane that failed at the Cherbourg harbour. No significant damage was reported.

The packaging of fissile material must take account of three main safety concerns: containment, radiation shielding, and criticality.

The packaging of fissile material must take account of three main safety concerns: containment, radiation shielding, and criticality. For a shipment to be certified, the applicant must produce a safety analysis report for packaging (SARP), which must be independently reviewed. The review, which is based on DOE and NRC guidelines, involved an iterative question-and-answer process between applicant and reviewer, which continues until the reviewer is satisfied that all issues are resolved. According to Jay Liaw, of Argonne National Laboratory, no accidents have occurred in 50 years of transportation.

Liaw described a procedure he uses for calculating the transport index (TI), which effectively determines the maximum number of packages in a shipment that will remain subcritical under all circumstances. An analysis must ensure that there is a sufficient margin in a worst-case hypothetical accident, which is defined as a vertical drop of 30 ft, followed by a 30-minute fire at 800 °C, after which the fuel is immersed in water (a neutron moderator).

Some countries outside the United States are much more familiar with the transportation of spent fuel.

Liaw described a Monte Carlo–based technique that considers all possible configurations following the hypothetical accident. In the example used, he assumed that the canisters were completely destroyed by the accident and the fissile material (in this case, 1.25 percent enriched uranium ingots each weighing 176 kg) was scattered into the most reactive configuration possible and all surrounded by a foot of water.

He calculated neutron multiplication factors for an infinite number of ingot arrays. Eventually, Liaw said, you come up with the maximum number of ingots in a shipment—no matter what configuration, distance apart between ingots, or amount of water—that could never reach criticality.

While the DOE is developing its own system for transporting spent fuel and other fissile material, there is already a spent fuel transportation program under way in the United States. This is the foreign research reactor (FRR) program, under which the United States is taking back spent fuel from research reactors around the world. Under the program, described by Tom Hill, FRR fuel receipts program manager at INEEL, the United States will take fuel from 19 countries through to 2009. INEEL was designated to receive Triga fuel, and the Savannah River Site to take aluminum-clad fuel.

Starting almost from scratch, INEEL and Savannah River had to develop suitable schemes for having the fuel shipped from the foreign reactor sites. This work started with visits to the FRR operators to see the situation firsthand and explain what needed to be done to accept the fuel for shipping. At home, acceptance criteria for shipping and receiving fuel had to be defined. Fuel data sheets were devised to include all information needed for doing safety and criticality analyses and for eventual disposal in a repository.

The teams established a schedule for site visits and determined the equipment needed to perform the mainly visual onsite examinations. A program was put together to train and qualify people on how to set up and operate the inspection equipment, and what kinds of defects to look for.

The countries that have returned fuel to Idaho since 1997 include Indonesia, South Korea, Slovenia, Germany, and Italy. A shipment from the United Kingdom is planned for this year to be followed by Germany, Indonesia, Japan, and the Congo. There are two categories of countries, paying and nonpaying, based on United Nations criteria. The DOE arranges for the canisters and shipping for the nonpaying countries.

Hill presented pictures of some fuel showing pitting, blistering, pinholes, cladding perforations, penetrations, cracks and tears, corrosion, microbes and other deposits, and other damage to fuel pins. If the amount of damage found suggested that pieces could be broken off during shipping, the fuel would have to be enclosed so that any loose material would not scatter inside the shipping cask.

Impact of nonproliferation

The session on "The Impact of Nonproliferation Measures on the Future of the Nuclear Fuel Cycle–I" provided the civil nuclear industry an opportunity to discuss how nonproliferation may influence the civil nuclear industry and vice versa. It also allowed ANS members, as noted by the panel's chair (and outgoing president of ANS) Andrew Kadak, to input technical information into the debate.

Roger Hagengruber, of Sandia National Laboratories, went through some of the history of society's attempts to build institutions to prevent war. The failure of such institutions earlier in the last century led to two world wars. Since then, new institutions have been created to deal with the threat of nuclear war and nuclear proliferation, including the United Nations, the Nuclear Non-Proliferation Treaty, and the International Atomic Energy Agency. These are attempts to manage the political risks, as well as the vast amount of nuclear material and wastes that continue to accumulate.

But, as the nuclear proliferation of the 1990s has shown, "the triggers of war do not disappear," Hagengruber warned.

Continued

In the 1950s, President Eisenhower's Atoms for Peace plan led to the setting up of the IAEA to control the risks of proliferation by providing countries with nuclear technology in return for not developing weapons. This did, however, also require an international safeguards system to monitor countries.

Since the end of the cold war, there have been attempts to build stronger institutions for arms control and nuclear material management. There has also been, however, a proliferation of nuclear weapons. Other elements have also entered into the equation: Energy and the environment have become major factors; international collaboration is increasing; and new technologies capable of supporting arms control and nonproliferation are becoming available.

Hagengruber believes that a "unique and perishable opportunity" now exists for developing a coherent management scheme. But it needs leadership. He optimistically points to a century of experience and hopes it can be put to good use.

John Taylor, former vice president for nuclear power at the Electric Power Research Institute, is now involved in the Nuclear Energy Research Advisory Council's work on nonproliferation. He argued that besides devising institutional barriers to proliferation, technical ones, such as proliferation resistant technologies, are needed. This will help keep open the nuclear option, he explained. There is also the need to improve nuclear material management, including the IAEA's safeguards regime, with better technology, such as digital telecommunication detection systems, he said. Collocating facilities, such as power production and reprocessing, also has advantages, such as reducing the transportation of nuclear material.


Taylor

Taylor warned that now may not be a good time to promote some of these concepts, which may be incompatible with existing facilities operated by "reliable organizations which do not pose a proliferation threat." At the moment, he says, there is little dialog with overseas "recyclers" and it could be unproductive to push them into accepting improvements in the proliferation resistance of their facilities. The U.S. needs to build bridges here, he noted.

Marv Fertel, of the Nuclear Energy Institute, gave an industry perspective on these issues. His main points were that the United States has an obligation to provide leadership and that the country must become more involved in developing nuclear energy and less isolated from the other players. He stressed that "we do not have a legitimate seat at the table without a strong nuclear program, including on nonproliferation R&D issues."

Fertel suggested that a new and expanded vision of nonproliferation was needed that takes account of the importance of energy supply, particularly vital for the resource-poor developing countries, and environmental issues. He also expressed his belief that reprocessing and other nuclear technologies will be needed to expand energy resources.

Bob Ebel, director of the CSIS (Center for Strategic and International Studies) Project on Global Nuclear Materials Management, was particularly concerned with issues affecting U.S. leadership. He sees U.S. influence in global nonproliferation weakening and made a number of relevant points:

■ U.S. defense policies are worrying much of the world, notably our desire to develop the National Missile Defense (NMD) system. Ebel said that the United States may see NMD as necessary for its own interests, but developing it will have consequences for its relationships with other countries.

A "unique and perishable opportunity" now exists for developing a coherent managing scheme.

■ U.S. expertise is dwindling: there are no plans for building nuclear plants; weapons and nuclear facilities are aging; the country's nuclear expertise is declining and its experts retiring; and funding is falling.

■ Other countries are still planning to increase their nuclear power programs, including Russia, China, and Japan.

■ The geopolitics of energy is changing. By 2020, the developing world will be consuming more energy than the developed nations. They will turn to the nuclear option.

■ U.S. influence was unable to stop Pakistan and India from nuclear proliferation.

The next administration will have to make some crucial decisions on the issues raised here, which will affect the country's leadership potential in the coming decades. "Good leaders lead by example," he said. "The opportunity to define a new age in post–cold war relations is at hand."

While President Clinton was completing plutonium disposition negotiations in Moscow, Cheri Fitzgerald, of the DOE's Office of Defense Nuclear Nonproliferation, part of the newly established National Nuclear Security Administration, described this and other programs that are under way with the Russians.

She began by describing a new initiative included in the FY 2001 budget proposals, the $100-million Long-Term Nonproliferation Program for Russia. Fitzgerald noted that this program is in line with the policy of Vladimir Putin, Russia's new president, to convert his country's military complex into a successful civilian industry that he called the "priority sector" for returning Russia to being a great power. She sees this as a window of opportunity to push forward disposition programs.

The new long-term program is divided into two main parts:

I. Nuclear fuel cycle ($70 million)—Fitzgerald stated that although the two countries have been working for more than eight years on weapons material disposition, there has been little cooperation on the civilian side. The objectives here include preventing the further accumulation of separated civil plutonium, enhancing the proliferation resistance of reactors and the fuel cycle, and securing the present stockpile of spent fuel.

She pointed particularly to Russia's annual production of 2 t of plutonium from the civil fuel cycle, while the United States is spending money to remove 2 t of plutonium per year from the military program. "This," she said, "does not make a lot of sense." The new initiative will support the Russians in developing a dry store facility in return for placing a moratorium on the separation of civil plutonium for either 10 or 20 years. The documents defining the core principles for this program are now being prepared.

The development of the next generation of reactors and fuel cycle is of great interest to Putin, and the United States wants proliferation-resistance to be built into the Russian program. The funding for this is linked to Russia's ceasing to support Iran's nuclear program. Workshops are planned to flesh out the activities.

II. Russian nuclear infrastructure ($30 million)—This includes further support of the Materials, Protection, Control and Accounting (MPC&A) program, where there are opportunities to blend down more high-enriched uranium and consolidate nuclear material. Another important activity is the accelerated closure of nuclear weapons production facilities and their conversion to non-weapons work. There is also money for Russia to initiate a foreign research reactor spent fuel return program.

As for the MPC&A program, U.S. personnel are now in 30 sites around Russia helping to improve security. Fitzgerald said that about 450 of an estimated 650 metric tons of material held by Russia's military complex is now secure. Similar work is under way in other former Soviet countries.

She also described the status of the plutonium disposition agreement. The negotiations for this began two years ago with the signing of a cooperation agreement. Since then, work has been under way on small-scale tests and demonstrations of the technologies to be employed. This year, the DOE is looking to complete the design for a demonstration-scale plutonium conversion system in Russia, the design of lead test assemblies of MOX fuel, and the MOX fuel manufacturing lines for VVER-1000 reactors. R&D will continue on gas reactor technology for Russian Pu disposition and on immobilization feasibility studies.

Fitzgerald also mentioned other achievements: At Aktau in Kazakhstan, 3 t of plutonium at the BN-350 breeder reactor is now secure under IAEA safeguards. Also, 80 metric tons of Russian high-enriched uranium have already been irreversibly converted to low-enriched uranium for burning in U.S. power reactors.

Dick Stratford works on nonproliferation issues in the State Department, and heads the U.S. delegation to the nuclear suppliers group. He started his talk with a useful division of the nonproliferation regime into six parts:
1. International treaty obligations.
2. Safeguards.
3. Multilateral export controls.
4. Individual suppliers' bilateral cooperation.
5. Specific country issues (Iraq, Iran, North Korea, India, Pakistan).
6. Dealing with fissile materials.

The last area, Stratford says, is where the money and technical effort rightly goes.

He then presented his views on a number of issues, noting that he was speaking only for himself and not for the State Department or the government. These included the following:

■ The current generation of light-water reactors is proliferation-resistant, providing there is no reprocessing. He applauds the IAEA's strengthened safeguards regime, which converts the agency from being accountants to being detectives. He called it a significant change in approach, not just more of the same.

■ Proliferation-resistance should be an integral part of next-generation reactors. He supports a multilateral development of reactors that are safer, more economical, and produce less waste, as well as being more proliferation-resistant.

■ U.S. policy on reprocessing and weapons-usable fissile materials has been remarkably stable over the last 20 years. But there is a lingering concern that the United States will "go back to the pulpit" and try to close down reprocessing and MOX programs in Europe and Japan. Stratford believes, in fact, that the policy is not as strongly ideological as some believe, pointing to the country's willingness to look at practical solutions to plutonium stockpiles. After all, the government has adopted a limited MOX burning program as a reasonable way forward.

He said that the U.S. priority for a moratorium on civil reprocessing in Russia is not its antireprocessing ideology coming out again. It is a practical, common sense approach to the specific problem. He asked if anyone would expect Congress to provide funds for Russia to get rid of 2 t of excess weapons plutonium a year if it were also producing 2 t of plutonium a year from the civilian program.

■ The United States needs to remain a major player in the power industry to give it influence with its industrial partners and to maintain technical know-how and leadership. He also believes that nuclear should get credit for environmental benefits.

■ Access to weapons-usable fissile material normally arises from waste management activities. This leads, he believes, to regional solutions for waste storage and disposal, whose time will come because it makes so much sense from a nonproliferation point of view. To bring this home, he pointed to the many countries of central and eastern Europe. Does the world want a disposal site in each of them?—*Dick Kovan*

TOPICAL MEETING

Using experience to improve safety

IN INTRODUCING A panel on nuclear safety at the opening plenary session of the Embedded Topical Meeting on Advanced Nuclear Installations Safety, held during the ANS Annual Meeting, Walt Simon, a senior vice president at General Atomics, pointed out that experience was possibly the most important source for improving safety.

Mike Hitchler, who represents Westinghouse at the Savannah River Site, described the good and the bad experiences in designing and operating nuclear facilities.

According to Hitchler, management at Savannah River had been failing for many years in many areas: Department of Energy requests were not being met and it seemed that people did not understand what was needed. He pointed particularly to weaknesses in areas such as project ownership, risk management, up-front planning, and technology management.

In 1997, the DOE, Westinghouse, and Bechtel teamed up to investigate the problems and come up with a plan to improve project management. It turned out that the source of many problems lay in the poor communication among the different groups working on a project. The engineering, safety, and operations groups spoke different languages and used different definitions. Efforts are now being made to break down traditional interactions between these groups and build up new relationships to ensure that they really do understand each other.

By examining several projects at Savannah River, the team came up with a number of "answers" that should help ensure that projects are safer and completed more successfully. These include:

■ Hazardous nuclear-chemical processing requires very large design margins.

■ Code compliance does not mean safety adequacy.

■ Security and safety requirements often compete.

■ Nuclear installation safety does not imply a reactor solution (NRC models of reactor safety may not provide the best method for assessing safety at waste facilities).

■ End users define technical baseline content (operators, not design engineers, are the users of a facility and must own the baseline).

■ Safety validates and optimizes the design.

■ Total life cycle costs should drive design, not just capital costs.

Major themes of the meeting:

♦ *Experience is possibly the most important source for improving safety.*

♦ *The IAEA has been very worried for several years about forgotten or stolen irradiation sources.*

Hitchler gave examples to illustrate some of these points:
1. The chemical process used at a large in-tank precipitation facility designed to remove high-activity cesium seemed simple. Operation started in 1984, but following a series of major problems, the facility was abandoned and is now being redesigned. The underlying problem was a lack of understanding of the chemical processes, along with uncertainties about what was in the tank. It turned out that the designers should have gone out to the chemical processing industry for directly relevant advice. Had they done so, some very fundamental errors might have been avoided. For example, instead of precipitating large batches of the liquid waste very slowly, the designers should have used a rapid process in small batches, which would have been inherently safer.
2. Hitchler discussed some important lessons from the Tokaimura criticality accident based on the report by DOE personnel who went to Japan to assess the accident with the Japanese authorities.

The conversion plant was originally licensed in 1980 for low-enriched uranium (5 percent). The design was criticality safe. In 1984, the plant moved from low-enriched uranium to intermediate-level enrichment of up to 20 percent without a good review of criticality safety. In 1986, to speed up the process, material was placed in buckets and stirring/mixing done by hand; at the same time, deliberate over-batching was allowed. This was not part of the license and was not approved. Nevertheless, this procedure was used for many years, and "nothing bad had happened." But, the final changes to the procedure, which included skipping a critical storage phase, as well as significant over-batching, resulted in the accident.

Hitchler listed a number of factors that contributed to the accident and many lessons learned. In particular, workers did not understand the process or the implications of deviations from the technical baseline. They did not understand or appreciate the built-in safety features or the emergency procedures.

The lack of understanding did not only involve the process operators. It went much farther, as shown by the delay of several hours in evacuating the public from the area and the length of time—more than 20 hours—to terminate criticality. This was also due to erroneous perceptions. The small size of the facility and the simplicity of the process contributed to people's being lulled into a false sense of security. They did not believe that a criticality incident was credible and did not prepare for such an event.

3. An example of lessons being successfully applied was the design of the spallation neutron source (SNS), which is to become the country's major pulse-neutron facility. In this case, the designers came to understand that the safety people were a plus, not just an add-on. The two groups taught each other their languages, and could understand where each was coming from. Together they looked at the target facility and identified where the hazards were and where safety was an issue. They came up with a bunker approach, producing a design with a small radiation hazard zone, which provided considerable savings in cost and dose.

Finally, Hitchler listed some of the main lessons he learned, such as identifying common themes from successful projects; facing problems early; training engineering staff on safety programs and safety staff on the engineering programs; and involving all stakeholders early. And finally, he stressed: "We had illusions that we were communicating. We were not. . . . The issue was really about understanding."

Thai irradiation incident

There were more critical human lessons from last February's irradiation incident in Thailand, in which three people died. The events were described by Patham Yankate, Deputy Secretary General of the Office for Atomic Energy for Peace (OAEP), who was directly involved in the recovery of the 425-curie cobalt source. About 40 OAEP staff took part. Six of them received doses of 20–30 mSv. After the source was located, it was grabbed using a long tong. Patham showed pictures of some of the victims who handled the source.

A very important lesson came at the end of Patham's talk, when someone made the comment that it was fortunate that incidents like this were rare. This comment was met by an immediate shout of "Not true!" by the next speaker, Annick Carnino, who said that there were all too many accidents involving such sources. Carnino, the director of nuclear installations safety at the IAEA, said that the agency has been very worried for several years about forgotten or stolen sources, and is putting together an international program for improving control of these devices.

Carnino

Carnino was one of several IAEA staff members invited to San Diego to describe the central roles that the agency plays, particularly on safety and the management of fissile materials.

The agency retains a dual role, promoting the benefits of nuclear technology while controlling its potential abuse. One of its main activities is developing a Safety Standards series, which provides a worldwide reference for the technology. The standards described are mandatory for countries that accept IAEA technical assistance. This includes countries that do not have a nuclear power industry, but are involved in nuclear research, medicine, agriculture, and other applications. The IAEA produces other safety-related documents, which, being approved by the member countries, noted Carnino, "really do represent a consensus."

The agency also provides a range of technical services, such as peer reviews of safety management at nuclear power stations and engineering safety reviews that cover, for example, design, seismic events, fire, aging, and software safety. Reviews have been done for several new designs, such as the advanced VVER-1000 model 428 being used for the Tianwan project, which was reviewed at the request of China. These reviews cover the integrity of primary circuit, I&C, accident analysis, neutronics, the PRA, the site (when known), etc.

The agency has just looked at the design for South Africa's pebble bed modular high-temperature reactor (PBMR). This did not follow the usual review procedure, as there are no standards to refer to and little relevant experience of operating this type of system. The review team told the South Africans that more information was needed to convince them that the safety features claimed for the system would work as described. The agency suggested that they set up an experimental program to test its features and to acquire data on the behavior of the reactor, including, for example, the integrity of the primary circuit, the applicability of the safety codes, and the reliability of the fuel. Carnino pointed to the lack of a large containment structure such as light-water reactors have; the project must demonstrate that it is not needed because the system includes enough levels of defense. Nevertheless, the system has many advantages and the IAEA is willing to play a role.—*Dick Kovan* NN