Minutes for the
Nuclear Energy Research Advisory Committee Meeting
September 30 to October 1, 2002, Sheraton Crystal City Hotel, Arlington, Virginia

NERAC members present:

John Ahearne
Thomas Cochran
Joseph Comfort
Michael Corradini
Jose Luis Cortez
Maureen Crandall (Monday afternoon and Tuesday only)
Allen Croff
James Duderstadt (Chair)
Marvin Fertel (Monday only)
Beverly Hartline
Andrew Klein
Dale Klein (Monday only)
Robert Long
Warren F. Miller, Jr.
Sekazi Mtingwa
Richard Reba (Monday only)
Joy Rempe
Allen Sessoms
Daniel Sullivan
John Taylor
Neil Todreas
Joan Woodard (Monday only)

NERAC members absent:

Steve Fetter
Leslie Hartz
J. Bennett Johnston
Linda C. Knight
Benjamin F. Montoya
Lura Powell
C. Bruce Tarter
Ashok Thadani (ad hoc)
Charles E. Till

Also present:

Ralph Bennett, Director for Advanced Nuclear Energy, Idaho National Engineering and Environmental Laboratory
David Berg, Office of Environmental Management, DOE
Nancy Carder, NERAC Staff
Herbert Feinroth, President, Gamma Engineering Corp.
John Gutteridge, University Programs, NE, USDOE
Norton Haberman, Senior Technical Advisor, NE, USDOE
Anthony Hechanova, Director, AAA University Participation Program, University of Nevada at Las Vegas
R. Shane Johnson, Associate Director, Office of Technology and International Cooperation, NE, USDOE
Silvia Jurisson, Department of Chemistry, University of Missouri, Columbia
Owen Lowe, Associate Director, Office of Isotopes for Medicine and Science, NE, USDOE
William Magwood, Director, NE, USDOE
William Martin, Washington Policy Institute
Leonard Mausner, Medical Department, Brookhaven National Laboratory
Corbin McNeill, Chairman, Exelon (ret.)

Kyle McSlarrow, Deputy Secretary of Energy Designate
Thomas Miller, NE, USDOE
Frederick O'Hara, Jr., NERAC Recording Secretary
Claude Oliver, Commissioner, Benton County, Washington
Andrew Paterson, Scully Capital
Harold Ray, President, American Nuclear Society
Michael Schmidt, NERAC Staff
Michael Sellman, President and CEO, Nuclear Management Company
Vincentica Valdes, Department of Civil and Mechanical Engineering Technology, South Carolina State University
David Wade, Director, Reactor Analysis Division, Argonne National Laboratory
Ralph White, Dean, College of Engineering and Information Technology, University of South Carolina

About 40 others were in attendance during the course of the two-day meeting.

Monday, September 30, 2002

Chairman **James Duderstadt** called the meeting to order at 10:08 a.m., welcomed the members, and had each introduce himself or herself. He pointed out that much of the work of the Committee is done by the subcommittees. He accepted and approved the minutes of the prior meeting. He introduced **William Magwood**, Director of the Office of Nuclear Energy, Science, and Technology (NE), to give an update on recent developments in the nuclear energy program.

The Office has several new initiatives to work on. The first off the ground was the first stage of Nuclear Power 2010. The Department has selected three U.S. electric utilities (Dominion Energy, Entergy, and Exelon) to participate in joint government-industry projects to demonstrate the Early Site Permit (ESP) process of the Nuclear Regulatory Commission (NRC) and to seek NRC approval for new nuclear plants by the middle of the decade. The second development was the Secretary's announcement of the reorientation of the management of the Idaho National Engineering and Environmental Laboratory (INEEL) from Environmental Management (EM) to NE, the revitalization of the laboratory's nuclear R&D mission, and its designation as the central point for Gen-IV activities. And the third is the agreement by the Generation IV International Forum (GIF) on the selection of six advanced reactor and fuel-cycle technologies for joint development. The Office is pleased with the outcome of this effort and is looking forward to working with the other countries on these technologies.

NE's total budget request for FY03 ($250.7 million) was lower than the FY02 appropriation ($292.1 million); however, Congress is moving toward a higher number (the Senate markup is $323.6 million).

Ahearne asked if he had a line-item number for INEEL. Magwood said that EM and NE are working on that target.

Duderstadt asked why the House zeroed out the Fast Flux Test Facility (FFTF). Magwood responded that they moved it from NE to EM. There may be a need for fast neutrons in the future. We are talking with the French and Japanese about using their facilities and perhaps the Russians will be consulted about the possibility of using their facilities in the future.

Miller asked if programs will be moved from other laboratories to the Idaho site, specifically to Argonne National Laboratory-West (ANL-W). Magwood replied, no. DOE has moved a program from Mound Laboratory to INEEL for security reasons. Most of the activities that are being discussed here are at INEEL already.

Reba pointed out that the isotope program is missing and asked if this omission meant that none of the recommendations of the Research Isotopes Subcommittee would be considered in the future. Magwood responded that NE's responsibilities in research-isotope production were mostly in the form of facilities. DOE is not subsidizing future research-isotope production. Congress is wrestling with how to deal with that topic. With the National Institutes of Health (NIH) getting so much medical-research funding, DOE lost support in key areas in Congress for the Advanced Nuclear Medical Initiative (ANMI). Reba said that the community needs as clear a message as possible about what is going on, and that message is, "No, NE will no longer pursue those recommendations." Magwood observed that the situation is more complicated than that. NE has kept some ideas (e.g., the isotope cyclotron) alive in its facilities budget. Reba asked if the facilities will be available to manufacture research isotopes. Magwood said, yes; that topic will be discussed later. However, how it is done will involve major changes.

Mtingwa asked how well the new process for ordering research isotope production runs is working. Magwood responded that it is too soon to tell, but it seems to be moving forward well. He asked Leonard Mausner of Brookhaven National Laboratory what BNL had experienced. Mausner responded that they had not received any advance orders for isotopes. Magwood said that the word needs to get around about sources for isotopes; NE has been talking with NIH about this problem. Mtingwa asked if funding for the 70-MeV cyclotron project ($200,000 plus $600,000 from markups) is still in the budget. Magwood said that he understood that it was.

Ahearne asked why $8 million was taken out by Congress. Magwood answered that Congress looked at unobligated funds and decided that NE did not need that funding. As a result, NE will need to find funding for some projects that had been planned.

Long asked if DOE will request more money for the Nuclear Energy Research Initiative (NERI), Nuclear Energy Plant Optimization (NEPO), and University Programs in FY04. Magwood replied that the Secretary is interested in supporting a strong nuclear power program, but these are difficult budget times. Duderstadt commented that the National Academy of Sciences (NAS) has been looking at better ways for evaluating R&D. The Office of Management and Budget (OMB) did not know how to apply these evaluation procedures to NE this year but should do a better job in FY04 and beyond.

Cochran asked if the funding for the Advanced Fuel Cycle Initiative (AFCI) includes hot cells etc. at INEEL. Magwood responded, no; it is still early in the transition of INEEL to identify specific needs like those. The picture will become clearer as that process proceeds.

The NE budget is moving toward the goals that we had set for ourselves. If we keep moving in the same direction, the prospect of making those goals is good, although priorities have changed over the years.

Ahearne noted that the interesting point in a graph of funding level of NE during the past decade is the drop in some programs and where the dollars are going. Duderstadt noted that, clearly, there has been interest on the Hill for keeping the nuclear option open, but those priorities have not been established at OMB and in the administration.

Magwood noted that the Department now has a Secretary who is on NE's side and is fighting to make increased funding for nuclear energy happen. Secretary Abraham went to Tokyo for the Gen-IV meeting and elsewhere to promote a nuclear R&D program. This is a sea change at DOE.

Dale Klein asked what the Executive Committee of NERAC can do in DOE and OMB to influence the directions of the FY04 budget. Magwood said that he would keep them informed. He introduced **Kyle McSlarrow**, Deputy Secretary Designate.

McSlarrow said that he had come by to say thank you for the Committee's work and support. It has had a huge impact on the policy and intellectual revolution that has occurred. The Committee will have as much work in front of it as it has had in the past. The Department has a vision for nuclear energy. Any rational national energy plan has to have nuclear in the mix and, therefore, has to deal with nuclear waste. he said that he believed that the Committee members will be heartened by the FY04 and future budgets.

Duderstadt called upon **Thomas Miller** to present an update on Nuclear Power 2010. The program was announced in February of 2002 by Secretary Abraham, and it is a direct outcome of the work started by this Committee. Its goal is to achieve an industry decision by 2005 to deploy at least one new advanced nuclear power plant by 2010. Cooperative activities include regulatory demonstration projects [ESP and Combined Construction and Operating License (COL)]. The reactor-technology-development projects include NRC design certification; first-of-a-kind (FOAK) engineering for a standardized plant; and material, component, and system testing.

Ahearne asked what his definition of "deployment" was. Miller replied, an aggressive schedule leading to the beginning of construction. Magwood commented that a presentation would be made the next day on the business case for nuclear power. Currently, utilities are not interested in building anything because of the influence of capital outlays on earnings per share. It is an economic as well as a technical question.

The Near-Term Deployment Roadmap was completed in October of 2001, and the business-case study has been completed. The site scoping study (the first done) was completed; the results for the cost-shared projects with Dominion and Exelon were completed this past summer. The study covered several commercial and federal sites; the top ones to be studied are (North Anna, Clinton, and Savannah River). The final report will be issued the end of September.

Corradini asked why these sites ended up as the top sites. McNeill cited market forces and site characteristics as the driving issues. Corradini asked about Grand Gulf. Miller said that a proposal was received from them but it did not meet the criteria. Cochran asked Miller to review the budget for this. Miller responded,

FY03	$38.5 million
FY04	$39.5 million
FY05	$42.5 million

ramping down thereafter and ending in FY08.

Cortez asked if they had studied the possibility of a federal demonstration program. Miller noted that this is a utility-led effort. The federal work is in site permitting etc.

Four-year, cost-shared ESP demonstration projects have been initiated with Dominion, Exelon, and Entergy. Current activities include coordinated application development among the utilities; the initiation of site environmental studies and data analysis; finalization of subcontracts and administrative requirements; coordination of the Plant Parameter Envelope approach, which was presented to the NRC in September; and site visits, which are occurring now. The Plant Parameter Envelope approach allows a broad list of technologies to be selected later on. This process is proving to be painful, but the participants are working hard to bring it about. The technologies are to be selected by 2004; that decision may be long in coming. Woodard asked how many proposals were received. Miller responded, three. McNeill pointed out that there are only three major nuclear utilities.

The next steps include initiating cost-shared reactor-technology-development projects with nuclear steam supply system (NSSS) vendors, completing design certification on two advanced reactor designs, and FOAK engineering (e.g., component testing) on one advanced reactor design. The program plans to initiate a construction-technology assessment next year as a utility cost-shared project, evaluating the schedule and construction methods of advanced reactor designs, making sure that they can actually be achieved. The Japanese completed a plant in 4 years with this technology. The program is looking at several options and expects to initiate COL demonstration projects by forming a utility/reactor vendor consortium, exploring a multi-utility collaboration for multiple COLs, award cooperation agreements in FY04, submit the COL application to the NRC in FY05, and have the COL issued in FY07. This schedule would leave 3 years for construction.

Duderstadt said that he would expect the vendor to be interested in a global market and asked if this program is designed to build domestic capacity. Miller replied, yes, it is designed to build the plant in the United States. Comfort asked what the nature of the federal assistance to the vendor is. Miller responded, cost sharing, particularly in design. McNeill commented that the plan is to get an independent generation plant that agrees to build a plant. The cost is then split between the government and the vendor. The vendor would consider how many potential plants they would need to split that cost cover (e.g., eight) to make it economically viable and then decide if an adequate market exists to justify that investment.

Cochran asked if that was the government view. He did not believe that a good view was being attained of the subsidy needed to make this program work. Ray said that being able to pay the debt back is the key here, not a subsidy. The utility needs a credit-worthy revenue stream, not just a contract. Magwood noted that there is a clear distinction between pursuing advanced technology and pursuing light-water-reactor (LWR) technology. It would be necessary for the government to put up $400 to $500 million to deploy a reactor in this timeframe. The government is wrestling with what its activities should be. This program should pave the front end (the regulatory processes) while leaving the real lifting to the utilities. One need is to help utilities with devising sophisticated financial management.

Mtingwa asked what happened to the excitement over the pebble-bed reactor. Miller responded that Exelon made a decision not to pursue that pathway, and no other U.S. utility was interested in it. The government would have done fuel-particle testing. ESCOM (the South African utility) is still moving forward with the concept.

Duderstadt readjusted the schedule and called upon **John Ahearne** to review the status of the joint DOE/EPA study of the impact of nuclear power on air quality. This Subcommittee effort has been a slow process. The U.S. Environmental Protection Agency (EPA) was to have run its cost minimization model through 2020. Nuclear power plants obviously do not produce NO_x and SO_x, so the critical question is, "Can nuclear power bring the total cost of electricity production down?"

The major variables include the cost of gas, capital costs of nuclear power plants, and regulatory caps on emissions that fossil plants would have to meet.

Preliminary findings have been arrived at; the final reports are expected at the end of next summer. Cost and performance estimates provided by DOE were put in the model with:

Case 1. *Annual Energy Outlook* (AEO) 2000 nuclear cost assumptions

Case 2. The "optimistic" nuclear-cost assumptions provided by DOE

Case 3. The "optimistic" nuclear-cost assumptions and gas-cost sensitivity

In Case 1, nuclear declines; in Case 2, nuclear starts to rise but still is at a deficit; and in Case 3, nuclear rises to prominence.

The Clean Skies Initiative would place caps on pollutant emissions. These caps are reflected in Case 4; these caps plus the NE ("optimistic") costs make up Case 5; and gas sensitivities added to all of these other variables make up Case 6. These cases are just being run, but Case 6 seems to have nuclear bringing in more coal (through competitive costs) and, therefore, more pollution. The preliminary results indicate that, in 2020, the capacity of nuclear power plants in gigawatts would be

Case 1	72
Case 2	85
Case 3	117
Case 4	72 (no different than base case)
Case 5	87
Case 6	123

The Energy Information Administration (EIA) is changing its numbers because it is seeing more relicensing and fewer retirements of nuclear plants than had been expected. These revised values will affect future runs of the model and its results.

McNeill observed that CO_2 might become taxable and that would change the situation tremendously.

Dale Klein asked if the EPA model reflects the shutting down of older plants. Ahearne responded that it does, but only if the shutdown is called for on an economic basis.

McNeill said that this modeling is very nice from a long-term perspective. But gas plants were built because the industry thought nuclear plants would be retired. That has not happened, and the industry is finding that gas plants are more expensive to operate.

Cochran noted that, at the beginning of the Gen-IV process, the program was looking out 30 years to solve economic, security, etc. problems. Now, the nuclear community is looking at an 8-year plan (being called Gen III+), which is focusing on licensing. The Department has refused to talk about economics while reducing licensing risk. No assurance is being given that there will be anything at the end of the pipeline. Either CO_2 must be controlled (which is outside the congressional and administrative will), or higher gas costs must be postulated (for which there is no evidence), or optimistic nuclear costs must be adopted (at a time when investors are walking away from domestic nuclear investment and looking abroad). He said that he did not think the timing is right for reducing the risk of licensing. All of these economic issues must be treated together.

Woodard asked if EPA has a plan to perform a kWh-by-kWh analysis of the impact on the quality of life. Ahearne replied that the EPA model can handle anything that has a cost associated with it, such as carbon tax. So far the model shows that such a tax has to be very high to make nuclear attractive.

Taylor, getting back to Cochran's comments about an 8-year plan, said that the study of the mid-term development effort was requested by DOE a year ago. The report from that study made it clear that many issues had to be addressed up front to determine what the economics are and that that analysis can be done with little cost.

(Crandall arrived at 12:04 p.m.)

Ray stated that one should not dismiss the idea that low-emission plants, including renewables, can be built and economically operated. There will be places in this country, though, where nuclear technology would be economical. McNeill added that, if the subsidies given to conventional plants were extended to nuclear plants, the utilities would be flooded with investment funding.

Duderstadt asked the attendees to get food and bring it back to the table for a working lunch. After a brief pause for that purpose, **John Gutteridge** said that University Programs' budget has not gone up, but it is starting a new program. Enrollments in departments of nuclear engineering are way up, some showing a tenfold increase during the past two years. The Cornell reactor closed, and there are concerns about the University of Michigan reactor. He then introduced the luncheon speakers, who were from NE's University Programs, starting with **Vicentica Valdes** from the South Carolina State University (SCSU) Nuclear Engineering Program. That university administers the Minority/Majority University Partnerships (MMUP) in Nuclear Engineering and Health Physics, which are sponsored by DOE/NE and which address that decline in the number of independent nuclear engineering programs and the increasing workforce requirements in nuclear science. The partnerships do this with minority-education awards between minority institutions and nuclear-engineering programs at major universities. A pilot program involving SCSU and the University of Wisconsin (UW) is currently under way.

The program is based on the SCSU-UW Articulation Agreement, signed July 2000 and approved by the South Carolina Commission on Higher Education September 2002. The Agreement provides for a BS in nuclear engineering from SCSU/UW, a BS from SCSU with a BS in nuclear engineering from UW, and a BS from SCSU with an MS in nuclear engineering from UW (either regular or fast-track). Students attend classes at both universities, some by distance learning (sometimes paying out-of-state tuition). The first graduating class is expected in summer 2006.

Hartline asked if those classes will be brought to SCSU. Valdes replied, No; one of the benefits is using the UW reactor.

South Carolina was chosen partly because almost 60% of the electricity demand in the state is met by nuclear power; seven power reactors are in the region; and the Oconee units have successfully renewed their operating licenses. Also, the Savannah River Site in Aiken offers internship opportunities for faculty and students, which can provide hands-on experience and state-of-the-art equipment.

The program is creating nuclear-engineering career paths. Students can go on to graduate studies, national laboratories, or industry. A successful program will create a steady supply of quality students prepared for careers in nuclear engineering. SCSU is using a three-pronged attack: recruiting and retaining students and faculty, collaborating with other universities and industry, and conducting research at the undergraduate level. The goal is to increase the number of students in the program through visiting high schools, solidifying contacts with high-school counselors and teachers, and expanding presentations on the role of radiation in everyday life. A marketing brochure has been produced.

Limited scholarships of about $78,000 over four years are available to qualified students. reducing this amount by using other programs and funding sources is a priority.

Research opportunities and collaboration with industry and academia are being sought with the aid of SCUREF [South Carolina University Research and Education Foundation] and others. Quality research proposals are being produced by partnering with industry and major universities. Collaborations with industry are being strengthened through the development of the SCSU Radioisotope Laboratory and the formation of a Nuclear Engineering Subcommittee of the Industrial Advisory Council. The SCSU Nuclear Energy Student Center will enhance the educational experience at SCSU by providing tutoring in mathematics and science, developing and implementing recruiting ideas, establishing the SCSU Student Section of the American Nuclear Society (ANS), and institutionalizing research at the undergraduate level.

SCSU students have already successfully completed 41 units at UW, 12 students are enrolled in the program, a new faculty member has been added, a relationship has been established with the Savannah River Site (SRS) for faculty and student research participation, and the students have applied to become an ANS student section. A major recruitment drive is under way in South Carolina high schools. Nationwide connections are being exploited to bring other minorities to SCSU. And relationships will be established with other nuclear-engineering programs.

Hartline noted that many of the national laboratories have research internships and other training programs for students. She asked Valdes about the school. Valdes responded that it has 4000 students on its Orangeburg, South Carolina, campus. It does not have the facilities that a nuclear engineering program needs. It only offers bachelor's degrees.

Gutteridge introduced **Anthony Hechanova** to speak about their transmutation research program funded under DOE's Advanced Accelerator Application (AAA) program at the University of Nevada at Las Vegas (UNLV). Hechanova distributed copies of the program's first annual research report. The program's mission is to establish a world-class program for transmutation research and education through faculty-supervised graduate-student projects. The goals are to build core competencies and facilities to promote UNLV's strategic growth, to increase UNLV's research activities (they are conducting 12 projects now), and to attract students and faculty of the highest caliber.

He reviewed the organization charts of the university and of the Harry Reid Center; many of the university's administrative personnel have advanced degrees in engineering and are very supportive of science and technology. The transmutations program is the president's top research priority. The program has four components:

- student research;
- program management, including stakeholder involvement, that is funded at $500,000 to $700,000 per year and that requires that all proposals be coauthored with national laboratory personnel;
- facilities enhancement, including a materials performance laboratory (MPL), electron microscopy and imaging laboratory, transmission electron microscopy laboratory (TEML), and lead-bismuth eutectic facilities (LBEF); and
- international collaboration.

The university does not have a nuclear engineering degree program but hopes to have one in place by the fall of 2003. It is requesting from Congress:

- program growth to \$6.5 million annual support for the Advanced Fuel Cycle Initiative;
- \$4 million annual support for the accelerator-driven systems mission;
- major new facilities (MPL, TEML, and LBEF);
- 21 graduate assistantships in FY01, 28 in FY02, and 35 in FY03;
- new academic programs in radiochemistry, material sciences, and nuclear engineering; and
- new faculty.

Gutteridge introduced **Ralph White** to describe the programs of the College of Engineering and Information Technology at the University of South Carolina (USC). He noted that at least 50% of the electricity produced in South Carolina is produced from nuclear energy and that there are seven nuclear power plants in the Carolinas. In addition, nuclear fuel is produced in the Westinghouse plant in Cola, S.C. Currently, there is a huge undersupply of graduates in nuclear engineering to staff those plants (with a ratio of 3.6 to 1 in demand and available supply), and the situation is getting worse. USC now has a graduate program in nuclear engineering. The University formed an advisory board in the fall of 2001, obtained state approval in the fall of 2002, started teaching courses in the fall of 2002, and had a new faculty position approved in the fall of 2002. It had help from SRS in setting up its program. It is now presenting one course, Introduction to Nuclear Engineering, to 12 students. It will offer two courses, Nuclear Materials and Nuclear-Waste Management, in the coming spring semester.

In January of 2002, it signed a memorandum of agreement (MOA) to perform collaborative R&D on producing hydrogen from nuclear power and on fuel-cell technology. To bring this technology to the University, tritium technology will be leveraged to maintain critical hydrogen scientists and engineers at SRS and to support the concept of SRS as an energy research park studying the use of high-temperature gas-cooled nuclear reactors to produce hydrogen as a way to promote energy security. Already at the University is a National Science Foundation (NSF) Fuel Cell Center and a NERI project on centralized hydrogen production from nuclear power. The NSF center has executed contracts with several regional industries, and Dupont has expressed interest. The NERI project is funded at \$1.35 million over three years and is partnered with General Atomics and Entergy. It postulates using either the sulfur-iodine thermochemical water-splitting cycle or high-temperature solid-oxide electrolysis to produce the hydrogen. The hydrogen programs are going to be integrated and coupled with the nuclear programs. Regional hydrogen users are numerous. The NSF center is currently under construction.

Fertel asked why enrollments are up. Gutteridge responded that the job market is up, funding is available for fellowships and scholarships, and a positive message has been put out from the administration about the need for nuclear power. In addition, the increase can be seen as a response to the marketplace, and much R&D funding is coming from the NIH.

Mtingwa acknowledged and praised the great strides that have been made in University Programs and especially noted the work of Craig Williamson. Duderstadt introduced **Shane Johnson** to give an update on the Gen-IV Program. The GIF is a government-chartered organization of ten countries working together to plan the future of nuclear energy. It also includes some observer organizations; the Organisation for Economic Cooperation and Development's Nuclear Energy Agency (OECD-NEA), International Atomic Energy Agency (IAEA), and Euratom have had input into the Gen-IV roadmap. The Russians still are not on the organization chart; some international issues are preventing them from being invited; it is hoped that that day is coming soon. A parallel research under the IAEA does include Russian participation.

The GIF is intimately connected with NERAC's Gen-IV roadmap. He gave an overview of the GIF. It recently met in Tokyo to determine how to go forward. Each country identified its particular interests in the selected technologies, which will allow assigning lead roles for each of the technologies.

Cochran asked if the results are those of the GIF or of NERAC. Johnson responded, both. Cochran stated that, therefore, believed that DOE was in violation of the Federal Advisory Committee Act (FACA). Magwood said that he did not believe that was true because DOE has not taken any final steps or made any commitments.

Johnson continued: The initial thinking about how to proceed is to have a policy group and a group of technical experts. These groups would operate jointly and would establish a technical committee for each of the selected technologies; each technical committee would include a member from each country represented in the GIF. Each technical committee would have a steering committee for each research project called for by that technology; the members of the steering committee would be from the countries paying for that R&D. Each steering committee would then oversee a series of R&D tasks. It is hoped that arrangements will be in place for implementing R&D next year.

After looking at the list of expressions of interest made in each reactor technology, Comfort commented that it seemed like the molten-salt reactor was a dead issue; only four countries expressed any interest in it and, in each case, that interest was "low." Johnson said that it was not a dead issue; it is just that no country made it a high priority. Magwood commented that many countries saw it as farther down the road; 5 or 10 years from now, it may be of interest.

Sessoms observed that, in the past, the United States has had difficulties in getting other countries to live up to the commitments they made in international agreements and asked how the GIF would manage the participation of countries like Argentina and Brazil that, because of economic pressures, may not want to carry out activities that they do not consider of high priority. Johnson responded: very diplomatically; Argentina and Brazil have been very active in the GIF but have made it clear that they would be interested in investing in only one technology. Cortez suggested that, given the countries, their expressed interest, and their economic conditions, perhaps the number of technologies pursued should be cut back.

Duderstadt introduced **Neil Todreas** to present the Gen-IV Roadmap Subcommittee report. Todreas, in turn, introduced **Dave Wade** to speak about dose comparisons of once-through and closed fuel cycles as a prelude to a discussion of the Gen-IV Roadmap.

The Gen-IV fuel-cycle options are meant to address the doses delivered to workers and to the public. The Gen-IV Fuel-Cycle Crosscut Group collected already-existing evaluations and prepared a briefing on what is currently known on the subject of doses from fuel processing and disposal. It looked at data compiled by the United Nations Scientific Committee on the Effects of Atomic radiation (UNSCEAR) for many decades for once-through fuel cycles. The UNSCEAR data are for public dose and worker dose at each link in the fuel cycle. For several potential closed fuel cycles, data were taken from the fuel-cycle parts of the OECD-NEA study, *Accelerator Driven Systems and Fast Reactors in Advanced Fuel Cycles: A Comparative Study* (2002), which provided calculational results for

- closed, multi-recycle, fast-reactor fuel cycles fed by LWR-discharged fuel;
- effects on operations-dose source terms; and
- effects on legacy-dose source terms.

The issue for evaluation is whether there is any indication from already-available information that would make dose considerations dominate over other considerations in future selections of Gen-IV fuel-cycle choices.

The group first looked at historical operating data, in which the Sievert (Sv) is used as the unit of dose to integrate all types of organ exposures. Worldwide, the individual average effective doses to the public from natural plus man-made sources (in mSv/y) are (by source):

Natural background	2.4
Diagnostic medical examinations	0.4
Atmospheric nuclear testing	0.005
Chernobyl accident	0.002
Nuclear power production	0.0002

He noted that the dose from nuclear power production is three orders of magnitude lower that diagnostic medical exams and four orders of magnitude lower than background.

The individual average effective dose to workers (in mSv/y) in various industries are

Nuclear fuel cycle (including uranium mining)	1.8
Airplane crews	3.0
Mining (other than coal)	2.7

Cochran took issue with the use of average annual dosages and said that cumulative lifetime committed doses should be used.

Wade said that natural sources dominate the effective dose to the public. The geographic variability of those natural sources dominate the sum of all man-made effective doses delivered to the public. Of all man-made contributors to the public's effective dose, diagnostic medical procedures dominate by a factor of 100 or more over all other man-made sources. The effective dose from nuclear power production is a factor of 2000 less than that from medical diagnostics. Within this context, the effective dose contributed by the nuclear-energy fuel cycle is dominated by reactor operation, mining is less than one-half, and reprocessing is less than one-third.

Magwood asked if the right way to read these results is that the recycling numbers are low because not a lot of reprocessing is currently done. Wade agreed with that statement and went on to describe projected future dose contributors.

The Gen-IV candidate fuel cycles include open cycles, closed cycles, and symbiotic cycles. The closed fuel cycles offer a potential to affect dose source terms to miners and in legacy stockpiles of mill tailings and nuclear waste. However, they also introduce new recycle and refabrication steps in the fuel cycle that might increase dose exposures to workers or the public. The question is whether this dose consideration on fuel-cycle choice is likely to constrain Gen-IV options.

Closed cycles hold the potential to (1) reduce the amount of material consigned to high-level waste having long-term heat emission, perhaps easing environmental conditions on the barriers, and (2) reduce the amount of material consigned to high-level waste having long-lived radioactivity, thereby affecting the source-term component of the future public dose risk.

The OECD-NEA has recently completed a detailed study that contains data relevant to the net of the tradeoffs for some (but not all) of the Gen-IV selected technologies. That study postulated a normalized set of steady-state energy parks, each of which included thermal reactors whose discharged fuel could be fed to fast reactors. The base case was a once-through uranium oxide fueled LWR (LWR-UOX) energy park; it produced 100% of its energy with thermal reactors and sent all its residual uranium, plutonium, minor actinides, and fission products to waste. Case B combined LWR-UOXs with mixed-oxide fueled (MOX) fast reactors (multiple recycle) or LWR-MOXs (mono-recycle); it produced 80% of its energy with thermal reactors, recovered and stored its residual uranium, recycled its plutonium, and sent its minor actinides and fission products to waste. Case C combined LWR-UOXs with multiple-recycle transuranic (TRU) fast reactors; it produced 65% of its energy with thermal reactors, recovered and stored its residual uranium, recycled its plutonium, recycled its minor actinides, and sent its fission products to waste. Case D consisted of only TRU fast reactors; it produced 0% of its energy with thermal reactors, recycled its uranium, plutonium, and minor actinides, and sent only its fission products to waste. Compared to the once-through base case: Case B reduced mining about 30% and the back-end long-term dose source term by more than a factor of 10. Case C reduced mining about 37% and the back-end long-term dose source term by about a factor of 100. Case D reduced mining by about a factor of 200 and the back-end long-term dose source term by about a factor of 100. Less mining and less long-term back-end dose source result in lower dose rates. The price that has to be paid is facilities for shielded remote refabrication, which is a monetary price, not a dose price. Wade noted that krypton release was not factored into these figures. The study showed that plutonium and minor actinide recycle increased the feedstock radioactivity over that for an LWR-MOX on a per-kilogram basis by less than a factor of 10 in both the recycle and the refabrication steps, except in the case of neutrons, where there is a significant dose increase.

In summary, the publicly available data on the past performance of open cycles and the projected performance of selected symbiotic closed cycles do not indicate that the effective dose to the public or workers is a potential show stopper among the Gen-IV selected technologies examined. Further R&D to address the technology issues is included in the Roadmap for closed, open, and symbiotic cycles.

A break was declared at 2:35 p.m. The Committee was called back into session at 2:56 p.m. Todreas introduced **Ralph Bennett** with an update on the Gen-IV Technology Roadmap activities. The Roadmap identifies systems deployable by 2030, specifies the six selected systems, summarizes R&D activities and premises, and lays the foundation for Gen-IV R&D program plans. The report discusses the goals, describes the evaluation and selection process, introduces the six systems selected, surveys the R&D needs for each selected system, collects crosscutting R&D needs, and recognizes the need for nearer-term deployment while specifying complete R&D activities. He reviewed the activities of the Subcommittee since the past NERAC meeting and the organization of the working groups.

The key steps in selecting a Gen-IV technology were to:

1. Define and evaluate candidate systems.
2. Review evaluations and discuss the desired missions for the systems.
3. Perform a final review of the evaluations and assess the performance to missions.
4. Make the final decision for selection to Gen IV.

The systems selected were the gas-cooled fast reactor (GFR), lead-cooled fast reactor (LFR), molten salt reactor (MSR), sodium-cooled fast reactor (SFR), supercritical-water-cooled reactor (SCWR), and very-high-temperature reactor (VHTR). The team tried to group these systems in a portfolio based on several characteristics:

Products:
- Electricity production: SCWR, SFR
- Hydrogen production: VHTR
- Both: GFR, LFR, MSR

Plant size:
- Large: LFR, MSR, SFR, SCWR
- Medium: GFR, VHTR, SFR
- Small: LFR

Fuel cycle:
- Once-through: VHTR
- Actinide management: GFR, LFR, MSR, SFR
- Either: SCWR

This portfolio exercise supports the idea of symbiotic fuel cycles, keeping options open. The roadmap addresses the viability, feasibility, proof of concept, and performance of R&D phases.

The major uncertainties:

- Uncertainty exists in the evaluation (captured as a simple probability distribution).
- Uncertainty occurs in the economic evaluation (very large).
- R&D costs and schedules are conceptual.
- R&D schedules assume steady progress and ample funding.
- R&D costs do not include demonstrations, infrastructure, or contingencies for setbacks.

Ahearne asked what Bennett meant by conceptual costs. Bennett replied, ballpark estimates. He showed high-level timelines for assessing viability, developing performance, and demonstrating the technology for each of the six technologies. The timelines included a listing of the key challenges associated with each of the six technologies.

The system-specific R&D areas include

- fuels and materials,
- reactor systems,
- balance-of-plant,
- safety,
- design and evaluation,
- fuel cycle, and
- R&D schedule and costs.

Except for the MSR, the different systems would share four fuel cycles, two types of recycle processing, and five fuel materials.

The issues and opportunities that were identified were

- communication and stakeholder feedback
- infrastructure development and use
- coordinated licensing approaches
- institutional barriers
- interaction with nearer-term systems

- R&D pathways

In summary, six systems were selected, R&D activities were developed and prioritized, a viability phase was instituted to look at key decision points, and a performance phase was established on priority issues to address demonstration and deployment.

Cochran asked how the subcommittee got past the economic criterion for selecting likely reactors to pursue. Bennett said that the economic criteria always focused on life-cycle cost and acceptability of risk of capital. There was a lot of debate about the achievability of those goals. The advice was that the rational analysis was just not available; it was an optimistic view. Todreas said that the economic issue was a major point of subcommittee discussion. Part of the narrowing down was done on the basis of economics. Sessoms asked why they had not extrapolated the LWR system's economics. Todreas responded, because if you lay out all the goals, you start to narrow it down. Very few once-through systems could achieve sustainability. The subcommittee woke up to that fact late in the game.

Cochran asked whether the report and its authors were a DOE advisory function operating outside the restrictions of FACA. Duderstadt said that his assessment was that this is a report about an international effort participated in by DOE. Cochran pointed out that the list of personnel on p. 106 was all NERAC members. Todreas stated that the report was the Subcommittee's observations of the international roadmap. Miller asked what the Committee was going to be asked to approve at the end of the day. Todreas responded that the discussion was leading to the NERAC actions recommended by the Gen-IV Roadmap NERAC Subcommittee (GRNS) and cautioned that the Committee might not want to endorse Item 7 on p. 13. Duderstadt said that it seemed to him that the observations are what the Subcommittee sees Gen IV doing, which are not recommendations from the Subcommittee.

Crandall asked if probabalistics or magnitudes could be assigned to the economic uncertainties. Todreas said that some of these systems, like sodium-cooled reactors, are known well. That system is obviously not a winner, but it can address certain problems, and it has not been investigated in many ways, such as modularity. Crandall pointed out that one needs to consider demand as well as costs.

Todreas showed the GRNS membership; it has only one NERAC member. This process started two years ago; its job was to give advice, not to write this roadmap. Three NERAC members were on the NERAC Roadmap Team. The Gen-IV Roadmap:

- is an international consensus about (1) nuclear energy systems that could be developed and (2) the needed R&D for each system;
- does not adopt the premise that success of Gen-IV development depends on continued success of currently operating nuclear power plants and the near-term deployment of new units (nor does it explicitly recognize the U.S. Advanced Fuel Cycle Initiative);
- is not a U.S. Gen-IV R&D program;
- is oriented toward closed-cycle R&D (although there are once-through concepts among the selected technologies) that is not resource-driven but waste-management-driven with the objectives of (1) developing economic, very-low-loss, nonproliferative separation strategies and (2) achieving competitive capital costs for fast-spectrum reactors;
- has highly uncertain and almost certainly optimistic scope, schedules, and costs;
- needs to be communicated to relevant stakeholders; and

- provides an acceptable basis for DOE to work with the GIF to develop collaborative research activities with NERAC observation and guidance.

Sellman noted that some of the needed technology is classified and asked if someone could look at that to make sure that the effort does not go down the same blind alleys that others have already explored. Todreas agreed that that would be helpful and said that such help had been offered. He emphasized that there is a serious concern whether any of these fast systems can compete with a thermal system.

Ahearne asked whether it was the Subcommittee that was saying that the research was waste-management-driven or the international community. Todreas responded that what was presented here was from the Subcommittee. Long noted that uranium resources do not become an issue until 2050; this report is aimed at 2030, when resources are not an issue. Sessoms suggested that something like the AAA system being looked at by the Richter subcommittee could be pursued for waste management. Todreas said that a lot of options could be pursued, but the state of knowledge is such that recycling and reprocessing technologies are the most promising. Andrew Klein asked if all the systems would need a demonstration facility. Bennett said that any system that was pursued would have to have a demonstration facility.

Todreas noted that the GRNS is finished and asked that NERAC endorse (1) the Gen-IV Roadmap as an acceptable basis for DOE to work with the GIF and other interested countries to develop collaborative research activities on Gen-IV nuclear systems subject to NERAC observations and guidance and (2) the observations of the GRNS on the Roadmap. He also suggested that NERAC establish (1) a subcommittee to succeed GRNS to review the strategy and programs of the U.S. Gen-IV Program and (2) a technically expert group of reviewers to advise that Subcommittee and DOE of the appropriateness and progress of the U.S. Gen-IV program.

The GRNS also recommended an NE Long-Range Program in nuclear-energy R&D because DOE has no recent history of funding truly innovative reactor systems. Such a program should have a time horizon beyond that of the selected Gen-IV concepts, should identify approaches having considerable promise, and should focus work on the major feasibility questions. A fixed portion, say 25%, of future NERI budgets should be allocated to truly advanced nuclear-energy concepts. And DOE should run an annual summer camp for students, dedicated to creating novel approaches, like what was done at Oak Ridge National Laboratory (ORNL) 40 years ago. Duderstadt noted that the national laboratories have run capstone workshops for students for years and suggested that a chunk of the NERI budget be directed to such activities.

Cochran said that the GRNS recommendations should not be endorsed because this program originated as an opportunity to do some basic research to produce reactors that produce electricity cheaper than those using natural gas, proliferation-resistant, and environmentally beneficial. These goals got lost in the international discussions. 9/11 made people aware of theft of nuclear systems. Closed systems may solve those concerns. But control will be lost. Iran is building a reactor and trying to import a tabletop laser isotope-separation system from Russia. This is not the time to promote an international program in actinide chemistry. There is no evidence that LWRs are going to become economically competitive with fossil systems. A closed system will cost several times the cost of an LWR. Each of those closed fuel cycles requires a fast reactor that costs twice what an LWR costs to build. One cannot solve the problems by going to more expensive technologies for the foreseeable future. There is a paucity of discussion of nonproliferation in this subcommittee report.

In terms of process, this "subcommittee" report is called a DOE report. As such, it is in violation of the FACA. DOE cannot go out and enlist these experts to advise it about Gen-IV developments.

Duderstadt stated that he believed that the issue of violation of FACA is beyond the purview of this Committee and should be considered by Magwood and the General Counsel of DOE.

Taylor said that it will take a long time before the Gen-IV activities will have any impacts. There are 18 potential combinations of fuels and systems here. This program should be narrowed to simplify future screening. The role of the near-term deployment program is important to DOE's planning. That reality should be explicitly reflected in the roadmap and the plan. The question comes up whether the driving force behind the program is conserving uranium resources or waste management. It is both, and both have economic ramifications. In the construction of the roadmap, reliability is underplayed; reliability has been a great drawback of these systems in the past.

McNeill said that Cochran's judgement on new nuclear plants is premature and it is premature to accept this report (1) because of the inadequacies of the economic model and (2) because of the inadequate political context presented and the concomitant economic effects. If one does not have a Gen-III investment, there may be a gap between Gen III and Gen IV. The advantage of eliminating some of these technologies limits flexibility in dealing with future uncertainties (e.g., the need to sequester carbon or spreading investment risks).

Ahearne commented that this report represents a tremendous amount of work. The near-term development program has clearer R&D needs. In the recommendations, Item 3 seems moot because of timing.

Duderstadt said that he did not understand how NERAC can endorse the observations the Subcommittee makes. Those observations can be communicated to DOE directly. He suggested the Committee consider the recommendations about the roadmap and that the observations be transmitted to Magwood. The Committee can discuss those observations, but it does not need to endorse them. The observations are included here as Appendix A.

Andrew Klein pointed out that, if present concepts were used, there would never be an R&D program. Cochran said that what he objected to was launching an international effort to go after closed cycles and fast reactors when the economics do not support them. McNeill noted that fuel reprocessing *does* triple fuel costs.

Corradini observed that, if recommendations 2 and 3 were removed, a very clean set of recommendations resulted. The uncertainties of the economics need to be bounded; if research solved the corrosion problems of a supercritical system and resulted in high fuel efficiency, the economics could be very good. In other situations, they could be very bad. Advances in cladding could produce benefits for current programs as well as for advanced systems. So these recommendations make a lot of sense.

Long noted that because the technical community needs to have young people coming in, NEPO, NERI, and other programs need to be supported. Succession planning is also needed. Long said that Taylor is right that the roadmap has to address maintainability and operability as well as decommissioning procedures.

Fertel said that these recommendations could be framed so that they reflect the fact that they relate to how DOE should pursue the international Gen-IV program. Miller asked if this was a basis for framing the U.S. program and suggested that the Committee ask DOE to come back with a U.S. Gen-IV program.

Mtingwa asked why Recommendation 3 should be deleted. Duderstadt replied, because it is too specific. Hartline pointed out that it is education oriented not research oriented.

Duderstadt asked the Subcommittee to redraft the recommendations and present them for a vote the following morning.

Magwood recognized the "epic effort" on the part of the GRNS and offered thanks to them for their work. He introduced the new staff of NE: Buzz Savage, Linda Gunther, and Collette Brown.

Mtingwa asked if the Committee would hear about the Advanced Fuel Cycle Program. Magwood replied that NE is working on a report to the administration about that program and that it is inappropriate to comment about the program now. As soon as the report is out, copies will be distributed to the Committee members.

Duderstadt adjourned the meeting for the day at 5:25 p.m.

Tuesday, October 1, 2002

Duderstadt called the session to order at 8:35 a.m. and introduced **William Martin** as the incoming chair of NERAC and noted that John Ahearne would be the incoming vice chair. Martin said that he was not a nuclear expert but an economist from MIT with a specialty in energy economics. He said the market does not always price things correctly. Nuclear power has to be seen as a part of the total energy system, both domestic and international. He is concerned about coal use and is worried about climate change. The gas industry told him not to count on gas for electricity production; it should be used closer to the consumer. He did not see any hope over the long run for any significant increase in oil production. Renewables can contribute. Nuclear will probably continue to be an important source of energy but with a declining market share in the U.S. and globally. How do we package what NERAC is doing, make sense out of it, and communicate it to a wider audience? The nuclear community has to work with reasonable environmental groups. Nuclear energy may hold the key for a long-term energy future. He said that he would like to take the recommendations that come out of this Committee back to the decision makers at the White House and OMB and accurately depict the realistic hope and vision of nuclear power.

Duderstadt gave the floor to Magwood. Magwood called NERAC's accomplishments under Duderstadt extraordinary, bringing the United States back to world leadership in nuclear technology. He thanked Duderstadt and presented him with a NERAC ceremonial gavel.

As a result of the Secretary's decision to assign a nuclear role to INEEL, NE would like to have NERAC form a nuclear R&D infrastructure task force to look at the facilities at the Idaho site. Long has agreed to lead such a task force. Hartline asked if this subcommittee was to look broadly at all the laboratories. Magwood said that it was to look specifically at INEEL to begin with to see what investments were needed to move Gen-IV reactors forward with the nuclear infrastructure roadmap as a baseline.

He also asked NERAC to address the concern that universities are not turning out the type of nuclear engineers needed by utilities to see if this is a legitimate concern. If it is, the Subcommittee should make recommendations to correct it. Duderstadt said that made a lot of sense. Corradini expressed concern with the possibility of a model curriculum coming out of this effort. Andrew Klein said there were a lot of reasons why power engineering has declined in academia and the decisions are made locally. Cortez pointed out that this study would be a good opportunity to assess the utility of university reactors as well as assessing curricula.

Cochran pointed out that the spread of highly enriched uranium (HEU) in the world represented a significant threat. Detecting this material after it is diverted is difficult. The United States has a number of programs to convert overseas research reactors to non-HEU fuels. That same objective should be pursued in the United States. This infrastructure subcommittee may be an appropriate way to assess the possibility of converting the U.S. university research reactors that are fueled with HEU. Magwood said that that suggestion was outside the scope of that subcommittee, but this issue is a legitimate one that should be addressed by this Committee. He suggested that it be put on the agenda of the next NERAC meeting. Ahearne concurred.

Todreas offered a revised version of the motion that was made by Fertel and seconded by Todreas, dealing with the Gen-IV roadmap. Cochran offered a change to the wording of the first item of the motion. Todreas, as the seconder, rejected the change. Hartline suggested deleting the word "acceptable" from the first item and that, in Item 3, DOE should "inform" NERAC. Todreas accepted the change to Item 3 but held out to retain "acceptable" in the first item. Cochran said he would accept Hartline's suggestions. Duderstadt suggested "initial basis" for "acceptable." Those changes met consensus. The revised motion read as follows:

> The Gen-IV Roadmap is an initial basis for the DOE to use in the design of a Generation IV R&D program for implementation in the United States. Further, the DOE should integrate the proposed Generation IV R&D program with its existing near-term deployment program and its proposed advanced fuel cycle R&D program.
>
> NERAC should establish:
>
> - A subcommittee (to succeed the GRNS) composed principally of NERAC members to review the strategy and implementing programs of the U.S. Gen-IV Program on an ongoing, periodic basis and
> - A technically expert, independent group of reviewers to advise this NERAC subcommittee and the DOE of the appropriateness and progress of the U.S. Gen-IV program.
>
> While the U.S. Gen-IV program is being developed, DOE should inform NERAC of its ongoing and proposed joint international R&D programs involving potential Gen-IV systems.

The revised motion passed unanimously. Further, it was agreed that the GRNS observations (with changes to resolve John Ahearne's comments on Items 3, 5, and 13) will be transmitted to DOE by NERAC. Cochrane subsequently submitted in writing a dissenting opinion to be transmitted to DOE with the formal report; that submission is included here as Appendix B.

Magwood introduced **David Berg** of DOE and **Andrew Paterson** of Scully Capital to present the results of a study on the business case for new nuclear power plants. They investigated the critical financial risks associated with early orders for new reactors.

Nuclear power provides about 20% of the nation's electricity and adds diversity to the mix of fuels used to generate electricity. Stable allies provide most U.S. supplies of uranium fuel, and supplies and prices are steady. Nuclear power may reach 25% of the U.S. electricity supply, but could not go beyond that with the current plants. If the high estimates for demand and low estimates for supply projected by the North American Electric Reliability Council (NERC) come true, a capacity shortfall for electricity generation could occur in the United States after 2006 when capacity is expected to level off and demand is expected to continue to increase. Crandall asked how Scully's projections compared with NERC's. Paterson said that the two studies have the same assumptions about new nuclear plants.

Nuclear-plant ownership is increasingly concentrated. Twelve utilities and TVA now own and operate more than 75% of the total U.S. nuclear capacity and two-thirds of the plants.

The Scully study started with a timeline for the development of power-plant projects. It then tried to determine the risks at each stage of project development. That analysis was vetted through 30 utilities and financial analysts. It then constructed a model to evaluate the application of risk-mitigation mechanisms.

The study found that the outlook for nuclear power has improved since 1990 because of several market and industry developments: a sharp rise in fleet capacity factor (65% in 1990 and nearly 90% in 2000), a good safety record, and lower interest rates. As a result, new nuclear plants are seen to be potentially competitive, with Nth-plant costs of about $1100 per kilowatt of capacity. After the deregulation of the industry by the Federal Energy Regulatory Commission (FERC), the value of nuclear assets underwent a huge shift.

However, three unresolved key barriers could prevent new U.S. orders:

- spent-fuel disposal;
- reauthorization of the Price-Anderson Act for accident indemnification; and
- clear, finite NRC licensing processes, particularly for commissioning.

These are considered show-stopper risks by some industry executives. Moreover, *early* plant capital costs still appear too high, especially if the cost of gas is less than $3 per million Btu. The capital costs (including financing) could be more than $1600 per kilowatt for the first plants, declining to about $1200 per kilowatt for the fourth and fifth plants of the same design. Therefore, orders of first plants could require government assistance. Such assistance should address particular risks rather than consist of grants or contracts and should reduce potential costs to the government.

Cochrane said that the nuclear industry had played the same game, claiming that costs would drop with more plants. He asked what evidence there was that costs will be driven down this time and why it was the government that should provide assistance. Berg replied that (1) interest rates are much lower; (2) construction is being done overseas, and that expertise can be brought home; and (3) computer-aided design/computer-aided manufacturing (CAD/CAM) and other tools allow better planning and analysis.

Ahearne asked if they were assuming identical designs. Berg replied, yes; first-time engineering costs will have to be gotten past. The first one built will be an experiment. The learning curve will bring the cost of subsequent construction down. Government participation is discussed later in the presentation. Sellman noted that Westinghouse has suggested a consortium to build six to eight plants with the same builders rather than starting at the bottom of the learning curve with each plant.

The study indicated that plants financed solely by the private sector face serious obstacles. In addition to the three show-stopper risks mentioned already, investors face (1) the difficulty of projecting demand and price out ten years in a time of adequate supply and moderate fuel prices and (2) the long lead times and high capital costs of nuclear plants that cause earnings dilution and lower stock prices.

The government is, however, making progress on the three show-stopper barriers. Congress voted to proceed toward opening Yucca Mountain. The administration is working with Congress on reauthorization of the Price-Anderson Act to cover new plants. The NRC is open to defining approval processes for new plants; although those processes are not yet certain and finite and will not be until tested in court. Within this framework, industry and the financial community are capable of addressing most, but not all, of the business risks associated with developing new plants. Without government participation, some risks and costs of new nuclear plants may remain at unmanageable levels, particularly:

- regulatory risks that lead to delays during construction and commissioning;
- FOAK engineering costs for the first plants;
- high capital costs and potential construction-cost overruns for the first new nuclear plants and designs; and
- transmission availability and congestion, which may vary widely by region.

Sessoms asked what length of time was being assumed from initiation to startup. Paterson responded, about 60 months; gas is 12 to 18 months. Crandall asked if these were greenfields. Paterson replied, no; the study assumes expansion of existing sites. Cochrane said, sardonically, that this was a great business plan and asked why they did not just indemnify all the problems of our society. Berg answered that the economy is rapidly being electrified, and society does not internalize the environmental costs of electricity production except for nuclear power.

As a result of this study, Scully capital recommends that DOE evaluate the authority, funding mechanisms, and funding sources for a federal energy-credit program that uses a financial risk-based approach. That energy-credit program should be applicable across all energy sectors (industrial, buildings, and residential) and types of energy projects, should have broad flexibility (allowing a variety of innovative finance techniques), and should leverage federal funds with private dollars. DOE should sharply focus any risk-based framework to better target assistance and mechanisms. It should use the business-case financial model to optimize the structure of DOE's acquisition strategy. And it should negotiate any assistance accorded to first plants with industry and investors.

The recommended risk-mitigation techniques are helping to

- address unique regulatory risks by establishing a standby facility comprised of interest maintenance, debt-principal buy-down, and equity options to support the financing in the event of delays or judicial intervention;
- address construction risk with a standby construction-cost-overrun mechanism;
- address FOAK engineering risk through a government preferred-equity facility with the government being paid back after a given capacity factor is reached;
- reduce high capital costs with direct loans and investment tax credits;
- augment revenues through power-purchase agreements, a carbon-emissions credit program for nuclear energy, and production tax credits (like those used for wind energy now);
- add specialized insurance capacity with broader coverage (e.g., if the plant never got switched on); and
- address earnings dilution through investment tax credits (like the current clean-coal credits).

Magwood noted that DOE is talking to a wide range of people about the recommendations Scully Capital has put forward in its report.

Duderstadt introduced **John Taylor** to speak about the NEPO program review by the Subcommittee on Operating Nuclear Plants Research and Development. The Senate and House appropriations committees have approved the bill providing FY03 NEPO funding of $5 million; the bill now goes to a conference committee to resolve other differences. Required reallocations by DOE will reduce the funding for NEPO projects to about $4.6 million for FY03.

The Nuclear Energy Institute testified to Congress that NEPO should be restored to $15 million. The Electric Power Research Institute (EPRI) and its Nuclear Power Council sent a letter to Congress asking that NEPO be continued at that same level. On the basis of industry input, proposed energy authorization legislation for FY04 includes $15 million for NEPO.

EPRI sponsored the annual NEPO Workshop last May to help identify the most valuable projects for FY03. A project-concept solicitation and selection process was defined to facilitate input from workshop attendees. DOE personnel participated in the workshop.

Robert Long attended the workshop and observed that

- it effectively provided important input for project planning and selection;
- although the purpose was to solicit mid- to long-term R&D, a few participants judged proposals on whether they would provide FY03 results of immediate use to the utilities, but this minority preference was not followed in preparing the workshop report; and
- because funds are not usually released until late in the fiscal year, it is difficult to assess actual work accomplished in evaluating projects for continuation, so the Subcommittee recommended that this problem be addressed vigorously (DOE has said that some of the causes of delay have been eliminated).

The Subcommittee made a series of recommendations for the selection of NEPO projects:

1. Projects that address issues of generic, long-term value to operating plants should be strongly favored over those that solve an immediate and specific operational problem.
2. New projects that address emerging issues should be introduced even when the funding is constant and when important projects that are under way need to be completed.
3. The primary focus on NEPO project selections remains on equipment systems and components, providing continued improvements in safety and reliability. However, a greater potential for gain in safety exists on the human side of the equation.

As a result of the recommendations made six weeks prior by the Coordinating Committee, 19 projects were selected, requiring funding of $4.75 million by DOE and $5.22 million by EPRI. Of that funding, 36% of the DOE funds and 43% of the EPRI funds are for new projects. The primary emphasis is on topics related to safety and reliability (i.e., steam-generator inspection, electric-cable aging, power-upgrade-fuel reliability, online monitoring, materials aging, and risk-informed technologies). Adjustments may be needed to fit the final budget and to meet the priority determinations set by the Coordinating Committee.

In considering the progress of NEPO, the Subcommittee believes that the selected projects are generic and have potential long-term value. However, no proposed projects that deal with behavioral research have been chosen. The new nuclear-plant-safety risk management will contribute to plant safety, as would the maintenance-performance sustainability project, if selected. The Subcommittee continues to urge that behavioral research be initiated in this program.

In view of the funding limits, the number of new projects is commendable. The Subcommittee suggests that an assessment of the value of continuation of all ongoing projects be made in the future to ensure that that balance is continued and improved. The ongoing NEPO projects are producing valuable results and are benefitting from input from the NRC, Institute of Nuclear Power Operations (INPO), Nuclear Energy Institute (NEI), national laboratories, universities, and nuclear utilities. The

Subcommittee strongly recommends a NEPO budget of $15 million for FY04.

Sellman commented that, from an operations standpoint, the biggest problem is reactor-vessel heads and their inspection and asked if that was being looked at. Taylor replied, not specifically, but it was being addressed to a degree under materials research. Cochran asked if NEPO should have foreseen the problem at Davis-Bessey. Taylor responded that the subcommittee has always advocated that more attention be paid to human behavior and that the problem *is* a human-behavior question. However, the Subcommittee's advice has been ignored. Hartline noted that the review committee ranks the proposal and asked if the review-committee members are all engineers? If so, one would not expect any human-behavior recommendations to come out of that committee. Some human behavior people need to be put on that committee.

Duderstadt introduced **Owen Lowe** to speak about the Advanced Nuclear Medicine Initiative (ANMI), the purposes of which are to sponsor nuclear medical-science research with a peer-review selection process, to sponsor the training of individuals in nuclear medical science, and to continue research and education programs. Fourteen 3-year research grants and five 3-year education grants have been awarded with a combined total of $7.5 million. However, no additional funds for new grants are in the FY03 budget. The R&D projects are at the University of Washington, University of California at Davis, University of Missouri (2), University of Chicago, University of Michigan, ORNL, Westinghouse Electric Co., and Garden State Cancer Center. The education programs are at Washington State University, University of New Mexico, University of Wisconsin, Purdue University, and Washington University. The research awards were for projects on

- production methods for carrier-free lanthanides,
- in vivo selection of novel prostate tumor-avid fab,
- bispecific antibodies,
- improved generators of bismuth-213,
- radioactive nanocomposites,
- a modular tumor-targeting system,
- microdosimetry for analyzing and predicting cell survival after alpha irradiation,
- reagents for labeling biomolecules with astatine-211, and
- separating isotopes with recoil-ion methods.

The education awards were for

- training for MS-level positron-emission tomography (PET) medical physicists,
- nuclear pharmacy education, and
- nuclear medicine.

Of the research grants, 69% went to universities, 13% to national laboratories, 5% to industries, and 13% to medical research centers. Five articles resulting from funded work have already been published in professional journals, and twelve papers have been presented at scientific meetings.

DOE is working closely with NIH to make special arrangements for NIH to pay for research isotopes on a full-cost basis. Sullivan noted that NIH may fund the medical research but not some of the other projects covered by this initiative. There is an area that will not be funded by NIH. There have been no applications for increased funding from NIH for the costs of the isotopes. The role of the Research and Medical Isotope Subcommittee is now unclear and seems marginal. The Subcommittee could use some clarification and guidance. Magwood responded that DOE has seen a declining demand for these services and Congress has questioned why DOE was getting $2 to 3 million per year for isotope production in the face of this decline. As a result, DOE was unable to get additional funds for the ANMI. Sullivan said that two areas need help: nonmedical isotopes and the *production* of medical isotopes. Mtingwa suggested that the Subcommittee should study the effects of these new policies and how NIH researchers are hurt by these policies. Lowe noted that ORNL identified eight research isotopes as candidates for production runs. When this availability was announced, production runs for many of these isotopes were fully subscribed, and one (actinium-225) was oversubscribed. Ahearne asked about plutonium-239 sales. Lowe said that tiny quantities are sold to research institutions.

Corradini asked what an ANMI research project costs per year. Lowe responded, about $250,000. Corradini suggested that another way to approach the problem would be to use Nuclear Engineering Education Research (NEER) funding for these projects. Magwood pointed out that NEER funding was for university nuclear-engineering programs, not isotope research.

Duderstadt declared a break at 10:41 a.m. The Committee was reconvened at 10:58 a.m. with the introduction of **John Gutteridge** to make a presentation on the Innovations in Nuclear Infrastructure and Education (INIE) Program. In the 1990s, the nation experienced a declining number of operating university research/training reactors; a dwindling student population in nuclear engineering; the closing or loss of identity of university nuclear engineering programs; a looming shortage of nuclear engineering graduates; and the threat of additional reactor closures, such as at Cornell, Michigan, and MIT, one of which (Cornell) has since come true. NERAC responded by establishing a task force to study the problem. That task force was headed by Michael Corradini, and issued a report, The Future of Nuclear Engineering Programs and University Research and Training Reactors, that confirmed that university nuclear engineering in the United States was in jeopardy, reactors were rapidly decreasing, the need for experts trained in nuclear science was actually increasing, and university reactors are an important part of undergraduate and graduate education in nuclear engineering. A NERAC Task Force on University Research Reactors headed by Robert Long followed up on this report and made several recommendations, including one that federal funding be provided in FY02 to initiate a competitive peer-reviewed process for the establishment of geographically distributed regional university research/training reactor user facilities. From this recommendation came the INIE Program.

A solicitation was issued December 21, 2001; 13 proposals were received March 15, 2002, and 7 were judged meritorious; a peer-review panel met April 2002; Secretary Abraham released a press announcement on the program June 10, 2002; and $5.5 million was divided among four consortia:

- Western Nuclear Science Alliance ($1,200,000),
- Big-10 Consortium University Research and Training Reactor ($1,970,000),
- Massachusetts Institute of Technology Consortium ($1,100,000), and
- Southwest Consortium ($1,050,000).

Funding was made available in late FY 2002.

The Western Nuclear Science Alliance participants are Oregon State (OSU), California-Davis (UC-Davis), Washington State, Idaho State, California-Berkeley, seven industrial partners, and five national laboratories. Its objective is to promote reactors to a wider scientific community and to offer unique internships and summer programs [similar to the Brookhaven National Laboratory (BNL) summer school in nuclear chemistry]. It focuses on neutron radiography and radiochemistry.

The Big-10 Consortium participants are Pennsylvania State, Wisconsin, Illinois, and Purdue. All of these institutions offer bachelor's, master's, and doctoral degrees in nuclear engineering. The consortium will issue minigrants of $20,000 to $25,000 (with $300,000 originally budgeted) for innovative research activities for faculty and graduate students in nuclear and other scientific disciplines at all institutions as well as with its industrial and national-laboratory partners. The project focuses on the increased use of research reactors and on designing an optimum university research reactor with new neutronics tools; it also focuses on relationships with industry. All the Big 10 wanted to get together, but that would have been too big an organization. Michigan wanted to go alone, so they submitted a separate proposal.

The MIT Consortium participants are MIT and the Rhode Island Nuclear Science Center (RINSC). The main thrust is facilities within the reactor, especially instrumentation and engineering support. The focus is on in-core-materials (cladding) testing, boron-neutron-capture (BNC) therapy, and providing hands-on experience to students.

Cochran asked about converting university research reactors from HEU to low-enrichment uranium (LEU). Gutteridge said that such conversion is being done on a reactor-by-reactor basis as funds are available. Eleven reactors have been converted so far; Florida and Purdue are next. Todreas noted that Argonne National Laboratory (ANL) is responsible for producing a high-neutron-flux fuel to replace the HEU, but that replacement has not been forthcoming. Duderstadt said that these issues are important and are imbedded in the question of the future of research reactors in this country, which is scheduled to be discussed at the next NERAC meeting. How the shift from HEU to LEU can be accelerated could be an important part of that agenda as well as whether the research reactors can take advantage of some of the other international negotiations going on.

Sessoms observed that, in an interview, the MIT provost was "cranky" about the BNC project. Todreas said that MIT wants the focus to be on nuclear energy, and the provost does not want to hang the project on BNC science. Duderstadt noted that a major purpose of the program is to train students in nuclear-power operations.

The Southwest Consortium participants are Texas A&M University, University of Texas at Austin, University of New Mexico, and Sandia National Laboratories. This consortium is seen as a way to get a lot of institutions interacting and to promote distance learning and remote reactor operation.

Funding for years 2 through 5 are increased over the level for FY02 for most of the INIE projects. DOE/NE would like to fund three additional projects beginning in FY03. Congressional markups of the FY03 budget request may or may not permit additional projects or full support of the initial four projects. Depending on the outcome of the appropriations legislation, DOE may need to cut back funding in the out years. Those first four projects include 14 universities. If the program was expanded to 7 projects, they would involve 24 academic institutions.

In summary, the enthusiastic and innovative responses of the first four INIE consortia are encouraging for the future prospects of nuclear engineering programs and university reactors.

Duderstadt noted that it is important to build in rigorous peer review and sunset plans. Gutteridge said that there will be a review at the summer meeting of the ANS. Corradini noted that the Big 10 proposal presumed funding for a limited time.

Duderstadt looked back over the previous four years and observed that NERAC, as a startup effort, has moved up a very steep learning curve and has been very successful. It has addressed a remarkably broad front of activities. He cautioned that efforts like these should be expected to have significance only over the long term, so persistence is important. The themes that have emerged during the past four years are people, ideas, and tools. Working with this group has been a very rewarding experience, and he expressed gratitude to those around the table for the opportunity to lead this group and for the help and support it provided. He opened the floor to discussion of what NERAC should do in the future.

Mtingwa pointed out that NE's budget is well below the $240 million per year target that was set for R&D funding. DOE needs to step up to that challenge.

Comfort commented that new programs (like Gen IV) have come in that will bring research funds with them. Perhaps the Long-Range Plan should be revisited to set new benchmarks and targets. Duderstadt said that the long-range planning effort was always considered to be an ongoing task and that revisiting it would be worthwhile. He noted that basic research is critical to NE; it is not the province of just the Office of Basic Energy Sciences (BES) in the Office of Science (SC). NERAC should grapple with that confusion and policy. Sessoms observed that engineering is not embraced by SC. Duderstadt said that the money spent in chasing bosons versus that spent chasing energy security is out of balance and should be redressed.

Andrew Klein stated that the support for university research on nuclear engineering has decreased 30%. Duderstadt added that one should not deceive oneself that undergraduates are going to sustain the nuclear-power enterprise; graduate studies are needed in nuclear engineering. And also in radiochemistry, added Jurisson.

Duderstadt opened the floor to public comment. A written submission from William Simmons of Energy Metals Corp. is incorporated in the record as Appendix C. A written submission from Carl Holder is incorporated in the record as Appendix D.

Claude Oliver said the FFTF would play an important role in nuclear-medicine isotopes, Gen-IV materials research, and waste-repository research. The City of Richmond and the Port of Benton Authority would like to obtain the facility and use it in a commercial enterprise as a Community Re-Use project. A report and video about the planned use of the facility by the city and port authority are available and can be requested via e-mail at cra@portofbenton.com. A 2002 study by Frost & Sullivan said that "The FFTF is perceived as a reactor that will drive growth by expanding the entire field of nuclear medicine." Isotopes are needed for 20,000 to 200,000 patients. The growth of medical isotopes would be driven by the FFTF. The facility could be online in 3 years. A letter of support and proposal for collaboration was received from the Ukrainian-Russian Limited Partnership Company and is incorporated in the record as Appendix E. Oliver encouraged this Committee to grow academic programs and to grow its network. He said that the Richland Community Re-Use Agency's plan to operate the FFTF as a commercial venture would benefit everybody and urged the Committee's support of the plan.

Herbert Feinroth said that the focus on waste management needs to be in the near term, not just in the long term. Even an expanded Yucca Mountain would not accommodate all the waste from the near-term deployment of new nuclear power plants. Closing the fuel cycles of these near-term deployments must be looked at. The right way to close the cycle is with fuel reprocessing and recycling. Ways have to be found to recycle fuels without aqueous and molten-salt technologies. It is not the optimal *technical* path, but the best *societal* path. He urged NE to conduct part of its R&D on these nonaqueous and non-molten-salt processes. Cochran noted that repository operations are driven by the heat load and asked why recycle would be of any benefit to Yucca Mountain when the hot species from the recycling process would still go there. Feinroth replied that the repository is the only hope for not only the next 50 years but for the next 150 years. The political issues are as important as the technical issues. Cochran said that this was the German model. Feinroth concurred. A subsequent letter from Feinroth appears as Appendix F.

There being no further comment, Duderstadt adjourned the meeting at 11:56 a.m.

Prepared by
Frederick M. O'Hara, Jr.
Recording Secretary

Submitted by
James J. Duderstadt
Chairman

Appendix A

Observations on "A Technology Roadmap for Generation IV Nuclear Energy Systems: Technical Roadmap Report"
October 3, 2002

The Roadmap Context

The development of advanced nuclear energy systems in the U.S. will depend greatly on the continued success of currently operating light water nuclear power plants and the ordering of new installations in the short term. DOE needs to give those immediate objectives the highest priority and any additional support they require to assure their success.

DOE is pursuing two initiatives to encourage a greater use of nuclear energy systems. The initiatives have been reviewed by NERAC Subcommittee on Generation IV Technology Planning (GRNS) and they are:

A Near Term Development (NTD) Roadmap which is in the process of being implemented and which was approved by NERAC. NTD identifies six nuclear plant designs with the potential for commercial deployment in the U.S. by 2010. All will operate on the existing once-through fuel cycle. DOE, through its "Nuclear Power 2010 Initiative" has taken action to implement the NTD Roadmap, in cooperation with U.S. industry.

A Technology Roadmap for Generation IV Nuclear Energy Systems which is described in a report distributed to NERAC and which is to serve as the framework to start to negotiate joint Research and Development (R&D) programs among the ten countries which have come together to form the Generation IV International Forum (GIF). The objective for Generation IV advanced nuclear energy systems is to have them available for international deployment before the year 2030.

DOE is getting ready to launch an Advanced Fuel Cycle Initiative. The purpose of this initiative is to develop highly effective and economical means to deal with nuclear waste management. GRNS did not participate in its formulation.

All three initiatives above need to be integrated to avoid overlaps and to define and modify their technological interrelationships as a function of time and progress.

Due to the significance of the Generation IV Technological Roadmap plans, a concerted effort needs to be made to communicate with other stakeholders including in the U.S.: the Congress, Administration, NRC, ACRS, environmental groups, anti-nuclear groups and the general public about the nature, basis and substance behind the Roadmap recommendations to solicit support for the agreed upon R&D effort. The process should provide for a process that allows for changes in the Roadmap based on this dialogue.

DOE is to be commended for its efforts to reach an international consensus on the formulation of a GEN IV Roadmap. The bringing together of a diverse group of over 100 international experts with different backgrounds and experience from ten different countries is particularly noteworthy.

The Roadmap Content

Six systems were selected to Generation IV by the GIF: Gas Cooled Fast Reactor System (GFR), the Lead-Cooled Fast Reactor System (LFR), the Molten Salt Reactor (MSR), the Sodium-Cooled Fast Reactor (SFR); the Supercritical Water-Cooled Reactor System (SCWR) and the Very-High-Temperature Reactor System (VHTR). The Roadmap describes R&D programs required by all six concepts to reach the viability and performance stages.

This is too many concepts to be effectively pursued in the US GenIV R&D program. GRNS has provided preliminary advice to DOE on such a strategy and, for example, has recommended no participation on the Molten Salt Reactor, focus only on the key viability issues of the Supercritical Water-Cooled thermal spectrum Reactor and very targeted participation beyond fuel cycle work on both the Sodium-Cooled fast Reactor (i.e. capital cost reduction) and the Lead-Cooled Fast Reactor (i.e. corrosion control and polonium management).

The Roadmap R&D for the six concepts is limited to the viability and performance phases and did not include their demonstration. Developing specific demonstration needs to be accomplished for selected concepts in order to achieve the industrial participation required to assure actual use of the Generation IV systems. The US roadmap effort needs to recognize that the demonstration scope will require significant DOE investment and support.

The proposed R&D scope, schedules, and costs are not detailed enough to pass judgment on their merits. The GRNS notes that these are not the result of a detailed planning process and are highly uncertain and almost certainly highly optimistic. Further because of the long term nature of the proposed R&D, it is very difficult to anticipated the downstream R&D which will be needed based on the results of early R&D efforts. Necessary specific facilities are not identified and their schedules, capital and operating costs, and locations are not provided. The forthcoming discussions among GIF members need to address such details in order to be able to prioritize and schedule the Roadmap R&D appropriately and support DOE budgeting and planning activities.

Execution of the Roadmap

The hard task of determining the R&D tasks and their schedules, the degree of participation by each country and the agreed means to measure progress and make appropriate changes is just beginning. The success of the Roadmap will be very dependent upon the organization, selection, and conduct of the R&D projects.

NERAC should endorse the GEN IV Roadmap for use by DOE to develop joint R&D programs with GIF members and other interested countries. When agreement is reached on most joint R&D programs and a definitive U.S. strategy is developed with respect to Generation IV systems, NERAC should review the strategy and the implementing programs. NERAC should continue to periodically review the progress and resultant adjustments of the GEN IV R&D and the complementary NTD and AFCI R&D programs on an ongoing basis.

The currently scheduled evaluation of the progress on the Roadmap by GIF experts once a year is inadequate. Quarterly reviews of the U.S. program and progress may be more appropriate and they should involve reviewers independent from DOE contractors and participants.

There are R&D programs included in the Gen IV Roadmap, which are likely better funded by other DOE offices. For example, it is proposed to develop a non nuclear-coupled thermo chemical hydrogen closed loop experiment. This process is best evaluated by the appropriate office involved with the production of hydrogen. Similarly, there are programs to improve the handling, storage of spent fuel, which right now are the responsibilities of the power generators and the Yucca Mountain Project. DOE should review the Gen IV roadmap and make appropriate revisions.

Appendix B

MEMORANDUM

To:	Chairman, Nuclear Energy Research Advisory Committee (NERAC)
From:	Thomas B. Cochran, Member of NERAC
Date:	October 16, 2002
Subject:	"A Technology Roadmap on Generation IV Nuclear Energy Systems," a report of the NERAC Subcommittee on Generation IV Technology Planning

Please include these additional remarks in your transmittal of the subject report to DOE's Office of Nuclear Energy, Science and Technology.

Perhaps the greatest security threat to the United States today, and of paramount concern to American citizens since September 11, 2001, is that nuclear weapon-usable materials will be stolen, seized, or secretly diverted from nuclear facilities and then used by terrorists to develop and deliver a crude nuclear explosive device, or by a hostile proliferant state to develop more sophisticated nuclear weapons. This is not the time for the United States to be launching an international research effort to develop advanced nuclear fuel reprocessing technologies to be deployed some 30 to 50 years hence. This research effort will likely expand the availability of weapon-usable materials in other countries in the near-term, result in the training and employment of new cadres of scientist and engineers with expertise in actinide (including plutonium) chemistry and metallurgy, but not result in the deployment of new commercially viable nuclear power technologies.

Over the past decade there have been several cases in which individuals or groups of individuals have sought to steal weapon-usable materials from civil nuclear research institutes and naval fuel facilities in Russia. In some cases the individuals were apprehended after the nuclear material was removed from the facility or institute, and in some cases only after it left Russia. The risk of diversion of plutonium or highly enriched uranium from the civil nuclear fuel cycle facilities and government research facilities represents a greater risk today than the potential diversion of nuclear weapons. Al-Qeada, Iraq, Libya and North Korea have all sought to acquire nuclear weapon-usable materials and nuclear weapons. The United States believes Iran, a signatory to the Non-Proliferation Treaty, is seeking to develop nuclear weapons and in this pursuit is using its civil nuclear power development program as a cover to train a cadre of nuclear scientists and to import dual purpose nuclear fuel cycle technologies, primarily from Russia. The United States should seek with great urgency the elimination of weapon-usable highly-enriched uranium and plutonium from commerce, and should not be pursuing a research agenda that will inevitably spread dual-purpose nuclear facilities and expertise around the world.

Two years ago DOE's Office of Nuclear Energy, Science and Technology initiated the Generation IV ("Gen IV") program to identify potential nuclear plant designs that in the 2030 time frame and beyond would be economically competitive with fossil-fueled plants, and safer and more proliferation resistant than existing nuclear plants The Office of Nuclear Energy asked the Nuclear Energy Research Advisory Committee (NERAC) to develop a technology roadmap to guide DOE research in this area. NERAC established a Subcommittee on Generation IV Technology Planning to develop the roadmap. In the process of developing the roadmap, the Office of Nuclear Energy organized the Generation IV International Forum (GIF), a consortium of ten countries, to pursue the cooperative development of advanced nuclear reactor and fuel cycle technologies. GIF participants participated in the development of the NERAC subcommittee's Gen IV roadmap. The roadmap identifies six "next generation" reactor technologies, including gas-, sodium- , and lead alloy-cooled fast reactors, and advanced aqueous- and pyro-processing fuel reprocessing technologies. DOE has also transferred management oversight of the Idaho National Engineering and Environmental Laboratory (INEEL) from the Office of Environmental Management to the Office of Nuclear Energy and anointed INEEL as the lead laboratory for developing Gen IV reactor and fuel cycle technologies.

What began as a small conceptual-study research effort has ballooned into a major international research effort focused on the development of a variety of fast reactor concepts and reprocessing technologies. The original goal(to develop a commercially competitive, cheaper, safer and more proliferation resistant nuclear power technology(has been all but abandoned as the entrenched fast reactor and nuclear fuel reprocessing research communities have sought to promote their own research agendas as they developed the Gen IV roadmap in the GIF meetings. The overwhelming majority of GIF participants represent state-owned or heavily state-subsidized institutions and cannot be considered experts in developing or operating commercially competitive energy businesses.

There are four key questions that must be answered satisfactorily before pursuing this research agenda. First, are any of the proposed technologies likely to be economically competitive in the foreseeable future? The answer here is "no," for reasons discussed below. Second, given the low likelihood of commercial deployment, are the ostensible nonproliferation benefits of the new technologies likely to be realized? Third, are the inherent proliferation risks of closed fuel-cycle deployment acceptable even with the increased proliferation-resistance supposedly available with GEN IV technologies. And fourth, is the "opportunity cost" of a big GEN IV program acceptable in light of the benefits likely to be forthcoming from alternative energy R&D investments, particularly in advanced solar and fuel cell technologies?

Existing nuclear plants in the United States can produce electricity at competitive(since the forward cost of these plants is limited to fuel and operating and maintenance costs(but there have been no new nuclear power plant orders in the United States since the early 1970s, and this is likely to be the case into the foreseeable future. New nuclear plants are not competitive with gas- or coal-fired plants in the United States, because the fully amortized capital cost of new nuclear plants more than offsets the higher fuel cost of fossil–fueled plants. These higher capital costs of nuclear plants are due to a combination of higher "overnight" construction costs, longer construction times which must be financed, and higher interest rates for debt financing of nuclear plants. It is widely recognized that for nuclear to be competitive a combinations of events must occur, for example, some combination of a large carbon tax or limits on CO2 emissions from fossil-fueled plants, a 25 percent, or so, reduction in "overnight" construction costs of nuclear plant, and a significant increase in the cost of natural gas over a prolonged period. It appears unlikely that such a combination of events will occur anytime soon.

We have considerable evidence from the failed attempt to develop plutonium breeding fast reactors in the United States, France, United Kingdom, Germany and Japan, that it costs more to construct a commercial-size fast reactor than a conventional thermal reactors—considerably more I would suggest. The cost of a new fast reactor is likely to be at least twice that of new light-water reactor(a pressurized or boiling water reactor. We also have over two decades of data from Europe and Japan related to the cost of aqueous reprocessing of irradiated nuclear fuel and the cost of fabricating mixed-oxide (MOX) fuel assemblies. These data indicate that the cost of reprocessing and fabricating MOX fuel is several times the cost of mining and enriching uranium and fabricating low-enriched uranium fuel. In the past thirty years uranium and enrichment costs have gone down, not up, and there is no reason to believe this trend will not continue for decades into the future, particularly when so few nuclear plants are being built. Certainly, there is no reason to believe that uranium costs will ever increase to the point that fast reactors and a closed fuel cycle will be economically competitive with new conventional nuclear plants, which are not now competitive with fossil-fueled plant in the United States.

Since these new fast reactors and reprocessing technologies are not likely to be competitive in the foreseeable future, they will not be deployed, and we will see no non-proliferation benefits even if there were net benefits to be realized.

Aqueous reprocessing and MOX fuel fabrication have resulting in huge stockpiles of weapon-usable plutonium and availability of weapon-usable plutonium and plutonium dioxide at reprocessing and fuel fabricating facilities. It is true that the deployment of new fuel cycles in theory could eliminate the need for separating plutonium entirely from radioactive fission products or actinides, but the various integral fast reactor concepts that have been proposed would nevertheless provide the inherent capabilities for making such separations if the owner were sufficiently motivated to do so. And the supposed benefit would occur only if the reactors and fuel cycles are deployed, and since there is virtually no chance that they will be competitive, there is little likelihood that this benefit will be realized, In the meantime(over the next 30 to 50 years, and even beyond(the research programs will spread hot cells and other dual purpose technologies around the world and encourage currently non-nuclear-weapon countries like Iran, South Korea, and Japan to pursue research in these advanced fuel cycle technologies and train cadres of experts in nuclear weapon related technologies.

While they have no weapon development intentions today, it should give one pause to reflect on the fact that of the ten member states of the Generation IV International Forum, four, South Africa, Brazil, South Korea, and Argentina, had clandestine nuclear weapon programs in the recent past, and one, South Africa, fabricated half a dozen atomic bombs. Switzerland has also dabbled in nuclear weapon design work, ostensibly to better understand the effects of nuclear weapons. It makes no sense for the international community to expend billions on an effort (KEDO) to limit North Korea's future access to plutonium while the GIF facilitates and promotes such future access in South Korea.

Pursuit of the GIF international research effort will increase U.S. national security risks, and it stands essentially no chance of reaping any energy security or economic rewards. In contrast, the world energy market is poised on the cusp of a major revolution in commercially competitive, distributed power generation, based on accelerating commercialization of solar and hydrogen sources. A billion dollars of public expenditure in this area is likely to have a far greater near- and long-term public benefit than a billion dollars expended on trying to resurrect highly-capital intensive, central-station nuclear power alternatives with serious (and costly) nuclear safety, security and safeguards requirements. The United States should withdraw its support for GIF, and the Gen IV program should be redirected to focus on improving existing reactors operating on the once-through fuel cycle, and on the potential optimization of LWR plants for hydrogen production via electrolysis.

Appendix C

September 18, 2002
TO: Dr. Norton Haberman, Designated Federal Officer, United States Department of Energy
FROM: William Simmons, President, Energy Metals Corporation (EmC)
SUBJECT: Written Statement for the NE Research Advisory Committee
REFERENCE: Office of NE Research Programs

Dr. Norton,

Thank you for the opportunity to offer a novel idea to the Committee regarding future planning for technical and scientific research by the NE.

We feel that the NE should support cost-effective means to make nuclear waste benign so that the radioactivity of the waste is reduced to a level whereby it is made unable to further undergo radioactive decay.

Rather than simply encapsulating nuclear waste and storing it away for 10,000 years, NE research should pursue research projects that will make the waste benign.

The product from such research will allow society to embrace nuclear power and all the benefits that it brings. However, society does not deserve the legacy of waste storage that failed past research programs has left it to deal with.

Accelerated transmutation (ATW) for instance will never be cost effective and some even question that it even works; therefore it is not practical so it does not justify further funding.

Nevertheless its intent was correct, only its means was not. Today, the nuclear waste dilemma has been solved by private research. However underfunded as we are, our solution is both practical and cheaper than long-term storage with the added bonus that the waste is no longer lethal and dangerous.

Therefore research into reducing the lethalness, the danger -the radioactivity of the waste above any other course for research is most pragmatic to pursue and should be the path to take for funding initiatives over and above any other course of action at this time.

Why store nuclear waste when it can now be made benign cheaper? Society is waiting for your answer.

Thank you,
EmC
Dr. David Mu, PE
Reinhardt Bsumek, PE

Appendix D

October 1, 2002

Professor James J. Dunderstadt, Chairman
Nuclear Energy Research Advisory Committee

Public Comment

I am sad to inform of the death of Dr. Vladimir Rozhkov, a Director of the Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine. Ironically he died, September, 19, 2002, the same day that DOE announced transfer of FFTF to EM. He died unexpectedly at his desk, apparently of natural causes.

A current project is, STCU-0294, "Research and Development of Fuel and Construction Materials for Accelerator Driven Plutonium Disposition and Nuclear Waste Transmutation Systems Using Molten Fluoride Blankets."

Another current project is the use of Europium sources for Gamma Irradiation.

Vladimir was recently appointed to the IAEA Council for Food Irradiation as the Ukrainian representative.

Vladimir was an ardent supporter of the FFTF. Attached please find his expression of interest relating to the production of gamma isotopes and for the technology of transmutation of nuclear waste.

I recall a conversation with Vladimir: He was describing his concepts for transmutation combining his ingredients, including lead, with nuclear waste in a high flux environment such as the FFTF, resulting in two products; one with very short half life, and a rock like radon bearing material with low activity and extremely long life. Vladimir was an extremely talented nuclear physicist.

Vladimir envisioned the day that Europium pencils would be irradiated in the FFTF achieving an activity of 100 curies/gram in 45 days. One of the major benefits of using Europium for gamma irradiation is the longer half life v. Cobalt-60. Another is the ability to recycle Europium back into the reactor to be recharged and returned to gamma irradiation service. He was very concerned about the shortage of Cobalt-60 and the increasing need for gamma irradiation services for the betterment of human kind.

I had the opportunity to tour the FFTF with Vladimir. He stood in awe of the magnificence of this great machine. Looking out over the Hanford site toward the B-Reactor, he said, “This is like a dream.” He later commented, “You will find a way to save the FFTF.”

Vladimir is a great humanitarian. His quest is the peaceful use of atomic energy. His good humor and extreme intellect will be missed by all who have known him. Our world will miss his science as the world will miss the science of FFTF if it should be gone.

Respectfully yours,
Carl G. Holder
PO Box 1316
Pasco, WA 99301

Appendix E

Ukrainian-Russian Limited Partnership Company
1, ulitsa Akademicheskaya, 61108 Kharkiv, Ukraine
Phone: (380) 572 - 356285; Fax: (380) 572 - 352811; E-mail: vrozhkov@kipt.kharkov.ua
June 3, 2002

Mr. Claude Oliver
Community Re-Use Agency
Benton County Commissioner
Richland Washington USA

SUBJECT: Expression of Interest for the Use of the Fast Flux Test Facility

Dear Mr. Oliver:

From the name of Ukrainian and Russian scientists and technicians involved in the R&D of irradiation technologies, new gamma sources construction for such technologies and R&D of new fuel and construction materials for Accelerator Driven Transmutation Technologies (ADTT) let me express strong support your efforts directed to restart of Fast Flux Test Facility (FFTF).

We express our strong support because two important issues affecting the future of humanity may be solved only with the essential use of the FFTF and FMEF: the need to develop new gamma energy sources from Europium radioisotopes to provide industry with reliable food pasteurization and medical product’s sterilization techniques and the need for Accelerator Driven Transmutation Technologies (ADTT) for nuclear waste treatment. The FFTF is unique in USA facility what has the capability to provide solutions for both of these issues.

The first problem is strongly important due to intensive worldwide development of food processing with gamma irradiation and the deficiency of about 20 MCi per year of Cobalt-60 gamma sources for these purposes. Switching Cobalt gamma sources with Europium gamma sources may successfully fill up this deficiency. The manufacturing of Europium gamma sources from the natural inactive Europium may be arranged in USA with the use of the FFTF. The parameters of neutron radiation in this reactor allow getting ready-made, technological gamma sources after about two months exposure of natural, inactive Europium rods in its core. Ukrainian-Russian Joint Stock Co GAMMTACH, State Scientific Center of Russian Federation “Research Institute of Atomic Reactors” and National Science Center “Kharkiv Institute of Physics & Technology” are ready to join their efforts with New Horizon Technologies Inc. for quick (in one year, not more longer) start of manufacture of Europium gamma sources from natural Europium with productivity up to 10 Mci per year. The use of Europium control rods in FFTF instead of standard ones can increase approximately in 10 times this productivity.

After exposition in FFTF it is possible to achieve the activity of natural europium about 100 Ci per gram. Therefore, taking into account, that wholesale price of natural Europium is about $20 per gram whereas after exposition its price should be about $200 per gram, the economic efficiency of proposed manufacture is evident.

The solution of second problem is strongly required for environmentally safe operation of future nuclear power industry and is especially important after decision of U.S. Government to recommend the development of this industry. The need for ADTT is driven by the lack of a facility where fuel and construction materials that can withstand intense irradiation with fast neutrons at high temperatures and in contact with aggressive substances could be developed for use in future ADTT facilities.

Although several laboratories and institutions in the U.S., France, Japan, Russia, and other countries are working on the ADTT problem, research and development has not yet produced the materials required. FFTF is the unique machine for testing of candidate materials, because it has several special experimental testing locations, where neutron fluxes and energy spectra are very close to those anticipated in future ADTT facilities.

Recently, the Science & Production Complex for Renewable Energy Sources and Sustainable Technologies of Ukrainian National Science Center “Kharkiv Institute of Physics and Technology” (SPC RESST NSC KIPT) received a grant for project number STCU 294 “Research and Development of Fuel and Construction Materials for Accelerator Driven Plutonium Disposition and Nuclear Waste Transmutation Systems” from the Science and Technology Center in Ukraine. Based on this project, the scientists of our Center and their colleagues from the Pacific Northwest National Laboratory should develop and execute an International ADTT Material Science Program using the FFTF, FMEF , and Kharkiv particle accelerators.

Sincerely,
Volodymyr Rozhkov
Director

Appendix F

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September 6, 2002
Professor James J. Duderstadt
Chairman, Nuclear Energy Research Advisory Committee (NERAC)
University of Michigan
2001 Media Union
2281Bonisteel Blvd.
Ann Arbor, Michigan 48019

Dear Professor Duderstadt:

I am writing to you because I believe that NERAC recommended to DOE an exceedingly high risk approach for the Advanced Nuclear Transformation Technology (ANTT) program (see April 15, 2002 ANTT subcommittee report). In addition, the recommendation was developed without serious consideration of an alternative fuel recycle technology that can achieve the fundamental objectives of the ANTT program. My purpose is to call attention to this oversight and ask that your committee consider a dual track approach to this extremely important program, one that includes further research and development on this alternative fuel recycle technology, as well as continued research on the separations and transmutation technologies recommended in the April 15, 2002 report. This letter summarizes some of the pertinent facts regarding this alternative technology, and the reasons why I make this recommendation to NERAC.

Background -The alternative technology is called AIROX (Atomics International Reduction Oxidation) dry recycle technology. It was originally developed by Atomics International in the mid 1960's, under contract to the AEC, as a means to recycle LWR spent fuel into LWR reactors without separation of either fission products or plutonium. It has since been further developed by AECL (Canada) and KAERI (Korea), with the support of the US State Department and the IAEA, as a means to recycle LWR spent fuel into existing natural uranium fueled CANDU reactors.

The AIROX process is the only technology that is considered by the U.S Government as acceptable for use in a country such as South Korea, from a non-proliferation point of view, because it is non-aqueous, and cannot be altered by a user nation to separate plutonium for possible use in weapons.

Application of AIROX to Existing Commercial Water Reactors- This AIROX technology also has application beyond those already studied by Korea and Canada. Specifically, recent work has been done under an INEEL LDRD project (LDRD 99-292) that demonstrates the use of AIROX technology for recycle of LWR spent fuel into operational LWR reactors. This broader application of AIROX to recycle of spent fuel into current LWR reactors is directly relevant to the Congressionally mandated goals of the ANTT program.

As part of the 1999 INEEL sponsored LDRD research project, Duke Engineering (now part of Framatome-ANP) developed the design of a 17 x 17 standard PWR fuel assembly reload design containing 75% AIROX recycled fuel with the balance of the LWR fuel assembly relying on 17% enriched uranium. Preliminary nuclear and thermal analyses by Duke/Framatome-ANP indicated this fuel could achieve the same burnup (50 gwd/t), and have the same performance characteristics, as a fresh LEU fuel assembly and reload design. Duke's Draft Report, "Equilibrium 18 month Cycle PWR Core Design using AIROX Recycled Fuel" dated January 29, 1999 was never published or released by INEEL.

Application of AIROX to Generation III Advanced Water Reactors Being Considered for Near Term Deployment - Based on the Duke/Framatome ANP work, it appears that AIROX recycle can be incorporated into the design of advanced generation III Light Water Reactors, or the Advanced CANDU Reactor. These reactor types are being considered for near term deployment. Detailed analyses to determine the potential fuel cycle benefits remain to be performed.

3) Application to Multiple Recycles – Waste Reduction Potential - Although the 1999 LDRD work focused on a single recycle of spent fuel, the original work performed by Atomics International, and the analytical work performed by Duke, both envision the possibility of multiple recycles. Both research projects concluded that this was feasible, but neither carried the work along far enough to analyze the reactor performance, economic, and waste minimization aspects of such a multi-cycle system. Application of such a multi-cycle system to an equilibrium recycle regime could reduce the quantity of spent fuel to be emplaced in a repository by a factor of 4.

4) Non-Proliferation Credentials - Avoidance of aqueous or pyro-metallurgical reprocessing in the AIROX system, may make the AIROX dry recycle technology more viable from a non-proliferation point of view, as compared to the approach recommended by NERAC for the ANTT program. The ANTT subcommittee report states that "…Separation will most likely require both aqueous processing (UREX) and pyro-processing. The problem is development of technologies for clean separation of fission products from uranium, and a separation of both plutonium and the higher actinides with very low processing loss…"

In contrast to this ANTT recommended approach, the AIROX dry recycle process does not involve any aqueous separation processes. Only those fission products that are volatile and released as part of the ceramic processing are separated from the bulk spent uranium oxide fuel. This unique feature of AIROX could become quite critical in the future, as the U.S. Government and others consider the potential of any new recycle regime for diversion to weapons useful programs. The U.S. Government has taken the policy position in the past, and may do so again in the future, that any technology involving aqueous and/or pyro-metallurgical separations is NOT acceptable because of the potential to convert such systems for weapons material production.

Because AIROX does not involve deliberate isotope separation, it may be less efficient, leading to a smaller reduction in high level waste quantities as compared to a total separation regime. But this loss in efficiency may be a small price to pay compared to the risks that the separations approach will later be rejected by future US administrations for the same policy reasons that such approaches have been rejected in the past.

5) Reducing the Repository Radioactivity Release to That of Ore - A key criterion established by the ANTT subcommittee, is to reduce "the radiological impact of spent fuel to below that of ore from which it came, in a period of time equal to or less than the NRC licensing period, now set at 10,000 years." The ANTT subcommittee assumed that the only way to meet this criterion is to subject the fission product and actinide components of the spent fuel to a transmuting fast neutron flux, either in a fast reactor or in an accelerator driven system.

In fact, here is another way to meet the intent of this radiological criterion that does not involve isotope separations systems, and fast neutron transmutation, and for which an AIROX system is uniquely qualified.

Because the AIROX process and facilities rely on ceramic processing technologies, it is possible to incorporate into an AIROX dry recycle system a waste immobilization component, in which the

25% of spent fuel not recycled is converted to a highly durable waste form such as Synroc. Based on recent work performed by ANSTO (Australian Nuclear Science and Technology Organization) and LLNL (Lawrence Livermore National Laboratory), a Synroc immobilization system would assure that the radioactive species emplaced in a repository would have up to 3 orders of magnitude greater durability than the current oxide based fuels. In effect, such an immobilization system could meet a criterion that is similar, but not identical, to that specified in the ANTT subcommittee report. It would reduce the already low amount of radioactivity calculated to be released from spent fuel emplaced in a repository such as Yucca Mountain, by an additional factor of 100 to 1000.

This remarkable durability of Synroc has led the DOE and LLNL to select a Synroc waste form for the immobilization component of the excess weapons plutonium disposition program. In fact an industrial scale demonstration facility has been erected at LLNL for production of synroc pucks (containing weapons grade plutonium) that could prove quite valuable, should the DOE choose to pursue AIROX dry recycle technology as part of the ANTT program.

6) The Need for a Dual Track Approach in the ATT Program - It is important for the DOE, and the NERAC Committee, not to put all its eggs in one basket. The successful introduction of a more efficient fuel cycle that substantially reduces the impact of long lived radioactive waste, is too important to the future of nuclear energy in the United States and overseas to depend on just one approach, as is currently recommended in the ANTT report. In the spirit of the authorizing legislation, that requires the DOE to investigate alternative fuel cycles that make good use of the fissile value in spent fuel, DOE should seriously consider at least one alternative approach, that is practical and of commercial interest, and is capable of achieving the intent of the ANTT criteria.

Summary - In summary, the use of AIROX technology as part of the proposed Advanced Nuclear Transformation Technology program would:

Provide the opportunity to achieve the objectives of the ANTT program in a way that can be deployed outside of the U.S. without fear of diversion of the technology to weapons purposes.

Provide an alternative approach towards achieving the radiological objectives of the ANTT program that is more affordable, because it does not depend on the development and commercialization of new types of aqueous or pyro-metallurgical separation systems, new types of fast reactors, or accelerator driven systems.

Provide a "dual track" approach for the ANTT program, and thereby provide greater assurance of success in achieving its objective (as specified by Congress) namely to enhance the value of nuclear power by recycling spent fuel and reducing the quantities and environmental impact of radioactive waste.

I urge the NERAC to give this fuel cycle technology careful consideration, and to recommend to DOE that it conduct sufficient research and development on this technology to determine its value and relevance to the Congressionally mandated program. I would be glad to provide and present further details on this technology to NERAC at your next meeting on September 30, or another time of mutual convenience.

Sincerely,
Herbert Feinroth
President, Gamma Engineering Corporation

Reference: Duke Engineering January 29, 1999 Draft Report "Equilibrium 18 Month Cycle PWR Core Design Using AIROX Recycled Fuel" Sponsored by INEEL LDRD 99-292