Minutes
Nuclear Energy Advisory Committee
June 26, 2015
Westin Hotel
Crystal City, Va.

Committee Members Participating:

Ashok Bhatnagar
Margaret Chu
Susan Eisenhower, Cochair
Susan Ion
Raymond Juzaitis
Mujid Kazimi
Richard Meserve, Cochair
Warren Pete Miller
Carl Paperiello
Joy Rempe
Burton Richter
John Sackett

Committee Members Absent:

Matthew Bunn
Dana Christensen
Donald Hintz
Regis Matzie
Alfred Sattelberger

Other Participants:

William Boyle, Director, Used Nuclear Fuel Disposition Research and Development, Office of Nuclear Energy, USDOE
Nancy Carder, NEAC Support Staff, Medical University of South Carolina
Sal Golub, Associate Deputy Assistant Secretary for Nuclear Reactor Technology, USDOE
Andrew Griffith, Associate Deputy Assistant Secretary for Fuel Cycle Technology, Office of Nuclear Energy, USDOE
John Herczeg, Associate Deputy Assistant Secretary, Fuel Cycle Technologies, Office of Nuclear Energy, USDOE
Shane Johnson, Deputy Assistant Secretary, Office of Science and Technology, USDOE
John Kotek, Assistant Secretary of Energy for Nuclear Energy, Office of Nuclear Energy, USDOE
Alexander Larzelere, Program Manager, Modeling and Simulation Energy Innovation Hub, Office of Nuclear Energy, USDOE
Peter Lyons, Assistant Secretary of Energy for Nuclear Energy, Office of Nuclear Energy, USDOE
Frederick O'Hara, NEAC Recording Secretary, Medical University of South Carolina
Franklin Orr, Under Secretary for Science and Energy, USDOE
Robert Rova, NEAC Designated Federal Officer, Office of Nuclear Energy, USDOE
Michael Worley, Director for Innovative Nuclear Research, Office of Nuclear Energy, USDOE

About 35 others were in attendance in the course of the meeting.

Morning Session

Before the meeting, **Wayne Gordon** of the DOE Office of the General Counsel presented the annual ethics briefing to the Committee members.

The meeting was called to order by Cochair **Richard Meserve** at 8:55 a.m. **Peter Lyons** introduced **Franklin Orr**, the new Under Secretary for Science and Energy of DOE. Orr emphasized how important the advisory committees were and mentioned that he himself had been a member of the Basic Energy Sciences Advisory Committee. He announced that Peter Lyons was retiring on the following Tuesday

after 46 years of government service. John Kotek will succeed Lyons as the Assistant Secretary for Nuclear Energy.

The nation needs to transform its energy production to sources that have a lower carbon footprint. The President has committed the country to a 26 to 28% reduction of CO_2 emissions by 2025. Nuclear energy now produces about 20% the nation's power generation. That level of production needs to be continued and expanded. The nuclear-reactor fleet is aging, and there are technical issues with waste disposal. The Department is working hard to ensure that nuclear energy is a main player in U.S. power production. $1.8 billion in loan guarantees for the Vogtle Electric Generating Plant has been recently added to the $6.5 billion that was issued last year. In addition, a solicitation for $12.5 billion in loan guarantees in FY16 was released in December 2014. A strong manufacturing base in the United States is needed to produce nuclear power around the globe. A path forward in waste management is also needed.

In March, the Department announced a defense-waste-only strategy for a consent-based siting of a high-level-waste repository. This pathway may make it possible to deal with commercial waste. The American people are depending on experts like NEAC for strengthening the workforce and for investments at Idaho National Laboratory (INL).

Meserve opened the floor to questions. Bhatnagar asked what the Department's views were on current light-water reactors. Orr answered that government and industry need to deal with questions related to life-extension recertification and ensuring that those are not only safe but also perceived as safe by the general public.

Kazimi noted that it has been difficult to bring engineering research to energy technology. Orr replied that discovery science depends on the use of facilities, and the research questions need to be identified through consensus of the research community. The voice of that community would be helpful in forming government policy and could be provided through NEAC.

Meserve commented that the real problems are political rather than technical. Advisory committees need guidance on how to work through the political thicket. Orr pointed out that the President's Blue Ribbon Commission on America's Nuclear Future (BRC) identified consent-based processes as being essential. NEAC could help there by identifying what technical questions should be addressed.

Meserve had each member introduce himself or herself.

Peter Lyons was asked to present an update on the activities of the Office of Nuclear Energy (NE). He started by thanking the NEAC members for their service. This is an appropriate time for him to retire. He will be moving to Colorado, but his interest in nuclear energy as a vital clean-energy source will continue. In mid-July, the National Aeronautics and Space Administration (NASA) probe New Horizons will arrive at Pluto after a 9-year flight. It is powered by a nuclear thermoelectric power source. All the more-distant NASA missions have been nuclear powered. The mission to Pluto will mark the completion of the historic first era of deep-space exploration. He showed a video explaining the mission and its significance. The NE team is now working on the fuel for the 2020 next rover mission to Mars.

The report on accident-tolerant fuels has now been released after 3 years. The first set of accident-tolerant fuel concepts has begun irradiation tests in the Advanced Test Reactor (ATR). The Office is on track in down-selecting the fuel systems in the accident-tolerant-fuel program.

The International Framework for Nuclear Energy Cooperation (IFNEC) Secretariat has been transferred to the Nuclear Energy Agency (NEA).

The advanced test/demonstration reactor study has been launched.

Criteria for advanced-reactor general design criteria have been developed in coordination with the Nuclear Regulatory Commission (NRC) and those criteria are currently being evaluated by the NRC, a step forward in the licensing of such a reactor.

There is continued cooperation between INL and the National Renewable Energy Laboratory (NREL) of hybrid energy systems, seeking to optimize the coordinated operation of clean-nuclear and renewable-energy sources; this is a key step in developing an overall energy system.

DOE, the nuclear industry, and the NRC are extending the licensing terms of reactors to 60 years, and DOE is developing methods to extend reactor lifetimes beyond even that limit. The LWRS program

continues in its cost-shared mode with industry providing extremely important support to both industry and the NRC in life extension.

The transition of the Advanced Test Reactor (ATR) from diesel backup to battery backup has been completed, obviating the need to run diesel generators 24 hours a day and cutting substantially the air emissions at the ATR site. Also at INL, the construction of the remote handleable liquid waste facility is well under way, and cooperation with the Naval Reactor Program will increase.

The floor was yielded to **John Kotek**, who introduced himself and thanked the NEAC staff for their continued help.

The Secretary has announced the development of a defense-only, consent-based-sited high-level-waste repository. NEAC feedback will be sought on this topic. Other areas in which advice will be sought include the transportation of spent fuel, hardware (casks and railcars), other infrastructure, borehole-technology demonstration, and relations with state and tribal governments.

Rempe noted that responses to the draft request for proposals (RFP) for deep boreholes were due in May and asked what the status of that process was. Boyle replied that changes to the draft RFP were made in light of the responses, and the final RFP will come out in a few weeks.

Richter asked what the current thoughts were about the use of boreholes and what type of wastes would go into them. Boyle answered that the National Nuclear Security Administration's (NNSA's) plutonium or cesium and strontium capsules and the calcined waste at INL were likely possibilities.

Ion asked why the diesel generators run continuously. Lyons responded that they run continuously to provide instantaneous power backup. Ion noted that, in the United Kingdom, Urenco is designing a uranium battery (the U-Battery), a micro nuclear reactor that will be able to produce local power and heat that can be trucked to the site of, say, a nuclear power reactor to provide backup power. In addition, americium is being used for thermoelectric generation at ITER [formerly the International Thermonuclear Experimental Reactor] in Europe.

Meserve noted that a commercial consent-based site in Texas is being prepared for the acceptance of spent nuclear fuel from commercial nuclear reactors.

Kazimi asked what the plan was for the accident-tolerant-fuel program. Griffith replied that the plan is still the same: to develop and prioritize by 2016 a select few concepts for the Phase 2 development qualifications and to insert lead fuel rods into a commercial reactor in 2022. A small set of concepts will go into Phase 2 and will be winnowed down there. Lyons added that a broad view needs be taken covering not just the fuel but other systems that would be affected by a severe accident.

Michael Worley was asked to describe the Radiochemistry Traineeship Program, which is awaiting budget authorization.

The Secretary has requested a coordinated effort to establish a model for DOE-supported traineeships that can be deployed by DOE program offices to promote workforce development at the graduate level in areas of critical importance to DOE. The Secretary envisions a model for DOE traineeships as university-led workforce training efforts aligned with the scope of traineeships offered by the National Science Foundation (NSF) and the National Institutes of Health (NIH). DOE's traineeships will be complementary to those efforts. Although university led, they could include partnerships with national laboratories or with private or public-sector entities.

The Office envisions providing funding for 2 years of graduate- or PhD-level training but could support terminal MS degree training if the degree requires a thesis project. The program would be relatively small in size and narrow in scope. It would cover a stipend and tuition up to $5500 per student with universities contributing the other student costs and faculty support. It might include curriculum development, intensive summer schools, or training workshops. The program will last 4 to 5 years with a series of blocks of students passing through it.

DOE traineeships will not duplicate the efforts of other federal agencies and will leverage DOE assets and capabilities, where beneficial and practicable. Training areas of focus will be derived from an evidence-based assessment of the DOE workforce needs. DOE has reached out to the advisory committees and laboratory leaders, who identified computational science, accelerator and detector R&D,

instrumentation, and radiochemistry as appropriate areas of focus. Radiochemistry training is a long-standing need, as expressed by NEAC and others. DOE program offices will follow the Office of Science (SC) model for open, competitive application processes. Program offices will develop evaluation plans, also. A funding opportunity announcement (FOA) will be issued. Oversight will be provided by universities, consortia, and DOE. A working group on traineeships has been formed. It has developed guidance for the Department. It will ensure that training programs across the Department will be coordinated.

NE has mission-specific and critical radiochemistry workforce needs. A competitively awarded, university-led traineeship is the preferred method for providing the required unique and innovative radiochemistry curriculum aligned with mission-driven workforce needs. The NE budget request includes $2 million for an anticipated 5-year award to university-led consortia targeting support for 2 years of each student's master's-degree/PhD training in radiochemistry. Training programs will be relatively small and focused, supporting up to five new students per year for a total of up to approximately 20 students. If funded, the radiochemistry traineeship is likely to be expanded to include Office of Environmental Management (EM) program objectives and funding. All of these characteristics are in compliance with the working group's principles. The key objective is to develop a focused curriculum at universities in target areas and to endure beyond the award period.

There will be two competitions: The FOA will select the university participants, and the applicant competition will select the student participants. The first group of students will be funded when the program starts; the next group will be funded according to the academic schedule. Success metrics will need to be developed and applied. A transition will be needed after the midpoint of the program.

If the traineeship program is to be continued after 2016, the topics to be addressed will need to be identified. Potential topical areas include seismic engineering, advanced instrumentation, fuels and materials, safety analysis and probabilistic risk assessment (PRA), reactor physics, thermal hydraulics, and modeling and simulation. Joint sponsorship of traineeships may be possible in health physics, power engineering, and advanced manufacturing. Documentation of the need for such traineeships will need to be prepared by NEAC and others. That documentation would be needed for the preparation of the FY17 budget request (early fall 2015).

Richter commented that he did not see how this program would work unless a particular university already has a program in the topic. Two years of funding may lead to a master's degree but not a PhD. Worley responded that comments on the proposed program from universities have come from those with extant radiochemistry programs. Funding will go to summer schools, internships, and curriculum development in addition to student financial aid for master's and PhD studies. Lyons added that this will be a learning experience and can be adjusted in conference with the Nuclear Engineering Department Heads Organization (NEDHO) or others.

Paperiello asked if DOE had talked with utilities and other employers about where the gaps in the knowledge, skills, and abilities of the workforce are. Worley replied that the program has to find the gaps, which were identified in reports from the President's Council of Advisors on Science and Technology (PCAST) and by other assessors.

Chu asked if SC had done an assessment of the capacity of radiochemistry laboratories because there may not be the infrastructure that will be needed by these trainees when they go into the workplace. Worley replied that the program was actively developing a database of nuclear-energy infrastructure.

Kazimi said that the traineeship process is a good one. DOE needs to assess the need for traineeships. Also, financial needs will vary from discipline to discipline. Worley noted that the Office's list of topics is not complete; NEAC's feedback on expanding that list is sought. One size certainly will not fit all.

Miller pointed out that there are only a couple of universities that have radiochemistry programs. Worley said that he had evaluated NSF data that showed 18 universities with radiochemistry advisors. The number of programs is certainly lower than that.

Sackett noted that a problem with radiochemistry instruction is the high cost of providing and maintaining infrastructure. Therefore, partnerships with national laboratories would be essential to provide some of that infrastructure.

Meserve suggested forming an ad hoc group to provide the needed input by the fall. Miller suggested the alternative of asking all the current subcommittees to comment on this issue. Meserve agreed and said that an assignment will be made, with Kotek coordinating that request.

John Kotek was asked to comment on the 2004 "world-class-laboratory report" prepared by the Nuclear Energy Research Advisory Committee (NERAC, the predecessor of NEAC).

In 2003, DOE decided to consolidate ANL-West with the Idaho National Engineering and Environmental Laboratory and to split off NE laboratory options from the EM cleanup activities. It issued a request for proposals (RFP) in May 2004, calling for the establishment of INL. In September 2004, NERAC issued recommendations identifying the characteristics, capabilities, and attributes of a world-class nuclear laboratory. In November 2004, DOE awarded the INL contract to the Idaho National Laboratory Battelle Energy Alliance (BEA); the contract had a 10-year term with a 5-year add-on option). In February 2005, INL was launched via the new contract. The INL contract and progress by BEA were constructively informed by NERAC's 2004 publication, *Report of the Nuclear Energy Research Advisory Committee Subcommittee on Nuclear Laboratory Requirements*. The 5-year contract option was exercised in March 2014, and the current contract runs through September 2019.

During the first 10 years of the contract, INL demonstrated the viability of using uranium oxycarbide tristructural isotropic (TRISO) coated particle fuel in advanced gas reactors; developed the multiphysics object-oriented simulation environment (MOOSE); established three new user facilities centered on biomass feedstock, wireless battery charging, and the Advanced Test Reactor (ATR); worked with TerraPower to design a nuclear-synfuels process and economic integration; collaborated with NuScale Power on processes to recover heat from light-water reactors for use in other industrial processes; was designated by the Army as a Center of excellence in armor; headed expert groups on accident-tolerant fuels and on validation and data centers; became a team member of the Critical Materials Institute of DOE; was designated as a center of competence in battery performance testing, electric-vehicle assessment, and wireless-charging testing; led the first integrated nuclear–renewable energy systems workshop; and won 17 R&D 100 awards.

INL has attracted and retained some of the best and brightest researchers and technical leaders, especially early-career researchers. DOE and other agencies and companies have made investments in upgrades and new facilities from 2005 to 2014. Capital have investments totaled $207 million.

To determine where DOE should invest in systems, facilities, infrastructure, new programs, entrepreneur encouragement, etc., the Department now requests that NEAC prepare a report that reflects on the 2004 NERAC report and recommends future opportunities that would enhance INL's stature as a world-class laboratory. In essence, the charge asks whether anything has changed in what comprises a world-leading research facility.

Meserve pointed out that INL has an advisory committee of its own. Kotek said that this is a chance for a group that is a step removed from INL to look at this question. The Laboratory's advisory board advises the Laboratory; the requested advisory committee advice would be to the federal government. Miller agreed that there is a big distinction between the two advisory committees and that Juzaitis had faced similar issues at the Nevada Test Site (NTS) and might be a good candidate for heading up this effort.

Richter stated that a $207 million investment had been made in INL and that that was peanuts. The Stanford Linear Accelerator Center (SLAC) has a capital investment over the past 5 years that is three times that amount. One should be asking, "What will it take to make INL a world-leading research facility 10 years from now?" and budget accordingly.

Juzaitis said that the NTS is very different from INL. Each national laboratory has its own culture and its own way of how it succeeds. At the NTS, the intellectual capital was provided by the weapon laboratories, and the tests were contracted out. The NTS is a service contractor, but that is not enough to attract world-class personnel. NTS decided not to do fundamental research but to focus on advanced field demonstration diagnostics. It works closely with the design laboratories. INL is very different.

Meserve suggested that the Committee work with Kotek on a charge. Other activities are affecting the national laboratories, such as the Congressional national laboratory effectiveness assessment and the

Secretary of Energy Advisory Board (SEAB) assessment, and should be considered in the charge in order to avoid duplication and needless conflict

A break was cleared at 10:46 a.m. The meeting was called back into session at 11:06 a.m.

John Kotek was asked to report on the status of NEAC recommendations, looking back on NEAC reports and seeing how NE has followed up on the recommendations made in those reports.

The Nuclear Reactor Technology (NRT) Subcommittee encouraged NE to consider the Industry Advisory Committee suggestion that the Light Water Reactor Sustainability (LWRS) Program identify and engage owner-operator decision makers, explain the program to them, and get their input.

DOE has established a broad engagement with industry decision makers. In the FY16 LWRS budget request, the $33 million request was increased by both the House and the Senate.

The NRT Subcommittee recommended that NE develop a set of metrics to evaluate the Integrated Research Projects Program's (IRP) benefits, involve universities in research-topic selection, and develop a strategy for continuing or graduating successful IRPs.

DOE will develop an Innovative Nuclear Research Program Plan by the end of CY15 to identify success metrics for associated programs, including the Nuclear Energy University Programs (NEUP). Universities, national laboratories, industry, and international research entities now have the standing ability to provide input to DOE. NE has incorporated new modules into the Program Information Collection System: Nuclear Energy (PICS:NE) program-execution management system to require and formally document annual go/no-go reviews on ongoing competitively awarded research as well as transition review(s) timed to support decisions related to the successful continuation, graduation, or completion of such research projects.

The NRT Subcommittee recommended that the Office reestablish a DOE–NASA partnership in the area of fission power systems.

NE is working with NASA to enhance the partnership on reactor-type options. DOE is working closely with the NRT Subcommittee and has held a series of meetings.

The Fuel Cycle Subcommittee recommended that, without additional validation data, Nuclear Energy Advanced Modeling and Simulation (NEAMS) developers should acknowledge the limitations that exist with new fuel product line tools (their applicability may be limited to interpolating between available engineering-scale data).

NE is actively working on responding to this recommendation. NE's primary response has been a concerted and broad-based effort to obtain, develop, and use validation data for NEAMS tools, which includes validation assessments that addressed the validation basis, applicability, and limitations.

The Fuel Cycle Subcommittee made a series of recommendations regarding NEAMS that called for more-compelling requirement definitions, program integration, computational efforts, milestone adoption, an accident-tolerant-fuels focus, and a compelling business case.

NEAMS has implemented all of these recommendations and continues to improve and prioritize program efforts in these areas.

The Facilities Subcommittee recommended that the program for a virtual user facility, which began in 2007, should be expanded to include the use of all facilities important to NE's programs in nuclear technology R&D.

DOE has initiated a significant effort and continues to evaluate the options to determine the most effective role for and scope of the Nuclear Science User Facilities (NSUF).

The Facilities Subcommittee recommended that the scope of the user facility should be expanded beyond the present emphasis on materials development.

NSUF's investment in high-performance computing is being pursued as part of the FY16 budget.

The Facilities Subcommittee recommended that NSUF be prominent in the next update of the NE Roadmap for Nuclear Technology R&D.

NSUF is prominently featured in the draft of the next update to the NE R&D Roadmap as part of the list of current major NE programs. The expansion of scope is in progress to potentially include materials, thermal hydraulics, code development with validation and verification, advanced fuels, fuel cycles, and nuclear engineering in the broadest terms. The name of the program has been revised from Advanced Test

Reactor National Scientific User Facility to Nuclear Science User Facilities to reflect this broadened scope.

The Facilities Subcommittee recommended that a new model for NSUF should be prominent in the next NE Roadmap.

NSUF will be featured in the draft of the next update to the Roadmap as part of the list of current major NE programs.

The Facilities Subcommittee recommended that high-performance computing be recognized as an essential dimension for a successful NE future.

NSUF investment in high-performance computing is being pursued as part of the FY16 budget to expand NSUF capabilities to support modeling and simulation as well as validation and verification.

The Facilities Subcommittee recommended that the success of the original NSUF should be leveraged to build a model of multiple new user facilities.

DOE's response to this recommendation is sort of in progress, moving beyond an ATR-centered program to a broader program including other facilities. Johnson added that the program now includes Oak Ridge National Laboratory's (ORNL's) hot cells, several universities, a beam line at the Advanced Photon Source at Argonne National Laboratory (ANL), user weeks to broaden exposure, and high-performance computing and coding that are available to industry. Meetings are being held with a user facility in the United Kingdom to explore international partnerships.

The Facilities Subcommittee recommended that a strong industry engagement be established along with a closer relationship with industry.

NE is actively working on this effort; a workshop with the Electric Power Research Institute (EPRI) will be held during the week following this meeting.

The Facilities Subcommittee recommended that a strong university engagement be established.

This effort is in progress.

Miller stated that it is good to hear feedback on recommendations. He asked why NE was not leveraging ORNL's computing capability. Johnson answered that use of the leadership-class computers at ORNL and ANL is limited by availability and appropriateness of the computers. Larzelere added that NE does not pay for computing time at ORNL. The Consortium for Advanced Simulation of Light Water Reactors (CASL) uses computing facilities at INL. INL needs modeling and simulation computing capabilities. This is a general capability that is needed for any R&D, and those facilities are oversubscribed at INL. Lyons noted that NSUF is focused on the university community. Their work does not require a leadership-class computer.

Sackett said that the Facilities Subcommittee is looking at engagement between the facilities and researchers. NSUF helps make the facilities accessible.

Kazimi asked if the LWRS Program had been revived. Golub answered that the LWRS Program has an oversight group and an interface with the EPRI; it also issues an annual plan. Industry leaders have been pulled into the process.

Kazimi asked if NSUF tracked usage of the facilities and whether a gaps analysis of needed facilities had been performed. Johnson replied that a database of facilities and usage rates is up and running. It is hoped to use that database to know where time is available for research to be funded and conducted. The federal government is to use it to identify where investments need to be made. Unique facilities in other areas (predominantly materials) need to be identified or established.

John Sackett was asked to present the Facilities Subcommittee report.

The Subcommittee looked at what facilities were available, where the gaps were, how the facilities were used, and what research was seen as needed going forward at ANL, INL, and ORNL. In addition, the Subcommittee surveyed universities, asking what capabilities they had available. The universities surveyed were Michigan, Massachusetts Institute of Technology, North Carolina State, Ohio State, Pennsylvania State, Rensselaer Polytechnic Institute, Tennessee, and Wisconsin.

There is considerable capability across the complex at the national laboratories and universities, but there are some gaps in capability: There is no transient test reactor yet; there is no fast-spectrum reactor for testing fuel materials; there is a lack of available hot cells, and access is difficult; there needs to be

coordinated availability and access; and there is a lack of validation support for modeling and simulation (e.g., in thermohydraulics and materials).

The Subcommittee recommends that the design, construction, and operation of a test/demonstration reactor should guide the planning and prioritization of future investments in irradiation, postirradiation examination, and other test facilities. The second recommendation is that the test/demonstration reactor is important to efforts to support and sustain the human-resource pool. The third recommendation is that a test/demonstration reactor project could play a major role in reducing investor risk by early resolution of key licensing issues. (This is important for any technology chosen, whether a test or demonstration reactor. Validation and verification of modeling and simulation will require additional test facilities for components and systems.)

In the absence of a fast-neutron test reactor, an ion-beam irradiation facility can produce radiation damage for materials studies. The jury is still out on whether this technique can adequately represent a reactor environment. The Subcommittee recommends that ion-beam-irradiation capabilities be supported to confirm their relevance to neutron damage of materials in a reactor environment.

If there is a decision to pursue a demonstration or test reactor, the role of NSUF should be expanded to enhance access to and utilization of test facilities across the DOE complex. To enable such expansion, the processes used to designate NSUF and partner facilities should be reviewed. The basis for allocating funding for research support at these facilities should also be reviewed.

Some progress is being made in addressing the gaps identified earlier.

The Transient Test Reactor (TREAT) is funded for refurbishment and restart, and activities supporting restart are well on track. The condition of the facility is excellent, with most systems found to be well maintained. The major current task is training of personnel.

With no fast-spectrum irradiation-test reactor in the United States, the only option is to use the BOR-60 reactor in Russia, which is problematic because it is nearing the end of its design lifetime. The BOR-60 would be useful for accelerated irradiation testing of fuels and materials. Ion-beam irradiation is a potential substitute for accelerated testing, but questions exist about its effectiveness.

Hot cell operation and availability has constrained postirradiation examination of fuels and materials. The hot cells at INL are oversubscribed and have been a constraint in irradiation testing. The hot cells at ORNL are underutilized and are currently supported by laboratory discretionary funding. The hot cells for postirradiation examination at ANL are not in use. Hot cell availability will become more important.

More test-facility development is needed in thermohydraulics and component testing.

Modeling and simulation and associated validation and verification are important areas for licensing and for cooperation between NE and SC.

In conclusion, NE has done an excellent job of prioritizing and maintaining essential irradiation-test facilities. There is sufficient infrastructure to support the design of a new reactor as long as the technology is known. Design and construction of a new test/demonstration reactor will provide an opportunity to prioritize, expand, and improve test capabilities across the complex, as identified by the Office's survey and database. The quality and enthusiasm of young researchers is impressive.

Meserve commented that the Subcommittee seems to hang everything on the development of a new test reactor (and the development of its technology) and this could be dangerous if funding proved not to be available. Sackett responded that a test and demonstration reactor will make it clear how and what testing can be addressed. A major effort is under way to make the ATR available indefinitely. To develop a new test reactor requires knowledge of what its purposes would be.

Kazimi noted that the cost of construction of a reactor is significant. Some facility to allow the discernment of cost savings would be helpful. Rempe added that funding of maintenance costs is a struggle to obtain, and the lack of such funding ends up limiting the capabilities of some facilities. Johnson answered that those costs go back to the national laboratories. They need to provide and train personnel, for example. That is why those costs were not considered in the report.

Lyons asked if validation and verification needs that could be dealt with in a university setting could be identified. Also, the Office has been providing an expert to the NEA to see if the NEA databank could be used for validation and verification.

Meserve noted that the full report included the trip reports in which specific recommendations for each facility were made.

A break for lunch was declared at 12:03 p.m.

Afternoon Session

The meeting was called back into session at 1:31 p.m. by Cochair **Susan Eisenhower**.

Warren Pete Miller was asked to present a progress report from the International Subcommittee.

A full report will be presented at the December 2015 NEAC meeting. This progress report focuses on China.

China has the fastest-growing commercial nuclear power program in the world, which will likely exceed that of the United States in about a decade. Expansion of China's commercial nuclear power program aligns well with U.S. policy initiatives, including climate change. In addition, China has a very aggressive R&D program on advanced reactors, including sodium fast reactors, high-temperature gas-cooled reactors, molten-salt reactors, and other kinds of reactors. Continued collaboration with China provides opportunities to U.S. companies and commercial nuclear exports and can leverage U.S. limited funds for advanced-reactor R&D. The present collaboration is a positive circumstance.

Collaboration with China has other potential long-term benefits: enhanced global nuclear safety, increased nuclear security, and more highly developed human capital (students) with a strong safety culture. The potential pitfalls in collaborating with China center on protection and management of intellectual property and security issues. However, the problems are well recognized, and it is widely believed that practices exist to properly deal with these issues.

The Subcommittee was charged to review the existing bilateral and multilateral nuclear collaborations between the United States and China as well as joint commercial activities between the two countries; to make recommendations to minimize any potential negative impacts on U.S. interests; and to make recommendations on how to increase the effectiveness of continued or additional collaborations.

The bilateral programs are conducted under Peaceful Uses of Nuclear Technology (PUNT), the United States–China Bilateral Civil Nuclear Energy Cooperation Action Plan, and the DOE–China Academy of Sciences collaboration. These agreements include workshops, collaborative research, nonproliferation activities, and two multilateral programs that both the United States and China participate in: IFNEC and the Generation IV International Forum (GIF).

The Subcommittee met on May 6–7 in Washington, D.C., to gain input from both governmental and private-sector organizations. Presentations were made by NRC, INL, ORNL, ANL, Massachusetts Institute of Technology, Texas A&M University, University of Michigan, Westinghouse, and Lightbridge. The findings and recommendations of this meeting are not yet written up. The preliminary findings are

- Nuclear power should be treated as a more strategic matter and not handled like other energy sources
- The United States and China have shared interests in ensuring that nuclear energy is safe and proliferation resistant and that nuclear waste is manageable.
- The United States and China system see that the United States university system should be treated as a strategic asset and that it provides a valuable component in engagement with China.
- The collaboration between the NRC and the Chinese nuclear regulator would be beneficial to both countries.

Next steps for the Subcommittee include obtaining additional input from DOE, commercial entities, and others regarding the benefits and risks of collaboration with Chinese; considering the likely strategy of the Chinese regarding continued reliance on light-water reactors versus moving to advanced reactors and the resulting implications for U.S. policy; exploring the adequacy of controls on this technology; and forging a consensus opinion on the recommendations with the full Committee in December 2015.

Lyons thanked the Subcommittee for its preliminary report. The comment about the NRC probably should not be in a NEAC report.

Juzaitis asked if there were any benefit to being briefed by the counterintelligence agencies about university collaborations. Kazimi responded that such a briefing would be good.

Eisenhower was concerned about the protection of intellectual property and asked how the Subcommittee might approach the issue and how it might coordinate with other U.S. Government agencies. Miller replied that the Subcommittee is being briefed by someone from the Department of Commerce. The Subcommittee needs to go into this process with its eyes open.

Joy Rempe was asked to present the report from the Fuel-Cycle Technologies Subcommittee.

The broad range of disciplines represented in the Subcommittee's membership has helped it to deal with the different topics encountered. The Subcommittee met April 19 and addressed five topics: separation R&D, accident-tolerant fuels, the Stakeholder Tool for Assessing Transportation (START), nuclear fuel storage and transportation, and used-fuel disposition.

In separation R&D, electrochemical processing, which is applicable to oxide and metallic fuels, has the potential to reduce long-term radiotoxicity and heat loads of the materials placed in a repository. It also has the potential for recovered actinides to be reprocessed. Members of the Subcommittee were pleased to see substantial university involvement, collaboration between NE and NNSA, and significant progress on electrochemical processing R&D. The Subcommittee recommends that the domestic program budget, currently at $1 million, be increased in phases; that the program continue laboratory-scale work prior to scale-up; that the NE/NNSA collaboration go beyond safeguards and security flowsheet analysis and apply safeguard technology to process material. The Subcommittee requests a progress review on aqueous separation at its next meeting so that it can compare the two separation methods.

In accident-tolerant fuels, the program is focused on light-water reactor fuels and cladding to improve reactor and spent-fuel safety. The top-level goal is to insert a lead fuel rod or fuel-rod assembly into a commercial reactor by 2022. In February 2015, rodlets for four concepts were successfully inserted into the ATR, meeting a first-step program milestone. Additional tests in pressurized water reactor loops are required. Needed analytical assessments include developing new fuel-performance codes and applying existing severe-accident system-analysis codes. The Subcommittee commends the program on the fuel insertion and the efforts to complete instrumental tests. It requests more detailed discussion on efforts to develop fuel-performance codes and to evaluate integrated performance of fuel and other reactor components under severe accident conditions.

Development continues of the START tool, which identifies transportation routes and assesses the impact of various shipping options for spent nuclear fuel. Highway and railway regulations can affect routing selection. The data represented in START are constantly changing. Risk evaluations for escorted vehicles and dedicated rail shipments differ from general accident-rate statistics and need to be developed separately. The Subcommittee is concerned about possible misunderstandings associated with START until it is fully developed and recommends that the START disclaimer be expanded to acknowledge its current limitations.

The Pilot Interim Storage Facility could address the BRC recommendations and contribute to the administration's strategy for the disposal of nuclear waste. DOE is planning to downselect to a non-site-specific generic pilot-facility design and submit a topical report to the NRC in the next year. The Subcommittee recommends that the program assess or clarify (1) the authorizing legislation required before the facility is slated and construction can occur, (2) that there will be no liability reduction if fuel from a shut-down reactor site is prioritized, (3) what is the impact of the uncertainties associated with ultimate-storage and regulatory requirements, and (4) the what coordination is needed between DOE and industry.

NE's Nuclear Fuels Storage and Transportation Planning Project (NFST) is developing a standardized transportation, aging, and disposal cask. A standardized-canister approach could minimize the amount of repackaging, reduce system-wide costs, streamline fuel handling and licensing, increase flexibility, and reduce the Department's waste-acceptance liability. Prior evaluations found that smaller canisters result in more handling, higher worker exposures, and increased costs. Uncertainties associated with the ultimate

storage and regulatory requirements limit the ability to optimize the design when there is no waste facility or regulatory framework in place. The Subcommittee recommends that work in this area be deferred until a final repository site is identified and under development.

The High-Burnup Dry-Cask Research and Development Project is to provide technical bases to address licensing requirements for extended storage for high-burnup uranium fuel. DOE co-funds this EPRI-led collaboration that includes AREVA Federal Services, Dominion, Westinghouse, NAC International, the Nuclear Energy Institute (NEI), and several national laboratories. The project includes multiple fuel/cladding combinations in a TN-32 bolted cask. Temperatures and gas samples will be monitored, and sister rods will be extensively characterized. The Subcommittee generally finds this project to be well conceived.

The deep-borehole concept is increasingly attractive because of advances in drilling technologies and the lack of progress in developing a mined geologic repository. It features boreholes drilled 5000 m into crystalline "basement" rock, canisters containing waste forms placed in the lower 2000 m, and the sealing of the upper borehole. A nonradioactive field test is to be initiated. The Subcommittee finds that the estimated field-test cost and schedule appear optimistic and that, once a site is selected, a comprehensive scenario analysis should be completed to identify vulnerabilities in the site, design features, and processes.

Richter noted that he had earlier asked what was going to be put into these boreholes and had been told that DOE has not made up its mind. He asked if the boreholes would be complementary to or a replacement for a geological repository. Kotek replied that they would be complementary to and not a replacement of a geological repository. Richter asked how one designs a waste repository without knowing what waste and what waste characteristics were to be dealt with. Herczeg answered that EM is working on designing capsules that can be lowered into and removed from the boreholes. The cesium and strontium canisters are about 40% of the radioactivity at Hanford. It would take 1.5 boreholes to dispose of all of those canisters. The goal is to reduce the curie footprint at Hanford.

Paperiello asked if how these boreholes were to be laid out had been thought out. Griffith responded that that is still under development as is the gaining of the concurrence of local and tribal governments in siting the boreholes.

Bhatnagar noted that 2022 had been cited as a goal for inserting a test fuel rod in a reactor and asked if there were any work on accelerating the effort to get a lead assembly into a commercial reactor. Griffith said that there is one industrial entity interested in inserting a lead-assembly into an operating commercial reactor. The timing is based on research and on performance improvements. Bhatnagar said that it would be important to the industry to see a test/demonstration performed. Griffith said that DOE has engaged with the NRC from the start. A workshop on this topic is coming up in a few weeks.

Kazimi asked about the ATR and whether DOE were working with industry enough to make sure that industry has the manufacturing capabilities needed to do the work. Rempe replied that fabricability has been reviewed with all four responding industrial companies.

Lyons noted that there is a tremendous interest in accident-tolerant fuels in China. The Chinese are looking at questions beyond just the fuel questions. If there is an improvement in safety, it is important that it is deployed globally. Herczeg added that the Chinese Nuclear Science Committee is doing experiments, and the United States can use the data. Griffith said that the vendors are highly engaged, also. They recognize that this is a global market.

Kazimi asserted that the entire borehole system has to be looked at because the actinide oxides may volatilize if mixed with plutonium.

Mujid Kazimi was asked to present the report of the Nuclear Reactor Technology Subcommittee.

For the rapid deployment of advanced technology and nuclear power plants and for the rapid commercialization of advanced nuclear-power technology, both small-scale and engineering-scale capabilities are needed. Several concepts for new types of water-cooled reactors and fuels proposed by industry groups and national laboratories could make good use of new facilities. An assessment is needed of the capabilities of existing irradiation and other testing facilities both in the United States and around the world. The current U.S. test reactors are more than 40 years old and do not have the needed volume

and neutron flux to accelerate the development of new fuels. In FY15, Congress allocated $7 million for an advanced test/demonstration reactor planning study by the national laboratories, industry, and other stakeholders.

Testing is needed to accelerate the development of improved nuclear options to secure a long-term energy source in the United States; to explore and enhance the economic and safety performance of nuclear reactors to enable a market-ready baseload source of carbon-free energy; to maintain global leadership in critical energy and security technologies; and to attract a new generation of experts in nuclear-energy technology.

Potential benefits of advanced reactor technology are enhancements to economy and safety in light-water and other types of reactors to attain higher power densities, longer fuel cycles, and higher temperatures. Potential environmental benefits include a reduction in the need for water for cooling and improved fuel utilization.

Options being looked at include (1) a demonstration reactor to evaluate the integrated aspects of a selected advanced reactor and (2) a test reactor to obtain data to support more-rapid research, development, and demonstration (RD&D) of many reactor concepts. The Subcommittee recommends the inclusion in the study of advanced technology for light-water reactors as well as other advanced-reactor concepts. It also recommends that international testing capabilities be considered.

New test/demonstration facilities could provide high fast-neutron fluxes to study neutron radiation effects on materials, claddings, and fuels; large test volumes to allow for integrated component tests; loops for a variety of coolants; high temperatures; easy physical accessibility; state-of-the-art instrumentation; and high availability to the research community. The Subcommittee recommends that the study considered the benefits and needed trade-offs among these capabilities.

Nontechnical considerations that should be included in the study are affordability, sustained funding, a broad user community, international collaborations, and policy constraints (e.g., constraints on required fuel enrichment).

DOE should establish the desired goals/capabilities and evaluation criteria on the basis of stakeholder input. It should also establish (1) a steering committee with a diverse membership and (2) working groups with national laboratory, vendor, and university participation to deal with the tactical issues. A year would be needed for the study, and a preliminary draft report would be prepared for the June 2016 NEAC meeting and a final report by December 2016.

In principle, test and demonstration facilities can be licensed by the NRC or DOE. If the reactor is to be connected to a grid, the NRC is the right licensee. Likewise, if there is more than 50% commercial output from a plant, the NRC is the right licensee. The NRC can license test and demonstration reactors under a Section 104(c) or Section 103 license. The public would have more confidence in an NRC license.

The Subcommittee met December 2014 to review the existing U.S. test-reactor capabilities and the new advanced capabilities in other countries, to review the gap analyses done by national laboratories, and to review the NRC's 10CFR50 Class 104 process for regulating test reactors. The Subcommittee held a meeting with broad participation in January 2015 to review stakeholders' views of the needs for test and demonstration reactors. DOE held a meeting in April 2015 to gather stakeholder input on the criteria and metrics to be used in evaluating test- and demonstration-reactor concepts. And the Subcommittee met in June 2015 to review the status of the study, including the reactor criteria and metrics.

A good start has been made that further work is needed on the metrics. The process will start with the screening of Gen IV plus industry concepts. Working groups will be formed to define point designs for the chosen concepts and to develop them over a year. A summary report of the study will be issued in August 2016.

Meserve stated that it the same criteria should not be appliedto a test reactor *and* a demonstration reactor. The criteria for a demonstration plant would include considerations unrelated to resting, such as costs, flexibility for the grid, proliferation resistance, etc. It would be advantageous for DOE to decide whether to proceed with a test reactor or a demonstration reactor at the outset and to develop just one set of criteria.Kazimi acknowledged that DOE is pursuing different criteria for test and demonstration

reactors. DOE would like to proceed with both separately. Golub replied that there will be two sets of criteria and the metrics will be different. Meserve said that the criteria in the report are more appropriate for a test reactor than a demonstration reactor.

Richter noted that there are a large number of concepts for advanced reactors. Until one sorts out the most promising, one cannot talk about a test reactor, and one needs a test reactor to determine unforeseen results. Years ago, 1000 to 2000 concepts were surveyed by NEAC, and the effort came up with nothing. There are four main criteria: safety, spent fuels, electricity cost, and proliferation resistance. The United States has nothing to offer in advanced reactors. A concept to be pursued needs to be decided upon. All he had heard here was one more year of wheel spinning. Kazimi responded that there will be a significant narrowing down. A test reactor could assess several concepts. A particular concept has to be chosen for a demonstration plant. Had DOE selected an application (e.g., high-temperature operation), it would have been easier. Richter said that reference to a demonstration reactor implies that one has picked a concept without testing one concept against the others.

Lyons noted that the reference to a test/demonstration reactor is directly out of the Congressional language in the FY15 budget directive. He did not know if a strong-enough budgetary case can be made for separate approaches. This is the best path open to DOE. Also, the NEI has formed a working group on advanced reactors, the first time industry has shown interest in advanced reactors. These broad inquiries are the best shot we have. The choice of the NRC as the licensing agent is absolutely vital; otherwise, one is back to 1974, when DOE did both promotion and regulation of nuclear power.

Juzaitis said that the test reactor should be designed to support multiscale, multiphysics validations. One has to consider the scales of all of the variables. It has not been done before. If one can design a system of validating or qualifying fuels, it would be cheaper because one would not need all the irradiations because one has predictive simulations. This process should also reduce the design-cycle times for reactors. These capabilities should be built into the instruments that one builds for the future.

Kotek thanked the members for their hard work and advice. He also thanked Peter Lyons for his leadership and knowledge, which he had generously shared over the years.

The floor was opened to public comment. There was none. The members of the Committee were asked for their final comments.

Eisenhower thanked Lyons for his extraordinary work and wisdom over the decades. [He received a round of applause.]

Rempe said that the idea of reporting back to the Committee on DOE's responses to the Committee's recommendations was a good one and should be continued.

Kazimi stated that the potential for data gathering through NEA was a good one.

Sackett said that he was optimistic about the prospects for a test and a demonstration reactor. Many young people have come to this technology because of the "nuclear renaissance," and they need the tools to make it happen.

Ion noted that Peter Lyons is held in terrific respect in the United Kingdom. At the international level, a top-down strategy is important, or technology will be picked off at the university level without an understanding of how things all fit together.

Miller expressed his great pride in Lyons.

[Rempe, Kotek, and Miller left the meeting at 3:00 p.m.]

Eisenhower said that the update on the Office's progress on the Committee's recommendations was a great idea. American leadership is a major national security concern and needs to be a goal of this Committee. What it takes to be a leader is more than what we have right now.

Meserve said that, indeed, advanced reactors need to be talked about; however, a nuclear industry is needed that can survive until such time that advanced reactors are deployed. The concern about climate change is increasing; people are seeing it occur. Carbon-free power is needed. New reactors are needed, and the current reactors need to be kept running safely. The grid is going to change with the addition of more intermittent sources. The nation needs to deal with the Achilles' heel of spent fuel. Finally, this Committee and Office will miss a great public citizen upon the retirement of Peter Lyons.

Richter praised Lyons who, he noted, had to lead this Office during a period of highly constrained budgets.

Chu reviewed Lyons's early years at Los Alamos and on the staff of Sen. Domenici. She said that he was unbiased, ethical, and respected.

Paperiello worked with Lyons at the NRC and was sorry to see him go. He noted that verification and validation are always discussed at these meetings, and a list of such efforts should be compiled, prioritized, and assessed by topic and location. The accident overseas has had a massive impact on the regulatory agencies. DOE cannot do it all. There's a lot to be learned from foreign cooperation. Non-technical considerations (like costs) will be important in designing and operating a test or demonstration reactor. One cannot change design during construction. One has to build what is licensed.

Juzaitis said Godspeed and thank you to Peter Lyons.

Bhatnagar thanked Lyons for his soft-spoken tenaciousness and congratulated him for the progress that he had produced. The meeting made clear that the Department should have medium-term goals as well as short- and long-term goals. The agency should continue focusing on reactor-life extension and get the industry involved.

Lyons thanked the members for their kind comments. He offered the following summary of the meeting:

In regard to the use of facilities, high-performance computing should be added to the NSUF. The Facilities Subcommittee's emphasis on the test/demonstration reactor was well placed. The importance of verification and validation came up often. Prioritization of verification and validation is a great idea; perhaps CASL or NEAMS might be the appropriate program to do that. What can be done with the NEA data is uncertain, but its use should be explored. Ion beams can make a positive contribution to studying fast-neutron interactions with materials. China should be a major partner for DOE. Accident-tolerant fuels' benefits should be quantified, and a cost/benefit analysis performed. The comments offered on a pilot waste storage facility are important as is the need for a high-burnup cask program. The update on DOE responses to the Committee's recommendations is a terrific addition to the meeting's agenda. The use of the LWRS program's data is very important to the NRC and industry. He thanked the Committee members for their help and support. [He received a round of applause.]

The meeting was adjourned at 3:29 p.m.

Respectfully submitted,
Frederick M. O'Hara, Jr.
Recording Secretary
July 2, 2015