Minutes for the
Nuclear Energy Research Advisory Committee Meeting
April 15-16, 2002, Marriott Crystal City Hotel, Arlington, Virginia

NERAC members present:

John Ahearne (Monday only)
Thomas Cochran
Joseph Comfort
Michael L. Corradini
Jose Luis Cortez
Maureen S. Crandall
Allen Croff
James Duderstadt (Chair)
Steve Fetter
Beverly Hartline
Leslie Hartz
Andrew Klein
Dale Klein (Monday only)
Robert Long
Warren F. Miller, Jr.
Benjamin F. Montoya
Sekazi Mtingwa
Lura Powell
Richard Reba (Tuesday only)
Joy Rempe
Daniel C. Sullivan (Monday morning only)
John Taylor
Ashok Thadani (ad hoc; Monday only)
Charles E. Till
Neil Todreas (Tuesday only)

NERAC members absent:

Marvin Fertel
J. Bennett Johnston
Linda C. Knight
Allen Sessoms
C. Bruce Tarter
Joan Woodard

Also present:

Ralph Bennett, Director for Advanced Nuclear Energy, Idaho National Engineering and Environmental Laboratory
Nancy Carder, NERAC Staff
John Clarke, Joint Global Change Research Institute, Pacific Northwest National Laboratory
Jae Edmonds, Joint Global Change Research Institute, Pacific Northwest National Laboratory
Norton Haberman, Senior Technical Advisor, NE, USDOE
John Herczeg, Acting Associate Director, Office of Advanced Accelerator Applications, NE, USDOE
R. Shane Johnson, Associate Director, Office of Technology and International Cooperation, NE, USDOE
Michael Lawrence, Associate Laboratory Director, Pacific Northwest National Laboratory
Owen Lowe, Associate Director, Office of isotopes for medicine and Science, NE, USDOE
William Magwood, Director, NE, USDOE
Glenn Morris, Applied Technology Programs, NE, USDOE
Frederick O'Hara, Jr., NERAC Recording Secretary
Burton Richter, Professor of Physical Science, Stanford University
Michael Schmidt, NERAC Staff
Christopher Scolese, Deputy Associate Administrator, Office of Space Science, NASA

Earl Wahlquist, Associate Director, Office of Space and Defense Power Systems, NE, USDOE

About 30 others were in attendance during the course of the two-day meeting.

Monday, April 15, 2002

The meeting was called to order by Chairman **James Duderstadt** at 10:02 a.m. He pointed out that October will be the end of some members' terms and that nominations for new members should be sent to Norton Haberman. The minutes from the previous meeting were approved. Duderstadt introduced **William Magwood** to present an update on the budget of the Office of Nuclear Energy, Science, and Technology (NE).

Magwood characterized 2002 as a transition year with several major program developments. Nuclear Power 2010 is a new R&D initiative announced by Secretary Abraham in February. It is designed to clear the way for the construction of new nuclear power plants by 2010 and resulted from the recommendations of the Subcommittee for Generation IV Technology Planning of NERAC. It defines an R&D program that makes sense and that can lead to the deployment of new reactors by 2010. It follows twin tracks for the development of advanced light-water reactors (ALWRs) and gas-cooled reactors.

To accomplish its goal, the program must remove several barriers. One of those barriers would be addressed by promoting early site-permit (ESP) applications. The program has issued a solicitation to conduct a DOE/industry scoping study that will develop schedule and cost estimates and elicit competitive, cost-shared proposals. That study will set the stage to conduct ESP regulatory demonstration projects. This would be the first time DOE would be a full partner in the Nuclear Regulatory Commission (NRC) licensing process.

A second major program development that came out of NERAC's recommendations is the Innovations in Nuclear Infrastructure and Education (INIE) initiative, which encourages close cooperation among universities, industry, and the national laboratories for the use of the universities' research and training reactors. In FY02, the program has $5 million available to it. It is planned that awards will be made within the next several months.

A comparison of the FY02 appropriation and the FY03 budget request indicates that NE is losing funding, largely in R&D programs, mostly in the Spent Fuel Pyroprocessing and Transmutation (SFPT) Program. The total funding currently decreases from $293.9 million to $250.6 million, and funding for research and technology declines from $129.4 to $89.7 million. Specifically, University Programs stays the same at $17.5 million, the Nuclear Energy Plant Optimization (NEPO) program is zeroed out after receiving $6.5 million this year; Nuclear Energy Research Initiative (NERI) goes from $32 million to $25 million; Nuclear Energy Technologies (NET) goes from $12 million to $46.5 million, including funds for Nuclear Power 2010; Advanced Nuclear Medicine Initiative (ANMI) is zeroed out after receiving $2.5 million this year; the FFTF stays about the same, a little over $36 million; SFPT drops off from $77.25 million to $18.221 million; radiological facilities management declines from $86.6 million to $83.0 million; and program direction increases slightly from $23.9 million to $24.3 million. The new item in the budget, Radiological Facilities Management, gathers funding for infrastructure in one place and includes maintenance of the facilities used for the isotope production and space power programs. That

program has been reshaped to ensure that DOE takes care of its infrastructure and that other agencies pay for the research and production that DOE carries out on their behalf. Although the R&D budget request is lower than the FY02 appropriation, it is possible that the amount may be increased as the budget is marked up and in the House and Senate. The trend from FY98 through FY02 would put such funding close to the NERAC long-term R&D recommendation of $240 million in FY05; a reversal of that trend would put accomplishment of that goal in doubt.

Miller asked where the INIE Program fits in. Magwood answered, under University Programs.

Duderstadt asked Magwood what he saw NE doing in Nuclear Power 2010. Magwood responded: work with industry on combined construction and operating license applications, as well as ESP applications. The department is not interested in developing technologies that no one is interested in, so it is looking for participation by and with industry.

Hartline, noting the difference in funding for research and technology in one chart and funding for R&D in another, asked what numbers in the budget were counted as R&D. Magwood said, NEPO, NERI, NET, SFPT, plus $5 million. Hartline pointed out that it then comes out to more than $105 million. Magwood responded that that is because the SFPT is just proposed, not yet funded.

Cortez commented that the Department wants industry partners in Nuclear Power 2010, but the budget shows no money for it. That is sending the wrong signal to industry. Magwood said that the Department will propose $38 million for next year; the budget will ramp up as the activities are undertaken.

Mtingwa asked him for his views about a dedicated isotope production facility. Magwood replied that the budget has a small amount for beginning the design of a dedicated isotope production facility.

Ahearne noted that Westinghouse has applied for certification of their AP series reactor design and asked if there is any participation in the certification process by NE. Magwood replied, no.

Corradini asked Magwood if he could point to any industry money for their contribution. Magwood replied that industry is going to spend more than the government, but the government will be putting in some funding to prime the pump and to show that the government is behind the effort. The concept of cooperating is not mature yet. Corradini pointed out that there are other ways for the government to participate. Magwood responded that the government will provide both funds and other actions.

Comfort asked if the pressure on the budget came from the Office of Management and Budget (OMB) or from within the Department. Magwood said that he would give two nonanswers: NE has solid support in the Administration for what it is trying to accomplish. The hurdles are higher in this Administration in terms of policy benefits. But budget targets never keep up with policy advances. Duderstadt commented that he sensed a sea change at DOE; at the same time, there is strong support on the Hill, and OMB is looking for places to trim the budget.

Cochran noted the proposed cost-shared demonstration and helping in the regulatory process and asked if the government will participate only in the licensing process or if it will also put money into the plant. Magwood said that it will put money only into the licensing process. In light-water reactors (LWRs), the technology does not need to be demonstrated. In gas-cooled reactors, the efficiency of the technology will be sorted out in the next year by the industrial proponents. Cochran went on to ask if DOE's contribution would be more than or less than Jack Welch's bonuses. Magwood responded that it would be less than that amount. Cochran asked if DOE would be providing the site. Magwood said that he would not rule that out.

Comfort asked if some of the NERI has been shifted to NET. Magwood replied that it had not; NE was just more fortunate in getting NET funded.

Duderstadt asked if there will be a peer-reviewed component of the NET. Magwood responded that some things will be peer reviewed, but the larger program will not be peer-review driven.

Crandall asked where the $240.0 million R&D target relates to the other figures. Ahearne stated that the $240 million presumed more aggressive pursuits of funding. Magwood said that the R&D budget might get there, but not by 2004.

Hartline noted that, in the FY02 budget request, NE was required to include performance metrics in the budget-development process and asked about what is happening in that arena. Magwood replied that the Department is talking with OMB about a long list of metrics, such as level of industrial participation in programs. His opinion was that the Department is seen to be doing quite well, although there are some cases where the measures are not appropriate.

Powell asked, if the NERI program is cut, what would happen to the International NERI (INERI) program. Andrew Klein responded that INERI holds its same level.

Powell asked if the National Aeronautics and Space Administration (NASA) is cost sharing in the Space Reactor Program. Magwood responded that DOE is supporting the infrastructure; NASA is supporting the research. National Security Programs also have similar interests. NASA and National Security have to pay the whole freight on the development and production of any systems.

Ahearne asked if OMB had asked for any documentation on the NERI Program. Magwood said that NE was asked to write a document that set criteria on how we ranked the NERI proposals, but never heard anything back from that document. Hartline commented that that document was about OMB acceptance criteria not Government Performance Results Act (GPRA) criteria.

Cochran asked if the NERI cuts affect ongoing projects or just new ones. Magwood replied, just new ones. Cochran asked, if the Office had more money, where would it put the additional funding. Magwood noted that that is not how the question would be presented; funding would be considered on a program-by-program basis. Cochran asked if the Administration is shifting away from long-term R&D to near-term programs. Magwood responded that that is one interpretation that could be made; it is much easier to show the benefits of near-term programs than it is for long-term programs.

Duderstadt noted that Under Secretary Card pointed out that near-term demonstration would be important in determining long-term efforts and asked what will happen to funding for the FFTF decommissioning. Magwood replied that it will likely be moved to the Office of Environmental Management (EM) in FY03, and the money will have to be appropriated to perform that decommissioning. As a whole, the DOE budget experienced ups and downs: the National Nuclear Security Administration (NNSA) and EM increased; Basic Energy Sciences (BES) stayed the same; and Fossil Energy (FE) and NE went down slightly.

Hartline asked if this request is higher or lower than last year's request. Magwood responded that this is a little more than what was asked for last year. It is unknown what the congressional process will do to the budget. The Senate markup will probably be much more than this; the House markup might be a small increase over the request. Then it will go to conference.

Powell asked if a compelling vision can be put forward of where NE might be going, introducing more initiatives. Magwood answered that the Office is trying to do some of that and hopes that the policy and budget actions will coalesce.

Duderstadt pointed out the National Institutes of Health (NIH) as a good example; there, a commitment was made to doubling the budget each year. Powell replied that everybody identifies with health; NE needs to identify some major planks to undergird a compelling vision.

Duderstadt introduced **Burton Richter** to present an update on the Advanced Nuclear Transformation Technology (ANTT) Subcommittee. The Subcommittee is only two years old. Originally, the program incoherently focused on technology. The ANTT has tried to produce a coherent program geared toward the needs of society. The Subcommittee report defines a three-phase program: a proof of potential utility (completed), a proof of technical feasibility, and a proof of project operability.

The cost of Phase 1 was relatively cheap, about $80 million. It defined a set of criteria that such a program would have to meet:

1. The radiologic impact would have to be less than that of the original ore in less than 10,000 years for 1% "leakage" and less than the lifetime of the pyramids for 0.5% "leakage." "Leakage" is the quantity of recycled fuel that reaches the ultimate waste stream.
2. It must reduce the requirements for nuclear-waste repositories. Under current estimates, Yucca Mountain will be full with the spent fuel produced by 2015. Because transmutation reduces volume by a factor of 4 and weight by a factor of 20, it would save the cost of three Yucca Mountains under a continued nuclear power scenario.
3. It must not make the proliferation problem worse. A once-through fuel cycle implies a continuous buildup of plutonium inventory; transmutation stabilizes plutonium at a lower level. For reference, one needs to consider the isotopic mix of plutonium. Weapons-grade plutonium is 94% Pu-239 and 6% Pu-240. LWRs produce spent fuel with 59% Pu-239 and 24% Pu-240; this could be used to make a weapon if cooling was incorporated into the weapon design. A standard mixed-oxide (MOX) fuel cycle provides more burnup and produces spent fuel with 40% Pu-239 and 33% Pu-240. A multicycle process with a 70% burnup rate would produce a spent fuel with 8% Pu-239 and 36% Pu-240; one probably cannot make a deliverable weapon with that. However, the long and the short of it is that any country that wants to build a weapon can.
4. It must provide discernable benefits to nuclear power and society. It must reduce concern about spent fuel, and it must be economical. The economics are not yet known; the most detailed analysis is a French report that estimates that a few percent (less than 15%) would be added to the cost of nuclear power by processing and recycling the fuel.

A year ago, the possible ways to deploy this technology numbered nine. Now there seems to be a preferred way to go forward: a multiple recycle in an LWR or other thermal-reactor systems and a fast-spectrum system (either a reactor or an accelerator; one for every seven to ten LWRs) to destroy the long-lived fission products and transuranics. Several questions remain:

- Do minor actinides stay with the plutonium all the time?
- Do the plutonium and minor actinides have to be treated separately in the final stage?
- How will Gen IV be integrated into this system? If Gen IV ends up with a fast-spectrum system, the entire job might be done with that type of reactor.

International collaboration on this topic has saved DOE an estimated $100 million up to now, and about 100 students are or have been involved in Phase 1. As a result, some solid information is now known about this technology.

The estimated life-cycle costs requested by Congress cannot yet be calculated; a rough estimate is $4 billion (for a fast-reactor back end) to $7 billion (for an accelerator-driven back end). A second

phase is needed to focus on fuels, separation, and system studies. It will take 5 to 6 years and cost about $500 million. R&D is needed to see if this process is scalable to production levels. Major issues include what the "leakage" might be from the waste-stream reprocessing system, what the different fuels might be and how easy they would be to recycle, and whether plutonium and the minor actinides would have to be separated or could be processed together.

The Phase 2 R&D would set the stage for Phase 3, where the big money is. Phase 3 would produce not a full-scale system, but one that would be large enough to determine with confidence whether or not a full-scale plant would be feasible. It would have to include a scalable demonstration of processing, separation efficiency, fuel fabrication, and proof of operability. It would take about 15 years; more for an accelerator-driven system, and less for a fast reactor.

Broad international interest in this concept exists in France, Japan, Korea, and Russia, providing a lot of potential partners. Test facilities will be needed. With the closure of the FFTF, these fuel tests will have to be done overseas.

It is now time for DOE, the Administration, and Congress to decide if the potential benefits are worth the risk of Phase 2: $500 million. The program needs some stability in funding if it is to be pursued in a coherent fashion.

Mtingwa noted that, with such a small amount of money going into FFTF decommissioning, it may come alive again.

Comfort stated that the recent Gen-IV report mentioned a complete recycle system and asked how that overlaps with ANTT. Richter responded that Gen IV is not well defined, and it is not clear whether it would be able to integrate recycling into the system. Gen IV could incorporate such a back end, and that is one (but only one) of the options being considered.

Till asked how much it would cost. Richter said that the Subcommittee did not make a detailed cost estimate; it is not possible to make such estimates at this state of knowledge.

Cochran asked Richter if he was claiming that, if you lost 1% out of the fuel cycle, you are still better off with this fuel cycle in terms of the overall life-cycle health effects than with the storage option. Richter replied, yes. The only study that has been done is an analysis by the United Nations Special Committee on the Effects of Atomic Radiation in *UNSCEAR 2000* of the MOX plants in France and England [Cogema and BNFL (British Nuclear Fuels, Ltd.)]. Their conclusion was that the radiologic impacts are negligible. The results of this analysis can be used as a model, but the outcome of the process will depend on what is fed into the LWRs.

Cochran stated that he did not believe that it is a factual statement that the multicycle 70% burn would not constitute a credible weapon threat. Richter commented that it does not change the proliferation rate for legitimate-country activities, but it does change it for the diversion to nonstate entities. The countries will do whatever they want, anyway.

Hartline asked if the Committee is involved in the report to Congress. Richter replied that that is a DOE report; the Subcommittee is not reviewing it or contributing to it. Hartline asked if DOE/NE will have NERAC review that report. Magwood responded that he would have to ask DOE Management whether it will be reviewed outside the Department. This is a 5-year program proposal that focuses on policy and budget, not on research needs. Richter said that the issue is clearly posed for the Administration: the policy question is whether $500 million should be committed to this program. Magwood asked what the total effort would cost. Richter responded that the cost would be the same as is being spent in Europe and Japan.

At 11:52 a.m., Duderstadt called a break for members to get food for the working lunch. He called them back into session at 12:15 p.m. to hear **Michael Lawrence** speak on the nuclear capabilities of Pacific Northwest National Laboratory (PNNL).

The Laboratory was founded in 1943 to conduct research on nuclear fuels, materials, processing, and environmental effects. It can go from science through deployment. At PNNL, all energy-related work is in one directorate. Funding from NE is a very small portion of the Laboratory's budget. A large portion of its funding comes from Nuclear Nonproliferation, with EM and Defense Programs (DP; funding work on tritium targets) providing other significant portions.

The largest program it has is the International Nuclear Safety Program (INSP), which deals with Soviet-designed-reactor safety, the Chernobyl shelter replacement, and the elimination of weapons-grade plutonium production in Russia. Work in reactor safety involves operations as well as hardware; they have upgraded the safety of all the reactors in nine countries of the former Soviet Union, and the program is now winding down. They are helping design the shelter that will supplement the sarcophagus over the damaged Chernobyl reactor. And $450 million is being devoted to addressing the problems of plutonium-production reactors in Russia. The power and heat from those reactors is needed. Short-term fixes in safety have been made. Fossil-fuel plants are being built, and the reactors will be shut down by 2007.

Under DP's Tritium Target Qualification Project, PNNL designed and fabricated 32 tritium-producing rods, which were successfully operated in the Tennessee Valley Authority (TVA) Watts Bar Nuclear Plant from 1997 to 1999, providing the technical basis for the Secretary's decision to meet defense-related tritium needs via LWRs. PNNL performed postirradiation examinations on those rods and developed process parameters for the Tritium Extraction Facility at the Savannah River Site (SRS). PNNL developed a ceramic powder amenable to automated processing of lithium-aluminate pellets for large-scale production of tritium-producing rods. It also supported TVA in seeking NRC approval of this and other demonstrations of the technology.

The Laboratory participated in planning and organizing several workshops for NE, is the Executive Agent for the INERI, has four NERI projects (on materials aging, radiation-resistant structural materials, defects in ceramics and composites, and modeling the performance of materials), and has two NEPO projects.

A powerful tool it has developed is the synthetic-aperture focusing technique for ultrasonic testing (SAFT-UT) that yields very-high-resolution 3-D images of flaws in solid materials. This system is being used to compile a database on welding, cladding, and base-metal flaws in the reactor pressure vessels of unfinished nuclear power plants. The results of these tests will provide a basis for the NRC to re-evaluate its rules for such pressure vessels.

It operates a number of projects in actinide science, dealing with radiomaterials characterization, actinide separations and transmutation, measuring ultratrace levels, and supporting the Yucca Mountain repository. One success story is the development of a way to separate yttrium-90 from strontium-90 so the yttrium isotope could be used by the National Cancer Institute (NCI) to treat cancer. PNNL has developed two therapeutic drug products with this isotope: a polymer composite for injection into nonresectable solid tumors (producing a high dose in situ) and a surgical bandage for treating minimum residual disease after tumor resection.

PNNL has developed intelligent diagnostic systems that look for precursors to failure of plant equipment and use radio-frequency tags (smart sensors) to send data to a central computer system.

Deployment of this system in three field tests produced dramatic economic effects on the cost of providing maintenance and avoiding outages.

PNNL does not have many nuclear facilities. The four it has are rather old but are well maintained. They house some special capabilities: a helium mass spectrometer, a nuclear magnetic resonance spectrometer, and an atomic-force microscope in a shielded glove box.

PNNL's Environmental Molecular Sciences Laboratory supports two ongoing NERI projects. The Laboratory is conducting climate-change research (which will be reported later in this meeting). And it is conducting an Advanced Nuclear Science and Technology Initiative to reinvigorate the equipment the laboratory has and to use it to look at materials, actinide science, and instrumentation and controls.

Mtingwa asked to what extent PNNL has nuclear chemistry students involved. Lawrence responded that it has a relationship with the nuclear chemistry program at Washington State University, but there is not a good answer about financial support for the program.

Cochran commented that most of the release of iodine-127 occurred between 1944 and 1947. So most of the health impacts occurred when you were constructing quickly. Now DOE wants to walk away from the grouted waste tank farm. He asked how PNNL advises DOE about this. Lawrence responded that PNNL has not taken a position on this. The ability to get all of the waste out of the tanks was questionable, and the benefits were not obvious. Powell noted that the major role of the Laboratory is to do technical research on which DOE can base policy decisions.

Duderstadt introduced **Shane Johnson** to speak on University Programs and the Innovations in Nuclear Infrastructure and Education (INIE) initiative. The INIE program results from the recommendations of NERAC to establish "regional facilities" that use existing university research and training reactors. INIE encourages universities to established enhanced cooperation with other universities, national laboratories, U.S. industry, and other private and public organizations to feed into a competitive peer-reviewed process. It seeks commitments from participating universities to maintain their current levels of funding support for their facilities. Through these regional centers, it is hoped that all of the university nuclear research community will be buoyed up. The community itself helped draw up the solicitation, which was issued in December and closed in March. Thirteen proposals were received with a total request of more than $50 million for the first year ($5.5 million is available). Awards are expected to range between $100,000 and $2 million yearly and be renewable on an annual basis for up to four additional years.

Till asked whether the innovation enters in in the form of the technology, approach, management, etc. Johnson replied that that was left open, and the proposals will reveal the innovations. DOE is trying to get the universities to think outside the box. The proposals come into the Contracts Office, which is arranging the peer reviews; NE is trying to stay out of the advisory process. Duderstadt pointed out that an estimate of the cost of maintaining university research reactors was $10 million per year and that what was being asked for here is a large increase in activities. Haberman asked if a university could propose building a new reactor or simulator under this solicitation. Johnson replied that that was not the intent.

The reviews will be completed in April, and funding decisions will be made in May.

The other university programs continue to operate. Three new radiochemistry grants were awarded; peer-review panels have been completed for matching grants, reactor sharing, fellowships and scholarships, university reactor instrumentation grants, and nuclear engineering education research

grants; and summer internships will number more that 20 this summer with significantly more applicants than last year.

Hartline asked how many applicants and assistantships there were. Johnson replied, in the low twenties, including both graduate and undergraduate students.

Andrew Klein noted that there is a roughly 30% reduction in university programs from changes in all of the different NE programs. Miller commented that the NNSA has a great dependence on nuclear engineering education and asked to what degree NE emphasizes that in dealings with NNSA. Johnson replied, basically not at all; NE hopes to have an agreement with NNSA to support nuclear engineering education by the end of the year. Lawrence offered that NNSA has established a fellowship program and designated PNNL to manage it. Andrew Klein stated that DOE should also remember the health physics community, which grossly needs support, even more than radiochemistry.

Powell asked what the National Science Foundation's (NSF's) role is in such programs. Duderstadt said that NSF is willing to provide a minor amount of support to nuclear engineering but does not see it as a major responsibility. He asked Miller how many summer students are at Los Alamos National Laboratory (LANL) each summer. Miller responded, 1400. Powell noted that there is a memorandum of understanding (MOU) between DOE and NSF to support undergraduate and graduate fellowships across DOE's areas of interest. That might be a point of focus to get more nuclear engineering scholarships. Corradini called attention to the existence of a Nuclear Engineering Department Heads Organization (NEDHO) white paper on how to break into NSF funding. Andrew Klein mentioned the fact that the American Nuclear Society (ANS) and others are conducting programs to encourage students to go into nuclear engineering. Miller pointed out that Texas A&M University has seen a great growth in nuclear engineering; they attribute it to the availability of funding for those students. Duderstadt suggested that it might be better to pursue a certificate or minor program in nuclear engineering within a broader, traditional engineering major.

Johnson then shifted to his second assigned topic, the Nuclear Power 2010 Program. The near-term deployment roadmap for this program was developed over 20 months. The roadmap called for an assessment of extant regulations to see if they work. A need was seen for a public/private partnership to develop advanced reactor technologies, explore sites that could host new nuclear power plants, and demonstrate new NRC regulatory processes. NE is trying to figure out how to put together a program to help the potential end user (a power-generation company) to get them through these regulatory processes to produce a generating asset.

Cochran asked if any utility had ever come to DOE and said that the regulatory process is standing in the way of getting a license. Johnson responded that some have said that, if DOE would partner with them to prove the regulatory process, they would go forward with plans to deploy new plants. Cochran asked who that was. Hartz replied, Dominion Generation.

Johnson said that DOE put the proposal out, and industry seems to be responding. The Nuclear Power 2010 Program is designed around three major tasks:

1. regulatory demonstration tasks, such as early site permit (ESP) application, design certification (DC) and final design approval (FDA) for advanced reactor designs, and a combined construction and operating license (COL);
2. design-completion tasks, looking at (a) R&D on material, component, and system testing, (b) fuel irradiation and testing, and (c) first-of-a-kind engineering;

3. a nuclear plant business case study, examining the economics and business decisions that have to be made.

Ahearne asked whether the site permit application had an envelope that specified a specific type of reactor. Johnson replied that that is true. Ahearne went on to ask how one would cover a pebble-bed reactor, which has no specifications associated with it. Cochran asked why the utilities do not cost share among themselves and leave the government out of it. Taylor responded that no investor is willing to put money into a nuclear plant. Even when you get a permit, others can enter the process through the courts. That is not an industry problem but a governmental problem. Those investments should not be held hostage by the process itself.

Johnson noted that the proposals are due the very day of this presentation, and NE is looking at a 50-50 cost sharing with industry.

Long noted that the ALWR process involved manufacturers, DOE, NRC, and others that produced a standardized-design document and asked if that same commitment can be achieved for gas reactors. Johnson replied that that work is in progress. What is not wanted is a nice design that sits on a shelf. The end users need to be put in the driver's seat so they will build a reactor if a solid business case can be made for it.

Crandall remarked that all the site comments could be made, but, until it is known what Federal Energy Regulatory Commission (FERC) is going to do, the state of the electricity market is going to remain uncertain, and no one is going to build a gas, coal, or nuclear [baseload] plant. What is being looked at here is just a small piece of a large problem. Johnson concurred; what DOE is trying to do is to eliminate those barriers that industry identifies and where DOE has authority to act.

The Nuclear Power 2010 Program has $8 million this year. It will complete the ESP scoping study, complete the nuclear plant business case study, will fund two or three cost-shared projects for ESP applications, will solicit and select cost-shared projects for the design certification and approval of advanced designs, and will continue planning and test-fixture fabrication for gas-reactor-fuel fabrication. For FY03, it has requested $38.5 million to solicit and select cooperative, cost-shared COL demonstration projects and to initiate a nuclear industry infrastructure assessment.

Haberman noted (based on a telephone conversation he had just received from Magwood) that Exelon has dropped out of the pebble-bed consortium. Johnson noted that the Nuclear Power 2010 Program will not put money into the pebble-bed reactor, then. It will not irradiate pebbles for the sake of science; that is not its mission.

Cochran asked what the total cost of this program was and how that cost is divvied up. Johnson responded that the total cost is about $340 million divided over 8 years.

Duderstadt asked **John Ahearne** to report on the activities of the Long-Range Planning Subcommittee. Ahearne started by asking Richter to confirm that the $500 million mentioned in the ANTT report is just the U.S. contribution. Richter replied, yes, there would have to be significant foreign contributions. Ahearne went on to note that the report refers to mothballed facilities like the Barnwell PUREX plant that could be brought into operation. That plant, he said, has been at least partly dismantled as well as being very old. Haberman commented that the Savannah River staff says that it could be recovered. Ahearne said that a lot of equipment was moved out when the plant shut down; that is a long way from being mothballed.

He then addressed the topic of the nuclear-power air-quality study called for by the National Energy Policy. A joint DOE-EPA taskforce was put together to conduct this study, but its charter is

unclear. EPA is going to run a model that they have, and if NE wants to put some money forward, some runs desired by DOE would be undertaken. The model is strictly an economic model aimed at identifying least-cost solutions. It is not designed to determine what effects nuclear energy can have on reducing air pollution. EPA will conduct a base-case run using the nuclear cost estimates of the Energy Information Administration (EIA). They will then do a run with "optimistic nuclear cost estimates." Then they will do a run probing gas price sensitivities vs nuclear power and one with the proposed new caps on fossil-plant emissions (on SO_2, NO_x, and mercury) vs nuclear power out to 2025.

Cochran asked why the model was not just run to determine the different costs associated with different amounts of pollutants. Ahearne replied that that is not the way the model is set up. Getting these runs done is a slow process. EPA will get the results of the runs and review them. DOE/NERAC will then get access to them. Ahearne was unsure if anything useful will come out of this effort. Crandall stated that EPA is not known for its sensitivity to economic considerations; Congress has not required EPA to consider economic considerations.

Ahearne proposed that the Subcommittee (1) review NERI's and INERI's accomplishments, problems, and status and (2) review the many pieces of the nuclear-energy program that is being constructed, asking if a consistent whole can be made from the elements (NERI, NEPO, Nuclear Power 2010, etc.) and an integrated strategy adopted. The Department desperately needs a single plan that makes all of this focused, efficient, and transparent. He suggested that the Subcommittee focus on developing an NE Strategic Plan.

INERI's recent solicitation elicited 242 notices of intent of which 204 met the scope of the request. There will be $10 million for new projects and $3 million for continuation funding.

Duderstadt said that he was concerned that NE is looked upon as an applied technology shop and asked to what degree NE can grow a peer-reviewed R&D program. He asked if SC should be asked to look into this. Ahearne agreed that that has been a large struggle in putting together the long-range plan. Duderstadt stated that, up the chain, there is not an adequate understanding that R&D is an appropriate activity of NE.

Hartline noted that, in the performance report, NERI is lumped with the business activities. Haberman pointed out that all of NE is put under applied science. That is done by OMB. Cochran asked where one draws the line between basic and applied science in the NERI Program and pointed out that Nuclear Power 2010, where NERI has been put, is not focused on research.

Miller asked why the Long-Range Planning Subcommittee is proposing to assess just one of these programs. Ahearne responded that it was because the Subcommittee was specifically charged with overseeing the NERI Program.

Duderstadt stated that what is needed is a vision that drives the types of investments that are being talked about in this Committee. It would be interesting to look at the nuclear-energy sector of the Federal Science and Technology Budget to see what portion of the nuclear-energy economic sector it represents. He expected one would see some devastating erosion of the R&D support during the past years and a massive turnaround since the sixties (when the government funded 60% of R&D) to today (when industry provides 60% of R&D funds). If the federal government is seriously underinvesting in nuclear energy, how can the industry be expected to invest in the future? It would be interesting to compare the situation in the nuclear sector with those in other sectors.

Rempe asked if the Subcommittee was going to visit all the NERI and INERI projects. Ahearne replied that it did just that. The main problem is that research programs have to have stable funding. It is

unconscionable to encourage someone to come into the field when you know that funding is going to end in a year or two.

A break was declared at 2:43 p.m. The meeting was called back into session at 3:15 p.m. to hear **Jae Edmonds** discuss the possibilities for nuclear power to stabilize CO_2 concentrations. He pointed out that climate change arises from increases in the atmospheric concentration of CO_2 from fossil fuels and land use; methane from rice production, ruminant livestock, land fills, and coal mining; N_2O; manufactured gases like SF_6, CFCs, and HFCs; and aerosols and dark particles (soot). These trace atmospheric components are emitted globally and are long lived.

In 1992, the United Nations Framework Convention on Climate Change was signed to promote "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Preindustrial atmospheric CO_2 concentrations were 280 ppm; the current concentration is 370 ppm. Fossil fuels contribute 6.9 PgC [about a billion tons of carbon] per year, and land-use change contributes 1.6 ± 1.3 PgC/year. Cumulative emissions in the atmosphere are what matter.

Cumulative atmospheric concentrations of CO_2 can be modeled with assumed population growths, energy-demand rates, energy-source mixes, emission rates for each energy source, and atmospheric-CO_2 withdrawal rates (from ocean uptake, sequestration, photosynthesis, etc.).

The B2 scenario of the Joint Global Change Research Institute assumes that, by 2100, the human population will increase to 9.4 billion people, per capita gross domestic product (GDP) will grow 1.85% per year, the gross world product will increase by almost an order of magnitude, and technologies will improve dramatically. With no other restraints than market forces, primary energy production (largely from fossil fuels) will increase from 400 to 1200 exajoules per year, and the percentage of that demand for primary energy that will be met by gas and oil will decline; coal will increase; hydro will stay the same; biomass and nuclear will double to triple; and wind and solar will each rival nuclear under this scenario. The portion of that primary energy devoted to electricity production will be largely produced from gas and coal, with the hydro contribution staying the same; oil, biomass, and nuclear increasing at the same rate as overall demand; and significant new sources from solar, wind, and hydrogen fuel cells being introduced.

Given this base case, the effects of changes in several variables can be tested. One such variable is the extent of nuclear-technology development and deployment:

- a nuclear-technology moratorium,
- current-cost nuclear power,
- advanced nuclear technology (with a 1% per year improvement rate for the next 50 years), and
- goal-driven nuclear technology (with a 1% per year improvement rate).

Another such variable is the policy response that might be made to climate-change emissions:

- no climate-policy regulation,
- limiting atmospheric CO_2 to a concentration of 450 ppm (through emissions regulations or economic incentives/disincentives),
- limiting atmospheric CO_2 to a concentration of 550 ppm,
- limiting atmospheric CO_2 to a concentration of 650 ppm, and
- limiting atmospheric CO_2 to a concentration of 750 ppm.

The effects of these variables have been tested with the computer program MiniCAM, which projects greenhouse-gas emissions based on world energy prices and quantities, energy demand, energy

supplies, energy-resource constraints, energy technologies, GDP, available labor force, labor productivity, and population rates.

Cochran asked how price vs costs is modeled. Edmonds replied that this is a market-driven model that uses a graded resource. It is a marginal-price-costing model. It factors in a lot of competition among the different power-generating technologies. It does not consider specific reactor designs, interactions among resource limitations, combined hydrogen production and electricity generation, weapons proliferation issues, or wastes.

The model results indicate that, with a nuclear moratorium, nuclear power disappears about 2005, and energy use stays same as in the base case but is more expensive. With 4 cents/kWh nuclear technology, nuclear expands its role in energy provision at the cost of fossil fuels. With 2.5 cents/kWh nuclear, there is a massive expansion of the use of nuclear with a lot of reactors going into developing countries (China, India, Africa, and Central and South America).

In terms of the different policy initiatives to stabilize CO_2 concentrations, nuclear gains market share in each case, but a lot of the market share is captured by technologies that produce electricity/hydrogen and capture the carbon. At 2.5 cents/kWh nuclear power, one sees a lot of deployment of nuclear power. With the imposition of a carbon tax to force the meeting of the CO_2-concentration caps, energy costs rise dramatically with the stringency of the policy. In each of the four cases of nuclear-technology development, the greater the deployment of nuclear technology and the lower the cost of nuclear power, the cheaper it is to meet the CO_2 caps. The market share is very sensitive to market price.

He cautioned that

- the greenhouse problem is not likely to disappear on its own,
- the problem does not necessarily mean that nuclear will be reborn,
- it is a competitive world and cost and performance matter big time, and
- nuclear power could be a major component of the global energy system with or without climate change if cost and performance are right.

Miller asked if Edmonds' computer program is generally available or if it only runs on his system. Edmonds responded that a downloadable version that runs on a PC is available on the Web site at CDIAC (Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory). The Joint Global Change Research Center is constantly updating the model for application to different research problems.

Corradini asked if they had benchmarked this model with historic macroeconomic data. Edmonds replied that all of the data are based on historic data. Projections that they made in the 1980s hit the carbon emissions for 2000 almost exactly.

Duderstadt called upon **John Taylor** to report on the NEPO Program review.

The primary objective of NEPO is to help assure that current plants continue to deliver safe, adequate, and affordable energy for up to 60 years of plant life by resolving open issues related to aging mechanisms and by developing and applying the best technology to enhance plant safety, reliability, and productivity. A major element in nuclear power plant aging is the electrical system.

In response to September 11, funds from NEPO FY02 are being diverted to support Threat Assessment/Mitigation tasks based on the initial EPRI/NEI (Electric Power Research Institute and Nuclear Energy Institute) efforts currently under way and to develop a roadmap for future R&D work related to nuclear power plant security. The tasks will be funded through $400,000 that was held back as contingency funds and the withdrawal of currently approved FY02 tasks totaling about $600,000.

The current plan is to discontinue four projects. Normal deductions were also applied to the $7 million FY02 funding of NEPO by Congress. In addition, a cut of $500,000 to cover a rescission and $400,000 to cover costs of DOE interactions with uranium enrichment plants were selectively assigned to NEPO, resulting in a total for FY02 of $5.5 million. These reductions prevented the funding of projects on motor rewind insulation, data on systems' aging, monitoring instrumentation and controls (I&C) electronic boards, wireless technologies, and Project 5-213 on instrument calibration.

DOE and EPRI staff have prepared summaries of the NEPO R&D done to date, including identification of the reports that have been issued.

Results from NEPO research include:

- Zinc addition to the primary coolant of pressurized water reactors (PWRs) can reduce dose rates and mitigate primary water stress corrosion cracking (PWSCC) effects, including reactor vessel head cracking. Experiments have shown that the zinc additive will not precipitate at operating temperatures, clearing the way for its use in PWR plants.
- Three nondestructive testing techniques (eddy current, ultrasonic, and electropotential) were identified that can be deployed for in situ measurements of irradiation-induced swelling in PWR core internals fabricated from austenitic stainless steels.
- An improved screening basis was developed for evaluating the likelihood of thermal cycling and consequent metal fatigue in PWR branch-line piping.
- Technical justification was provided for reducing current ASME (American Society of Mechanical Engineers) Boiler and Pressure-Vessel Code stress-intensification factors for tees and branch connections.
- Guidelines were provided for addressing fatigue environmental effects as well as for fatigue management during the extended operating life.
- Support was provided for licensing applications for an increase in maximum fuel burnup (to 45 to 50%), improving the efficiency of plants.
- Connector sealing systems were found to prevent moisture from entering coaxial cables during severe accident conditions, and procedures were identified to assure correct assembly of the connector during installation.
- Training aids were developed for use in training personnel in assessing the aging of cables for low-voltage instrumentation, control, and power using visual/tactile methods.
- An application was developed for a commercially available smart pressure transmitter to replace obsolete analog transmitters; the method has potential in evaluating commercial-grade digital equipment for use in nuclear-safety applications.
- The guide on digital upgrade issues in the design, evaluation, and licensing processes was updated.
- A Human Performance Assistance Package was developed for identifying and applying leading indicators of human performance. The software was tested successfully in a nuclear plant.
- Two techniques were developed for proactive management intervention to respond quickly to rapidly initiating corrective-action processes.

Looking at prospects for FY03, DOE has zeroed out NEPO in its FY03 budget submission. EPRI and its Nuclear Power Council (NPC) are disappointed by this decision, but they decided to pursue the following actions:

- The Nuclear Energy Institute has testified to Congress that NEPO should be restored at the $15 million level for FY03.
- The NPC is preparing a letter to Congress recommending that NEPO be continued at the level of $15 million.
- EPRI is sponsoring on its own the annual NEPO Workshop to gain input for purposes of identifying the most valuable projects that should be pursued in FY03. A FY03 solicitation and selection process has been defined and is being announced to potential workshop attendees.

The ongoing NEPO projects are being carried out competently, are producing valuable results, and are benefitting from input from the NRC, the national laboratories, Institute of Nuclear Power Operations (INPO), and universities, as well as from the nuclear utilities. The program to date is meeting the needs originally identified by the President's Committee of Scientific and Technical Advisors (PCAST) when it recommended that the NEPO program be initiated. DOE is urged to maintain its support for a continuation of NEPO through FY03.

Duderstadt asked where the deleted funds are going. Glenn Morris responded that senior DOE management felt that threat assessment and security should be addressed. DOE is trying to address what R&D is needed to enhance the security of nuclear plants. Duderstadt noted that the umbrella committee of National Research Council is issuing a classified document on the topic this week and that the government investment on the topic will be immense. Ahearne commented that the NRC is evaluating the threats that could be posed by terrorists. Morris added that DOE does not want to duplicate efforts by others, but this type of research is what NEPO is here for. NE will be prepared with a proposed program for FY04.

Ahearne called attention to Taylor's list of actions that resulted in reports and asked how utilities would get hold of those reports. Taylor responded that EPRI distributes the reports, sets up user groups, and uses other mechanisms to get utilities to not only receive but use the reports. Morris noted that, under the NPC, there are other committees that review and disseminate research results. Ahearne wanted to make sure that plant managers would be knowledgeable about these reports and their availability. Hartz stated that Dominion Generation has a single point of contact for EPRI information; they then distribute each report to the people who can use it. Comfort asked how many of these reports have been implemented in the plants. Taylor was not sure, but stated that many times EPRI has little working groups that foster the implementation of findings, such as the NEPO results.

Mtingwa said that he thought that industry was supposed to support NEPO. Taylor responded that the goal was for industry to support at least 50% of the cost of the program.

The meeting was adjourned for the day at 5:11 p.m.

Tuesday, April 16, 2002

Chairman Duderstadt called the meeting to order at 8:01 a.m. and called upon **Neil Todreas** to review the activities of the Generation IV Roadmap Subcommittee.

The program is currently in the transition between selection of the concepts and identification of the needed R&D. DOE asked that proliferation and physical protection be made a separate goal. That now joins sustainability, safety, and economics. The challenge is to do something on the whole system associated with physical protection.

Cochran asked if economics and sustainability can be combined. Todreas responded that sustainability includes fuel utilization, and that, indeed, could be considered under economics. The near-term deployment is focused on siting, licensing, and R&D associated with a few key issues.

The Nuclear Power 2010 program is based on this near-term deployment. The question is, what R&D should be launched to support this near-term deployment. He personally suggests particle fuels for gas reactors, a high-burnup UO_2 fuel, and an inert-matrix fuel for partial recycle. The reactor concepts should include direct-cycle gas reactors and critical development issues for the integral reactor. All of these will have to have industry participation.

The main output of the R&D plan/nuclear development strategy is to be a well-thought-out roadmap for R&D. The focus should be on some specific nuclear systems. The pressure is to identify six to eight concepts. But there could be an alternative approach to identify sets of concepts, allowing flexibility in dealing with new concepts for nuclear systems. The selection process is focused on reactors. It is necessary to move quickly to generic R&D, which obscures the integrated system view.

Till asked what the fuel cycle crosscut group says. Todreas said that they were supposed to be out front so we could embed the selected fuel cycle in the R&D. They took longer than expected. Till commented that the report is an insightful, balanced document. Todreas noted that the industry is going to have systems committed to the once-through fuel cycle for years. It needs to start moving toward high-burnup fuels.

Nonclassical concepts are included in the roadmap considerations, but they have long time frames. High-temperature systems and other concepts are included. Several nonclassical concepts are in the mix, including high-temperature, gas-core, molten-salt-cooled reactors. This nonclassical development needs to get back into consideration.

NERAC has asked the Department to move on public outreach. The Subcommittee has reached out to the technical community, but the Department has not come forward with a plan to go broader.

Todreas asked **Ralph Bennett** give an overview of the recent Gen-IV Roadmap Subcommittee activities. Generation IV is "the next generation of nuclear energy systems that can be licensed, constructed, and operated in a manner that will provide a competitively priced and reliable supply of energy to the country where such systems are deployed, while addressing nuclear safety, waste, proliferation and public perception concerns."

The objective of the Technology Roadmap is to describe systems deployable by 2030 or earlier; to determine which systems offer significant advances towards sustainability, safety and reliability, and economics; to examine R&D pathways for nuclear technology (systems that can be deployed in 30 years); and to plan for a Gen-IV R&D program.

The key steps to prepare the roadmap are to:

- Define technology goals for Gen IV
- Identify concepts with potential stimulated by a broad-based request for information (April 2001)
- Evaluate concepts with a common methodology resulting in a qualitative screening for potential (September 2001)
- Conduct the quantitative final screening (March 2002)
- Select six to eight long-term concepts with Gen-IV International Forum (GIF) guidelines (under way)
- Identify R&D gaps and needs (under way)

- Assemble a program plan (summer 2002)

A concept is a reactor and fuel cycle, including the front end, back end, and disposal/recycle system. Cochran asked what the selection criteria were. Bennett said that there were 24 metrics divided among the four goals; it was a good sample (e.g., in economics, the life-cycle cost).

The work is being done by the members of the five working groups and the fuel-cycle crosscut group (half of whom are non-U.S. nationals) put together by the GIF, which itself grew out of the nine countries that signed the Gen-IV communique in January 2000. The GIF's charter was signed in July 2001; it calls for the GIF to

- Identify potential areas of multilateral collaborations on Generation IV nuclear energy systems,
- Foster collaborative R&D projects,
- Establish guidelines for the collaborations and reporting of their results, and
- Regularly review the progress and make recommendations on the direction of collaborative R&D projects.

The GIF has no permanent staff or centralized funding of projects. GIF participants pay for their own R&D and share the resulting information.

Mtingwa asked if there was any prospect for Russia to participate. Bennett said that it was being discussed.

The GIF sponsors nearly 50 staff on the roadmap, it reviews and brings an international perspective to those reviews of the Gen-IV Technology Goals and the Gen-IV Roadmap, it endorses key elements (such as concepts and the roadmap), and it collaborates on Gen-IV R&D. It has held six meetings, with four more planned for this year.

Concepts were evaluated by issuing a broad request for information. More than 100 ideas were submitted, about one-third were from the international community. Qualitative screening looked at qualitative criteria for each Gen-IV goal. Many ideas were coalesced into 30 concepts, a few did not advance. The quantitative evaluation has caused a further refinement into 19 concepts. This process will come to a close with the selection of the most promising long-term systems, which will be discussed at the April and May GIF meetings. Of the 19 reactor concepts, 6 are water cooled, 5 are gas cooled, 5 are high-temperature, and 3 are nonclassical.

In regards to sustainability, the closed-cycle fast-spectrum systems are faring the best. These systems include the sodium and lead alloy liquid-metal concepts and the fast gas-cooled concepts. In regards to safety and reliability, thermal gas-cooled concepts are leading. In economics, there is an interesting division: For water- and gas-cooled concepts, the life-cycle cost points to large, monolithic plants, but investment risk points to small or modular plants. For hydrogen production and high-temperature applications, very-high-temperature gas-cooled reactors, Molten-salt-cooled prismatic-fuel reactors, and lead-alloy liquid-metal concepts can reach temperatures adequate for thermochemical production of hydrogen.

The R&D challenges include:

- Higher temperatures for fuels and materials
- Increased corrosion/erosion in alternative coolants
- Design with inherent safety
- Fuel fabrication methods
- Recycling technology and methods
- Manufacturing and constructability

- Hydrogen by thermochemical processes
- Component technologies to match coolant conditions

These are the price tags for reaching promising systems.

The Subcommittee is asking the working groups to identify gaps and needs in R&D. This practice often leads to cases where crosscutting needs can be identified.

R&D integration is drawing together (1) concept-specific R&D (resource requirements, facilities, duration and sequencing with other tasks, prioritization, and risk); (2) crosscutting R&D(which can be looked at similarly); (3) basic science and technology needs; and (4) opportunities for international collaboration.

The Subcommittee is looking forward to finalization of concept selection (May 2002), R&D integration (July 2002), finalizing the roadmap report (September 2002), and transmittal to NERAC (fall 2002).

Cochran asked how many concepts are being considered. Bennett replied, about six to eight. Cochran asked if they could not now select six to eight concepts that met the goals. Todreas responded that the concepts do not need to meet the goals today; the Subcommittee wants to identify the R&D needed for them to meet the goals when they are developed and ready for deployment.

Bennett summarized by saying that the roadmap is a 2-year project, to be completed at the end of FY02. Its primary objective is to define an overall R&D plan to advance the next generation, with significant international participation of the 10 countries in the GIF. Nearly 100 international experts staff the working groups, with significant industrial participation. More than 100 ideas and concepts have been refined to about 20 most promising concepts; the objective is to get to the six to eight with the best long-term potential and to develop an R&D program that advances them.

Todreas identified the individuals who have contributed to the efforts significantly. Intermediate reports are not submitted for NERAC acceptance, but comments are welcome. The final report will be submitted to NERAC for review and consideration.

Cochran said that he had major structural problems in that the process has been turned over to the usual cast of characters and sustainability has been put at the top of the list. This is akin to the mistakes made with the breeder program. The price of uranium has gone down rather than up as was projected by the breeder proponents. He said that the economic analysis is also bogus. Sodium-cooled reactors cost 2.5 times LWRs. He would kick out all those that cannot pass the economics test. The Subcommittee has included anything that can pass muster in any group, even if it is a dog. The Subcommittee should look at the original objectives and put some R&D into some advanced concepts to see if they can be made economical. Todreas responded that there are many valid points in what Cochran said. The issue of cost is well established. The analysis is pointing to using closed fuel cycles, but that does not mean that other systems should be locked out.

Duderstadt pointed out that much of the growth for energy will occur in lesser-developed countries and asked if that had any implications for the Subcommittee. Todreas replied that the Subcommittee was not focusing on that issue specifically, but it is being discussed, especially among the GIF countries that are lesser developed.

Fetter noted that the uranium resources only cost a mill per kilowatt-hour and asked how eliminating the cost of waste disposal translates into an advantage when it constitutes only a 2% reduction in cost. Todreas replied that the major challenge for fast-fuel systems is to come within a factor of 2 of once-through systems' costs. One can separate radioisotopes in the waste stream and cut down on the waste

burden. Fetter pointed out that two-thirds of the concepts still on the table are recycle systems, and it seems counter intuitive. Todreas said that the Subcommittee has been looking for new ideas, including those that exploit that advantage.

Corradini said that one cannot overconstrain the system. If one rules out recycle systems, one has to calculate how many Yucca Mountains are needed. Miller noted that the economics of these concepts is quite complex. The fact that sustainability is first on a viewgraph does not mean that it is the most important aspect. He asked if any of the goals are more important than the others. Todreas replied, no; economics has been the central focus. The subjects of the discussion might be systems that are 20 or 30 years in the future. Cutting back on considering concepts rules out innovation. There is a scheme that considers probabilities, promises, and risks.

Bennett noted that the various countries involved also have specific goals that they are each interested in.

Hartline commented that, 30 years ago, no one would have thought that we would have mapped the human genome by now. She asked if the Subcommittee is going to analyze the needed R&D for meeting generalizable long-term requirements. Bennett replied that the strong recommendation about long-term R&D is going to be external to Gen IV. Magwood said that whatever research is done will be broad-based and not directed toward a given concept. Having a separate program for these long-term concepts may be a good idea.

Hartline asked why the Russian Pb/Bi concept is listed if Russia is not a member of the consortium. Bennett said that the Subcommittee included concepts no matter where they had their origin. Some advocate of that technology must have suggested it.

Duderstadt called upon **Owen Lowe** to speak about the Nuclear-Energy Protocol for Research Isotopes (NEPRI), the purpose of which is to select which isotopes DOE should produce.

NEPRI implements DOE funding priorities for FY03, a year in which a sea change occurred. NEPRI will introduce a formal procedure to bring order to DOE's responses to requests for research isotopes. It will also introduce high-quality peer review to the selection of research isotopes and enable DOE to concentrate on operating its unique isotope production facilities.

Before 2003, DOE used appropriated funds to maintain the infrastructure for isotope production, support research through ANMI grants, and produce research isotopes. Isotopes were produced in advance of collecting customer payments and DOE paid for an entire isotope batch even if only part of the batch was sold. Isotopes selected for production were based on an informal understanding of need.

Starting in 2003, appropriated funds will be singly focused to maintain the infrastructure for isotope production. No working capital will be available; customers must provide the entire budgetary resource before a production run is started. Customers must subscribe to an entire isotope batch. Isotopes will be selected for production with a rigorous peer-review process.

The peer-review isotope-selection process will be based on the merits of the research. Research-isotope customers must file an expression of interest (EOI) if they want DOE to produce their isotopes. Only NEPRI-listed research isotopes will be considered for production by DOE. Letters of financial commitment will be required to schedule isotopes for production. Advance payments will be required for all isotopes before production begins.

It is a five-step process:

1. Notice of Program Interest (NOPI)
2. Review of expressions of interest (EOI)

3. Generation of the NEPRI list of isotopes
4. Publication of NEPRI list
5. Production of NEPRI isotopes

NOPI is intended to poll the research community to find what research isotopes are in demand. The notification of NOPI appears in the *Federal Register,* on the Web on FedBizOps (formerly *Commerce Business Daily*), and on the Industry Interactive Procurement System (IIPS). NOPI, as posted on IIPS, asks researchers to file an EOI that identifies what isotopes are needed, how much, and when; what organizations support the research with what resources; what the research is; and what are its significance, approach, and expected outcomes. Research must be peer reviewed; if it is not already peer reviewed, DOE will peer review it.

In May, DOE will compile the EOIs and eliminate any that request isotopes that the DOE cannot make with existing facilities or are already commercially available. The preliminary list of isotopes and EOIs will be submitted to the Isotope Review Advisory Panel (IRAP), which will have five members: one from NERAC, one from NIH, two from research institutions, and one from the commercial sector. The panel will rank the EOIs on their scientific merits and return a recommended list of research isotopes to DOE. The IRAP will review the list of DOE commercial isotopes. DOE will then take the IRAP-recommended list of NEPRI isotopes and approve the final list based on feedback from research community, availability of facilities and production capacity, and whether or not the research is supported by an active DOE grant. DOE recognizes that many grants are multiyear; DOE's intent is to produce the isotope for the life of the grant.

In June, DOE will announce the final, approved NEPRI list of isotopes in the *Federal Register* and FedBizOps, at DOE stakeholder meetings, at professional-society meetings and in their publications, and on the DOE NE web page. The list of commercial isotopes will also be published.

DOE must receive funding commitments in order to schedule production. Commitments will be accepted between June 1 and September 1. Production will begin in October once cash advances are made. If insufficient funds are received, production will be postponed. NEPRI requires that the customer must provide advance cash payments to cover isotope production costs for both research and commercial products and services. A budgetary resource must exist before work can begin. No Isotope Program funds will be expended on the development or production of these isotopes. Progress payments may be made if the work exceeds 60 days or $25,000. The advance must be sufficient to permit the work to proceed for 30 days. This policy aligns with DOE M 481.1-1A, and some of the procedure may be incorporated into the program.

Research prices will be based on product cost for the batch, not just what the researcher needs. The (primary) customer must cover the entire batch product or service cost. The primary customer owns the batch and can distribute it as desired.

NERAC needs to approve the creation of the IRAP as a NERAC subcommittee. Duderstadt noted that the Committee would need a letter from Magwood to initiate this approval.

Mtingwa asked why advance payment was chosen as a way of doing business. Lowe said that the Department does not have appropriated funds to make the isotopes. Some budgeting resource is needed; this is the best that could be arranged. Some states have prohibitions against advance payments; the program has to work on that. Reba asked if NIH has the flexibility to accommodate advance payment. Lowe replied that it depends on the grant. Cochran asked if commercial vendors ask for advance payment. Lowe responded, no; they charge upon delivery.

Hartline asked how much of the costs are to be recovered. Lowe said, the full costs, including infrastructure costs used for commercial customers. For researchers, just the direct costs of production. Hartline asked how much that was. Lowe said it is usually in the range of $5,000 to $50,000, depending on the isotope. Hartline asked what happens if a need for an isotope arises between the annual calls of interest (COIs). Lowe replied that, if there is significant demand, there may be more frequent COIs.

Cochran asked how much the cost is to maintain the infrastructure. Lowe answered, $10 to 12 million. Cochran went on to ask how big the market is for such isotopes. Lowe said $4 million.

Comfort asked if the grants currently have funds in them for isotopes. Lowe said that most grants consider isotopes as supplies; but they are pitifully underfunded. As a result, DOE has been subsidizing the costs of isotopes. This program shifts the costs back to the grantee.

Hartline asked if there are other sources that researchers can go to. Lowe said that the answer is yes and no, depending on the isotope.

Reba asked if these facilities will be dedicated to isotope production and provide a reliable source of prepaid isotopes. Lowe said that the vulnerability to unreliable production will still be there. Reliability will be improved by the Isotope Production Facility (IPF) at LANL. This change by itself will not improve reliability, though.

Duderstadt introduced **Christopher Scolese** to discuss the NASA Nuclear Systems Initiative (NSI). There, safety is the absolute highest. This technology initiative has three components:

- Radioisotope power development for potential use on Mars 09 and planetary exploration,
- Nuclear fission electric propulsion research, and
- Nuclear fission power research.

For 40 years, spacecraft have used 15 minutes of acceleration and then coasted and occasionally used gravity assist. This is very inefficient. Nuclear electric propulsion (NEP) will alleviate that problem.

Radioisotope power systems (RPSs) enable the search for life's origins on Mars. They will enhance surface mobility, increase operational options, allow more-advanced instruments, and provide longer life. Fission power and propulsion enables exploration not otherwise possible: orbiting (as opposed to fly-by) missions, abundant power in deep space to run more-capable instruments at much greater data rates, reduced trip time, and multiple sites and sample-return options.

Solar power is impractical in some parts of the solar system. At Jupiter, one gets only 4% of the solar energy that one gets at Earth. Flight times are long and gravity-assist opportunities can be rare. Mass is limited, and data rates are low because of low power levels.

Space missions encounter environmental extremes that damage equipment and limit the lifetimes of missions. Spacecraft encounter radiation, high and low temperatures, atmospheric and subsurface conditions, and particle hazards.

The planets are dynamic systems that might include giant planets, rings, and/or satellites with magnetosphere systems. What would be good would be to use one mission to do many tasks and sites on a mission, which typically costs $1 billion.

Power is

- energy for science, mobility, playback, etc.;
- time for surface reconnaissance and discovery;
- accessibility to the planet (over latitude and terrain); and
- resiliency and adaptability.

The 2009 Mobile Surface Laboratory Mission is designed to search for evidence of life (hospitable environments, organics, etc.) on Mars. It has been delayed to investigate RPS as a way to deliver the capabilities and time to maximize the science yield. If the mission was operated on solar power, the baseline would be 180 days (daytime only), an equatorial landing site, and a yield in the tens of sensor-suite analyses. If it was powered by RPS, it would have continuous power for 1000+ days, could land anywhere at any season, would have the time and power to test the "right stuff," and the yield would be an order of magnitude greater (in the number of analyses, images, and distance).

NASA wants to establish the capability to produce advanced radioisotope power systems for future solar system exploration missions. Radioisotope power development efforts focus on increasing the efficiency of future power conversion technologies to lower launch mass and plutonium usage. The first use of a new RPS is being considered for the Mars 2009 Smart Lander.

NASA has a long history of working with DOE. The missions that have used radioisotope thermoelectric generators (RTGs) include NIMBUS, Apollo, Pioneer, Viking, Voyager, Galileo, Ulysses, Pathfinder, and Cassini. NASA would like to go to electric propulsion because it provides dramatic advantages over chemical propulsion. It enables new classes of solar system exploration missions with multiple targets. It eliminates or reduces the need for particular launch windows that are required for gravity assists. It reduces cruise time to distant targets. It reduces mission cost because smaller launch vehicles may be used

Nuclear fission power dramatically increases the scientific return of future missions. It provides electrical power for the electric propulsion system. Its greater operational lifetime increases the productivity of spacecraft and instruments. It enables multiple destinations on a single mission. It provides energy for high-power planetary survey instruments for remote sensing and deep-atmosphere probes, just like the satellites around Earth. It allows higher bandwidth communications.

One U.S. nuclear fission power system was launched in the mid-1960s. Research was conducted through the early 1990s. Many options are available:

- The reactor could be heat-pipe cooled, direct gas cooled, or liquid-metal cooled.
- The power-conversion system could be based on the Brayton cycle for moderate/high power, thermionic, Stirling for low/moderate power, thermoelectrics, or Rankine for a liquid-metal application.
- The thruster, which uses energy to accelerate propellants to high exit velocities, could be an ion engine, magneto plasma dynamics, Hall, VASMIR (variable Isp), or pulsed inductive thruster.

These options raise many questions, so a joint DOE/NASA research activity is proposed. NASA will establish its requirements in the Space Science Strategic Plan, which is in place, is updated periodically, and is vetted by the National Academy of Sciences. Technology research will be openly competed and open to U.S. industry, universities, NASA Centers, federally funded research and development centers (FFRDCs), and other government agencies. NASA Headquarters will lead the peer review and selection process (the Office of Space Science competes 82% of its program). The NRC will be involved in safety approval. The Nuclear Systems Initiative Management Review is staffed by NASA and DOE. NASA would like to release announcements of opportunity by the end of this year.

Cortez asked about the possibility of Russian cooperation. Scolese replied that NASA has a relationship with them for planetary exploration and is talking with them about expanding that relationship. Other countries have offered to participate in this program.

Cochran asked how much plutonium-238 the space program has and how much would it produce. Earl Walquist answered, 9 kg and buying 6 kg more.

Andrew Klein commented that it is good to see this renewal in interest and to see that it is mission driven.

Miller asked what the President's budget is for this. Scolese answered, through FY07, it is $800 million for both the RTG and this system. Miller asked how much new money is going into nuclear R&D. Scolese replied that all of it is new; $550 million is for the fission research. About half is for the R&D. Hartline asked what is in the FY03 budget request. Scolese responded, $79 million for RTGs and $43 million for fission.

Andrew Klein asked why the DOE/NE initiative was not mentioned by the NASA administrator. Scolese said that the administrator wanted to use all the NASA resources available; the staff is educating him to the fact that everything we have ever flown has come from NE-50.

Duderstadt opened up discussion of the ANTT report. Rempe asked how the report would be used. Duderstadt noted that NE owes Congress an official report by May.

Hartline suggested that the Committee thank the Subcommittee for their work and fine report and that it should be attached as an appendix to the official report to Congress.

Cochran suggested that NERAC thank them for their work but not accept or transmit the report. It says transmutation can meet program goals, which are not stated. It implies transmutation is worth pursuing and that the research should progress to the next stage. He did not believe that any goals for the program could be met technically or economically. The program would not reduce the health effects of dealing with the final nuclear waste stream. The proliferation discussion is inadequate; it does not even state any goals. There is no discussion about near-term proliferation risks being increased to decrease the long-term risks. The economics are not considered; the discussion loosely refers to some unreferenced French study. It says that one of the eight reactors will be a fast reactor; fast reactors cost twice as much as LWRs. The program will therefore increase electricity costs by a third. The report focuses on multiple recycles; one recycle is uneconomical, and multiple recycles will be even more uneconomical. In Europe, MOX burning does not keep up with plutonium production; the same will occur here. In all, he believed that it is a bad report and comes to the wrong conclusions.

Hartline asked Cochran what technical flaws he was referring to. Cochran said that he did not believe that, in an unregulated economy where implementation of the program depends on private investment, an uneconomical technology will be deployed. Mtingwa asked him if he would be happy with a larger repository that is radioactive for tens of thousands of years. Cochran said that he would be happy to have a shorter-term storage facility, but there are tradeoffs. The thrusts here are that the government would spend a lot of R&D money on fuel-cycle technologies. Why do that when the thing will not work? If the French are foolish enough to go ahead with this technology, let them put up the money for the R&D.

Fetter said that it is not clear that the goals cited in the report can be met. It *is* clear the program would increase costs. That would be okay if benefits accrued, but it is not clear that benefits would result in nonproliferation, radiation exposure and dose, etc. In some ways, the report does not make the case for the technology.

Richter responded that the report is a benchmark in the program. There is not enough R&D to say that it will work on a production scale. The components have been tested at the gram scale. You have to decide if it is promising enough to pursue this technology. In terms of economics, consider that Yucca

Mountain cost $59 billion. NERAC must decide if it is worthwhile to take the next step, which should answer the questions raised by Cochran and Fetter. This project is not at the deployment point. The Subcommittee recommends we go to the next step.

Magwood commented that Congress asked for an assessment of the technology and other issues (such as where it would be deployed) that we are not ready to answer. Hartz stated that what is needed is to decide is the state of the program or technology and to publically make it clear that there is a long way to go.

Comfort noted that there is a lot of overlap between this program and Gen IV and asked if the research being considered for Gen IV is applicable to this issue. If so, he pointed out, there may be more motivation to move forward with this program. Todreas replied that there is a lot of potential for linkage, but the two communities have not worked together. The GIF is looking at closed fuel cycles; that is the intersection. Some of these questions should be defined. The Gen IV program has not started to grapple with specifics yet. Magwood agreed that there is a significant overlap. Some of the Gen IV process will define several concepts, including fast reactors that may be deployable. Indeed, with the deployment of fast reactors, accelerators may not be needed for dealing with waste.

Duderstadt noted that programs like this are high risk but offer high payoffs. To the degree that a jump start is gained on important scientific research, it seems worthwhile. Todreas said that the people in the Gen IV working groups are well aware of the consideration of transmutation and pyroprocessing. Hartz stated that there currently is no good answer to the waste problem, and the government has a responsibility to move forward.

Fetter said that it is clear that waste can be transmuted and greatly reduce repository requirements, but the transmutation and separation processes would cost more than the storage option. Rempe asked if it was clear that the cost would be more than a second Yucca Mountain. Fetter cited a National Academy study as saying that the health effects and costs would be greater with the transmutation route. The Subcommittee report says the goals can clearly be met, and they cannot.

Cochran asked, if this approach is less expensive, how is this program going to be implemented? Duderstadt said that he would spend the money just to develop the human capacity and the knowledge base.

Richter said that any part of Gen IV that wants to use a closed fuel cycle would use at least part of this program. The $59 billion per Yucca Mountain is a large economic motivation. Further, nuclear is the only power source currently required to pay disposal costs. In the future, fossil-fuel generators will likely be required to also pay disposal costs.

Crandall pointed out that one must also look at how the North American power market is going to develop in the future. There will be an effort to level the playing field in environmental terms. There will be a huge political outcry. The question is much bigger than what can be debated here. She called the question on accepting this report.

Duderstadt noted that the Committee's practice has been to accept reports as long as they reflect the discussion of this Committee. The report should not address broad policy questions; rather, it should address whether the technology is promising enough to go on to the next stage of research.

Hartline said that the only waste that is not recycled in any way is nuclear waste. Sewage and paper are recycled; why not nuclear fuel. The research should be done to find out what path would produce the least environmental impact.

Cochran asked whether or not the report should lay out in a balanced way the pros and cons. He said that this report is a one-sided advocate. It ignores what some of the technology's problems are.

Richter said that this report says that, at the laboratory scale, when you cut plutonium, you cut long-term exposure and increase the cost by 3 to 15%. It recommends that DOE go forward to find out if the rewards are worth the cost. Hartline pointed out that, if the report is not passed on, the opportunity to convey what is known is lost.

Long moved that the Committee receive the report of the Subcommittee and transmit it to DOE with a letter of transmittal that includes the concerns expressed in this morning's NERAC discussion. Miller seconded the motion. The motion carried with one dissension and one abstention. Cochran asked if a minority opinion could be included. Duderstadt said that it could be done.

Public comment was invited. There being none, the meeting was adjourned at 12:05 p.m.

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Submitted by
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Chairman