Minutes
Nuclear Energy Advisory Committee
June 13, 2013
L'Enfant Plaza Hotel

Committee Members Participating:

Brew Barron
Ashok Bhatnagar (via telephone)
Matthew Bunn
Dana Christensen
Margaret Chu
Michael Corradini
Susan Ion
Raymond Juzaitis
Mujid Kazimi
William Martin
Regis Matzie
Richard Meserve, Co-chair
Carl Paperiello
Burton Richter
John Sackett
Alfred Sattelberger

Committee Members Absent:

Susan Eisenhower, Co-chair
Donald Hintz

Other Participants:

Tracey Bishop, Acting Deputy Assistant Secretary for Nuclear Facility Operations, Office of Nuclear Energy, USDOE
William Boyle, Director, Office of Used Fuel Disposition, Office of Nuclear Energy, USDOE
Nancy Carder, NEAC Support Staff, Medical University of South Carolina
Jonathan Gillman, Senior Energy Analyst, Washington Policy & Analysis
Sal Golub, Associate Deputy Assistant Secretary for Nuclear Reactor Technology, Office of Nuclear Energy, USDOE
Tina Hymer, General Counsel's Office, USDOE
Shane Johnson, Deputy Assistant Secretary for Science and Technology Innovation, Office of Nuclear Energy, USDOE
Peter Lyons, Assistant Secretary, Office of Nuclear Energy, USDOE
Sean McDeavitt, Nuclear Engineering Department, Texas A&M University
Edward McGinnis, Deputy Assistant Secretary, International Nuclear Energy Policy and Cooperation, Office of Nuclear Energy, USDOE
Dennis Miotla, Chief Operating Officer and Acting Principal Deputy Assistant Secretary, Office of Nuclear Energy, USDOE
Frederick O'Hara, NEAC Recording Secretary, Medical University of South Carolina
Joe Perkowski, Manager of Energy Initiatives, Idaho National Laboratory
Per Peterson, Department of Nuclear Engineering, University of California at Berkeley
Robert Rova, Office of Nuclear Energy, USDOE
Monica Regalbuto, Deputy Assistant Secretary for Fuel Cycle Technologies, Office of Nuclear Energy, USDOE
Michael Schmidt, NEAC Support Staff, Medical University of South Carolina

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

Morning Session

Before the meeting, **Tina Hymer** of the DOE General Counsel's Office conducted the annual ethics briefing for the Committee members in closed session.

Cochairman **Richard Meserve** called the meeting to order at 9:06 a.m. He had the members introduce themselves. Bhatnagar was attending by telephone.

Peter Lyons introduced the Office of Nuclear Energy (NE) team (Dennis Miotla, Shane Johnson, Tracey Bishop, Monica Regalbuto, John Kelly, Sal Golub, and Edward McGinnis) and was asked to present an update on the Office's activities.

The Office is facing a number of challenges: the budget and the fact that four operating plants have shut down as a result of private investment decisions, a disturbing trend.

Ernest Moniz was confirmed as the Secretary of Energy on May 16, 2013, and has hit the ground running. He has been a professor of physics and engineering systems at MIT, Undersecretary of DOE, a member of the President's Council of Advisors on Science and Technology (PCAST), a member of the Blue Ribbon Commission (BRC) on America's Nuclear Future, and a member of the Council on Foreign Relations. He has helped shape nuclear-power policy to where it is today. On the day of this meeting, he was testifying before Congress for the first time. He is pulling together his own leadership team, and those positions require Senate confirmation.

The President's FY14 NE budget request protects some priorities:

- Small modular reactors
- Used-fueled disposition (extremely high priority)
- The nuclear energy university program
- The Modeling and Simulation for Nuclear Reactors Hub (which is doing outstanding work)
- Idaho facilities management
- A focus on the disposition of used nuclear fuel

The Integrated University Program (scholarships and fellowships) was zeroed out in 2013 but continued under a continuing resolution. The Small Modular reactor (SMR) Licensing Technical Support increased from $67 million to $70 million. Reactor Concepts RD&D [Research, Development, and Demonstration] decreases from $110 million to $72 million, making worrisome Argonne National Laboratory's ability to support the needed range of work with such low funding. Fuel Cycle R&D was reduced from $181 million to $165 million. Nuclear Energy Enabling Technologies was reduced from $71 million to $62 million. Radiological Facilities Management (which is largely the power) suffered a dramatic change from $69.5 million to $5 million; it could not be supported in DOE's reduced budget but will transition to the National Aeronautics and Space Administration (NASA), including infrastructure. The Idaho Facilities Management, which is studying the restart of the Transient Reactor Test Facility (TREAT; including an environmental assessment), increases from $154 million to $181 million. And the Idaho Safeguards and Security, which covers all site security, which was formally a defense program responsibility and an important consideration, transitions to NE and increases from $93 million to $94 million. (This is the President's Request; this budget has not been marked up by Congress. It is unknown if there will be a FY14 budget or another continuing resolution.)

Christensen noted that the University Programs were to be moved to the National Science Foundation (NSF) and asked whether there would be a loss of control over nuclear education. Lyons answered that there is a PCAST report that points this out as a substantial concern. The program may go to Department of Defense (DoD) research. STEM [science, technology, engineering, and mathematics] education will go to the Department of Education.

Meserve asked if there had been any feedback from Congress on this request. Lyons replied that questions had been received from committee staffers.

Corradini asked if Committee members could meet with the Office of Management and Budget (OMB) to inform their discussions on the nuclear budget. Lyons replied that one can do so as a private citizen.

Another challenge is on conferences: there are many restrictions that hamper the Office's ability to participate in and support conferences. Bunn pointed out that that hampers international engagement, and junior laboratory people need to present papers to get promotions. These restrictions chase people away.

Lyons pointed out that what is a "conference" is still under discussion, and confusing guidance is evolving. Richter pointed out that overall costs have gone up because a lot of small conferences are replacing large ones. Lyons pointed out that, if a conference costs more than $100,000, an assistant secretary has to approve the expenditure; over $500,000, the Secretary has to approve. Corradini noted that the Health Physics Society's attendance is down 15% this year because of these restrictions. The Committee's comments seem to have gone unheeded.

A continuing resolution has lowered the level to $20,000 for a conference to be reported. The administration budget supports many recommendations of the BRC.

The estimated programmatic cost of this effort on the disposition of used nuclear fuel over its first 10 years is $5.6 billion, including construction and operation of a pilot interim waste storage facility and progress on both full-scale interim storage and long-term permanent geologic disposal. DOE continues to consider Yucca Mountain to be unworkable. A 2048 date for a geologic repository site has been set and assumes starting from zero, but many sites have been characterized already. The proposed funding will consist of ongoing discretionary appropriations of up to $200 million beginning in 2014 and will continue for the duration of the waste-management mission. Mandatory appropriations from the fee collections and the balance of the Nuclear Waste Fund in addition to the discretionary funding provided annually beginning in 2017 will fund the balance of the annual program costs. Care must be taken not to move to site-specific activities until there is legislative approval.

Other strategy elements in the President's budget include (1) funding and authority for the Environmental Protection Agency (EPA) to begin the revision of generic (non-site-specific) disposal standards to help guide the siting of used-fuel and high-level-waste facilities and (2) explicit recognition of liability payments (DOE has paid $26 billion to utilities because it did not accept spent fuels in 1998). There is a dollar impact on not moving ahead on this back end of the fuel cycle. Barron asked if that were a line item. Lyons replied, yes: $400 million per year.

Barron asked whether the number of dollars over 10 years would exceed what will come in. Lyons said that that was correct; it would be capped in the future so it will not

exceed "taxes" from nuclear power production. There will be other expenditures: generic R&D for waste disposal and program-specific R&D.

Richter pointed out that an authorized railcar is needed to transport nuclear waste. Lyons responded that that should come from the nuclear waste fund.

Juzaitis asked what the costs were of maintaining Yucca Mountain in its current condition and where the money was coming from. Lyons answered that it is not in the NE budget area. If it were decommissioned, it would be the responsibility of the Office of Environmental Management (EM); recordkeeping is the responsibility of the Office of Legacy Management (LM). Yucca Mountain is closed and dark with no access.

The President's Request funds a pilot interim storage facility; a consolidated interim storage facility; and a geologic repository, putting fees to their intended use and funding a government corporation or independent government agency. There is not a legislative basis for any site-specific activities, yet. To move ahead, there must be legislation. Senators Feinstein, Alexander, Wyden, and Murkowski have put that legislation forward; the draft legislation has been out for comments, and it is being marked up now. Substantial progress has been made.

Meserve noted that the BRC leadership commented on the legislation, calling for management continuity, stakeholder participation on the board of the organization responsible for waste management, and the need for limitations on the linkage between a storage site and a disposal site.

Will the administration comment on the draft legislation? Lyons replied that the administration's view has been provided in the strategy documents issued earlier this year.

The President's Request supports the first phase for deployment of a small modular reactor testing technical support program. A second funding opportunity announcement (FOA) emphasizing innovation closes July 1. This would be funded out of the $452 million in the cost-share program over 6 years. Richter asked if the fuel cycle were included in this. Lyons replied that the FOA is not limited to just light water reactors (LWRs). There is a long list of criteria. Ion asked if deployability and licensing will be taken into account. Lyons answered that the program requires progress toward licensing. Corradini pointed out that it still requires a 50-50 match.

An agreement has been reached among DOE, the Nuclear Regulatory Commission (NRC), and industry (the Electric Power Research Institute, Areva, and Dominion) to investigate extended storage of high-burnup fuel to support storage license extension and transport. The goal is to address a hole in the data by benchmarking predictive models and empirical conclusions developed from short-term laboratory testing for aging of dry-storage-cask-system components and building confidence in the ability to predict performance of the systems over extended periods.

DOE has been setting up agreements with other repositories around the world for data sharing. Czech Republic cooperation involves the transfer of 75 kg of fluoride salt from Oak Ridge National Laboratory to the Czech Nuclear Research Institute Řež for experiments at Řež's critical test facility. The data resulting from the test will advance U.S. and Czech R&D on advanced reactors.

In University Programs, integrated research projects are multi-year, multi-university projects to encourage collaboration among U.S. universities and, through them, with international universities to make substantial and direct programmatic contributions on inherently safe reactors, accident-tolerant fuels, accelerated aging of used nuclear fuel in

storage, and advanced thermal reactor concepts. They deal with key aspects of much larger programs.

For example, in the FY12 integrated research projects, three proposals were selected from 3 lead universities and 19 additional collaborating organizations that represent 12 states, 1 minority-serving institution, and 3 foreign countries.

The FY13 integrated research project solicitation closed on the day before this meeting. It was on the simulation of neutron damage to high-burnup-reactor materials. Six proposals were received with 37 additional collaborating organizations (25 universities, 7 national laboratories, 4 industrial partners, and 1 foreign institution) that represent 18 states and 3 foreign countries. The evaluation process will select one project for funding.

Four U.S. power reactors have been shut down, including Crystal River and San Onofre. One was shut down because of the economic pressure of natural gas as a fuel; serious failures led to other closures. Construction continues apace at Sanmen, China; Summer; Vogtle; and Watts Bar II. About 60 reactors are being built around the world, half in China. A new nuclear renaissance is playing out around the world. We have many opportunities to contribute.

Barron noted that the economic pressures of cheap natural gas have contributed to the replacement of aging nuclear power plants with fossil-fueled plants.

Sean McDeavitt was introduced to comment on the integrated research project (IRP) on fuel aging in storage and transport.

The Fuel Aging in Storage and Transportation IRP addresses low-temperature creep, hydrogen behavior and delayed hydride cracking, canister corrosion, and novel (real-time, live) system monitoring.

Dry storage raises the fuel-rod temperature and pressure, and creep rupture is a potential degradation mechanism. The objectives of the IRP are to characterize low-temperature creep behavior for unirradiated, irradiated, oxidized, and hydrided Zircaloy cladding under high-burnup conditions and to produce relevant models that can be inserted into the FRAPCON fuel-performance code to predict cladding behavior for high-burnup fuel in long-term storage. Tests are needed, and mechanisms must be identified. Creep testing is in various stages of operation.

Past studies are being reviewed, and a database of international creep data is being assembled. Atomistic simulations are being used to understand the long-term creep behavior with emphasis on the effects of oxygen, hydrogen, and neutron irradiation. Data will be translated for use as input to FRAPCON and other codes to predict used-nuclear-fuel behavior in dry storage. Significant international exchanges are occurring with Korea and Spain.

After storage, vacuum drying (up to 400° C), and transfer to dry storage, the fuel sits under load at low-to-moderate temperatures. The hydrogen is very mobile, and stress-directed redistribution of hydrogen creates a potential failure mechanism: delayed hydride cracking (DHC). Multiple hydride methods are being employed: electrochemical methods, high-vacuum vapor-phase insertion, and aqueous autoclave and flowing gas. Hydrogen will be implanted, the Zircaloy will be stressed, and the effects will be investigated with X-ray diffraction, electron backscattered diffraction, nano-indentation (which causes stresses that can be characterized), and small-angle X-ray scattering to quantify re-orientation and produce data for modeling.

In canister corrosion, the IRP has ongoing collaborations with the DOE Disposition Program [at Pacific Northwest National Laboratory (PNNL) and Sandia], the Massachusetts Institute of Technology (MIT) Nuclear Energy University Programs (NEUP) project, and the Electric Power Research Institute (EPRI) Extended Storage Collaboration Program (ESCP). An effort is being made to standardize the material being investigated. Samples are being taken from actual canisters that have aged in vacuum environments. Analyses of these samples employ electrochemical corrosion testing, salt-spray corrosion testing (simulating coastal air environments), direct salt-corrosion exposures, electrochemical impedance spectroscopy, and fatigue-driven and static-load crack-growth testing. A pit-growth model is being developed.

The new thing being introduced is a novel method of system monitoring to ensure retrievability, subcriticality, and fuel confinement, looking at the canister exterior, canister internals, and the concrete overpack. The project is developing sensor selection and miniaturization, external and internal packages, and communication and power methods. The sensors measure humidity and oxide thickness, among other values, and will provide data for chemical environmental modeling. These systems will have to be modified for any given canister design. The current design is for new canisters; it will not retrofit well.

In summary, the used nuclear fuel (UNF) dry storage system is complex, and the mission is bigger than the IRP team. The project comprises a matrix of applied research with strong elements of basic science. Collaboration is being conducted with ongoing programs.

Matzie noted that there is fuel that has been in casks for a long time. He asked if there were any plans to open a historic cask. Regalbuto replied that the Office plans to open a cask, but it does not have a facility to do it. The facility in Idaho is gone. The plan is to open a canister in the next 10 years. This is a large-ticket item.

Sackett noted that spent fuel has been available for some time and asked to what extent this work has been integrated with the modeling and simulation community. McDeavitt replied that the Consortium for Advanced Simulation of Light Water Reactors (CASL) uses some of the same methods and has a focus that is complementary to that of the IRP. However, it does not necessarily investigate the conditions of interest in the IRP. The two efforts are focusing on two sides of the same coin. They are cooperating but not coordinating at a deep level.

Kazimi noted that this is an attempt to characterize processes that occur over a long time. He asked how such processes will be modeled. McDeavitt answered that mechanisms that produce change will be looked at, and those mechanisms will be modeled. Also, a variety of tests will be used to produce a best-guess estimate of what will happen over 40 years.

Chu pointed out that that is why it is important to open a few casks to validate or invalidate the mechanistic models. Meserve pointed out that the older fuel does not have high burnup.

Lyons pointed out that these IRPs are set up to be 3-year programs. Some programs are coming up on their third year. The Office needs advice from this Committee on what to do about these programs: to end them, to continue them, or to redirect them.

Per Peterson was asked to present an overview of the Fluoride-Salt-Cooled High-Temperature Reactor (FHR) IRP. The FHR would operate at 600 to 700° C with current materials and produce supercritical steam.

Fluoride fuel cycles were used for the Airplane Nuclear Propulsion Project after World War II. During the past decades, it has been looked at for low-pressure, high-temperature, liquid-cooled reactors. China is showing an emerging interest in this type of reactor, and the Shanghai Institute of Applied Physics (SINAP) of the Chinese Academy of Sciences has decided to build a 2-MWt FHR test reactor by 2017. It would use a solid-pebble fuel. The research effort would cost $350 million over 5 years. They are using a crown ether to replace mercury in the enrichment of lithium-7. A fluid fuel is planned for subsequent reactors. The American Nuclear Society (ANS) has formed an ANS 20.1 FHR Safety Standard Working Group.

The motivation to study FHRs lies in the much higher power density that is possible, addressing key issues for helium-cooled high-temperature reactors and leveraging existing U.S. fuel and materials capabilities. The low pressure and high temperature of FHRs enable a potential improvement vs. advanced LWRs in terms of design and license, compact reactor buildings, and use of gas Brayton cycles. This is a key learning experience; the design and simulation of new experimental facilities is an opportunity to learn the fundamental principles for reactor safety.

The IRP FHR uses a nuclear air-Brayton combined cycle (NACC) power system that is similar to those used in natural-gas combined-cycle plants. However, only FHRs could couple to a NACC because of the 350 to 500° C exit temperature from the standard air compressor. It would be less efficient than natural gas, but the fuel cost would be much lower. Combining cycles allows rapid load response.

The NACC power system maximizes revenue in a low-carbon nuclear-renewable future for both baseload and peak electricity production with a natural-gas assist. These plants could sell electricity at twice the base cost of production and still be economical.

The University of Wisconsin and MIT have completed work for starting experiments with flibe salt (a mixture of lithium fluoride and beryllium fluoride). This work includes static corrosion tests and the assembly of a nitrogen trifluoride salt-purification system.

At the University of California at Berkeley, pebble-recirculation experiments are being conducted, a facility for compact integral effects testing is being completed, and various separate effects tests [soiled-tube air heaters, pebble friction (molten salts turn out to be good lubricants for graphite), pebble heat transfer, and natural separation] are being conducted. Reactor thermal hydraulics, neutronics/depletion, and power conversion are being modeled.

Current FHR design requirements call for a peak flux that is 3 times that of the maximum commercial FHR, a minimum cycle length of 0.5 years, and negative power and void coefficients of reactivity. The pebble-bed reactor under design has the capability to provide additional grid-support services besides reliable nuclear baseload generation. It is designed to drive a credible nuclear air rate in combined cycle with a natural gas co-firing with no alternative off-site power required. It would therefore be capable to black-start grids. It would also be rail shippable.

The preliminary 270-MWt design includes direct reactor auxiliary cooling system (DRACS) heat exchangers, defueling machines, shutdown-rod channels, control-rod channels, a defueling chute, an outer radial reflector, a graphite pebble blanket, and fuel pebbles. It would have an annular pebble-bed core with a center reflector. The reactor vessel would be 3.5 m in outer diameter, 10.0 m high, have a peek power level of 270 MWt,

support a baseload of 110 MWe, convert power with a General Electric 7FA gas turbine modified with two external air heaters, and allow tritium control and recovery.

The IRP will continue engaging students and professors with conference calls among universities and with numerous workshops. About 15 students are working on the IRP. Nonproject students are also engaged. There are multiple professors involved beyond the IRP principals. The key question is what FHR activities will be funded after 2014.

There is a large incentive for the United States to work with the Chinese Academy of Sciences; they are down-selecting among three sites for a new SINAP campus for a thorium molten-salt reactor (TMSR). An Oak Ridge National Laboratory (ORNL) TMSR cooperative research and development agreement needs to be approved. A 2014 TMSR summer school in Shanghai is planned to exchange test reactor data for each side to validate their safety codes.

There is a strong case to continue DOE's investment in FHR R&D efforts. Major facilities are being built, but there will be limited data by the end of the IRP; more time is required for test and irradiation data.

In summary, the IRP has developed a strong and unique FHR market case. Major experiments are to begin this year. An American Nuclear Society ANS 20.1 FHR Safety Standard is under development. Universities, national laboratories, vendors, and international collaborators are engaged. Opportunities exist for students to study a new technology. The IRP needs to work with the DOE on the actions beyond the IRP.

Matzie noted that he had attended all the workshops. The students did all the work for the workshops. The collaborative learning environment was excellent.

Sackett said that this is a good example of the university community providing leading R&D. He asked for further comments on international graduate students' contributions. Peterson replied that with the expansion of nuclear power research in China, we need to broaden exchanges and cooperation with China.

Ion said that this was a stunning success in engaging students and providing experience. At the numbers involved (15 students), it will be difficult to keep up with developments in China. Peterson replied that the United States needs to identify its core strengths and concentrate on them. The research community is also handicapped by the export-control regulations, which put U.S. researchers at a disadvantage to their international competitors. It now takes a year to get such a license. An expedited process needs to be developed. In addition, work in reactor design needs to be leveraged.

Richter pointed out that 2014 is the end this project's 3 years and asked what needs to be done to determine whether this is a direction that DOE should pursue. Is more R&D needed to answer that question? Peterson said that another 3-year period is needed. High-temperature fuels and material programs are at risk and should be supported. Richter asked whether the Chinese agree with that; they are building prototypes. Peterson replied that if there were more resources, they could be used productively. The Chinese will drive progress. The United States needs to strengthen its core competencies. Lyons said that criteria need to be developed about program direction, and the results need to be transitioned into DOE's mainline programs (which are unfortunately austere). The SMR funding has come out of NE's Advanced Reactors Program, the budget of which is plummeting. It is quite a challenge to see how to move ahead.

Ion said that one of the criteria for evaluation should be participation in international programs. Rebidding the project means that much of the effort in the third year of a 3-year program is spent on how to extend funding.

Paperiello stated that lower operating and maintenance (O&M) costs should be promoted because some systems will no longer be needed. The new designs have higher external-event risks than internal-event risks. There is a decade or two to figure out how to lower decommissioning costs and to solve other problems (like fuel design and ultimate disposal costs).

Bunn asked if it were possible that we might end up building joint test reactors. Peterson said that the Chinese are very aggressive in their business interests and competent in protecting their interests. The United States can protect its national assets in a way that it could not accomplish for electronics. SMR technology helps, but the Chinese market is for large reactors and their market scale is large, also, and that would be a licensing opportunity for the United States in construction technologies and safety systems.

Barron asked to what extent the front and back ends have been looked at. To license a new reactor today, one has to look at the back end. Peterson said that it is not practical to operate these fuels at less than 5% enrichment. The Chinese are looking at enrichment to 9% for high-temperature reactors. In the United States, it would not be technologically possible to reprocess our LWR spent fuel. The natural uranium use drops 20 to 30% with high-temperature reactors.

Matzie said that the United States has a value proposition in molten-salt technology that should be captured in a limited, specific timeframe.

Burton Richter was introduced to report on the activities of the Fuel-Cycle Subcommittee.

The Fuel Cycle Subcommittee meeting of Apr. 23, 2013, concluded that the DOE Advanced Reactor Program starts much, finishes little, and throws away what it does accomplish (e.g., the Fast Flux Test Facility (FFTF), the Global Nuclear Energy Partnership (GNEP),, reprocessing, and TREAT) in various fits of changing program direction and budget savings as administrations come and go. Though the United States led the world in the development of commercial nuclear power, it is now behind almost everyone else, including, for example, China, India, France, Japan, Russia, and possibly even South Korea. As a result, the United States has gone from being a leader in nuclear technology to being a follower in a few decades.

In fast-reactor R&D, the United States focused on reduction in cost via advanced materials; improved modeling and simulation, shutdown heat removal, etc. and conducted Advanced Test Reactor (ATR) irradiation tests of fuels. On the international front, the United States initiated the Generation-IV International Forum; engaged the Chinese, French, Indian, Japanese, South Korean, and Russian programs; and established U.S. collaborations. Ideas have come from vendors, such as SMRs (e.g., the Gen4Energy and Toshiba 4S), Breed and Burn (e.g., the General Atomics EM2 and Terrapower), and Fuel Cycle Applications (e.g., the GE PRISM and Westinghouse ThFR). The Fuel Cycle Options Study tries to provide a framework and process to allow *decision makers to evaluate* the impact of policy decisions but not to *make* policy decisions; to provide information for R&D prioritization but not to decide what R&D will or will not be conducted; to evaluate fuel-cycle options as groups based on differentiating attributes but not to evaluate the engineering design of fuel-cycle facilities.

The Study found that it is taking longer to develop the analysis system than was hoped when the Subcommittee first heard of the program in 2011. The final report is not due until March 2014. Even then, a further evaluation will be required to sort out which of the many paths forward is most appropriate for U.S. goals. The Study recommends that a few, simple, clear options should be identified as soon as possible by the systems study and necessary follow-on studies.

TREAT is one of two U.S. test reactors. It is located at Idaho National Laboratory (INL) and was shut down in 1994. The other is the Annular Core Research Reactor Facility (ACRRF), which is located at Sandia National Laboratories and is still operational. These rectors provide transient testing, which is required to fully qualify fuels. The ACRR can produce 35-GW peak power for 0.007 seconds; TREAT could produce 10-GW peak power for 1 second. In addition, TREAT is better instrumented and delivers more energy to fuels under test.

The Study found that TREAT is of interest to other countries and would make a good contribution to a collaboration in which test facilities around the world would be used by many countries. It can be put back in operation for about $100 million. It is more capable than the ACRR. The Office of Science (SC) has a lot of people that would want to use TREAT. The Study recommended that DOE should proceed with the restart of TREAT so that it can be available for transient testing of DOE and other countries' down-selected fuel type(s) by 2018. In addition, although TREAT upgrades and modifications [such as a change from highly enriched uranium (HEU) to low enriched uranium (LEU) fuel] may be desirable, DOE should not let such changes delay the restart of TREAT. TREAT should resume operations with its original HEU fuel and qualify the LEU replacement fuel in TREAT after it is operational. The United States is a nuclear-weapons state and can manage its own HEU.

The Nuclear Waste Storage and Transportation Program is part of the DOE response to the BRC report that went to Congress in January 2013. The Program includes the establishment of a Pilot Interim Storage Facility by 2021 focused on used fuel from shut-down nuclear plants. It also calls for a Consolidated Facility by 2025 to take used fuel from operating plants. Present law does not allow work on interim storage, but does allow R&D on the topic. The Fuel Cycle Program at NE has started planning activities.

The Study found that there are problems with moving used fuel. There are no standard canisters; there are 26 types of welded canisters, some licensed for storage and some for transport, too. Even from shut-down sites, only 5 out of 400 casks are "transport ready."

All casks tend to be too large for direct eventual disposal (containing 37 pressurized water reactor or 89 boiling water reactor fuel assemblies, for example). There is no tested and certified rail car for moving canisters. As a result, there will be big problems and costs in moving from interim to repository storage.

The Study recommends that (1) a new standardized storage, transport, and disposal canister design be developed for the large amount of used fuel still in cooling pools and for the roughly 70,000 tons of used fuel still to come during the remaining life of the existing reactor fleet and (2) DOE should carefully and systematically evaluate the features and requirements of the pilot interim storage that are linked to the future bigger consolidated interim storage facility.

Corradini asked whether the Subcommittee had discussed cost-cutting technologies. He also asked whether Richter would be open to modifying the recommendation on an

advanced reactor prototype. Richter replied that the Subcommittee would prefer to leave the statement generic.

Bunn noted that the very-high-temperature reactor had been left out. The effort to design and build a very-high-temperature reactor had failed to gain traction in industry and in DOE. He asked what the rush was to build a prototype. Richter replied that the rush is to stop the United States' falling further and further behind the rest of the world. The nation will end up as a purchaser of technology rather than as a developer and manufacturer of innovative energy technologies. Bunn said that the United States can protect its own HEU, but is trying to convince other countries to give up HEU. Those other countries will look at what the United States does. Richter countered that it is not whether one never converts to LEU but to get the facility back online with the extant HEU and to convert later, if desired. Lyons also pointed out that there is one part in 10^4 of HEU in the fuel. That uranium is diluted in carbon.

Kazimi said that the fuel program and the reactor program need to be joined to make advances in both programs. Richter said that there will be some joint meetings of the Fuel Cycle and Advanced Reactor subcommittees. When one gets down to the kilowatt hours, the capital costs do not go up as fast as the efficiency goes up.

Meserve suggested reserving action on all recommendations until all subcommittee reports were presented.

Matzie said that the 50-50 cost share makes sense with near-term LWR research. Once one moves into advanced reactors, that expectation is not realistic. No one else in the world does it. Congress should be made aware that that exigency exists. The United States should go forward on a test reactor, not a prototype. It would show the maturity and value proposition of the technology. Richter said that he would be happy to change "prototype" to "appropriate-scale test reactor" in the recommendations.

A break for lunch was declared at 12:05 p.m.

Afternoon Session

The meeting was called back to order at 1:12 p.m., and **William Martin** was asked to present the International Subcommittee's report on the U.S. role in global nuclear futures.

Everything is connected internationally now. This report celebrates Atoms for Peace and it tries to discern what the next 6 years might bring and to point out that nuclear science and technology has touched the great majority of American life.

Jonathan Gillman called attention to the history, status, and future of Atoms for Peace, all of which were described in the Appendix of the Subcommittee's full report.

Martin said that the 123 agreements need to be updated to reflect the current exigencies.

The goals or objectives of NE related to its international activities should be to:

- Assist in preventing nuclear proliferation and terrorism, catastrophic climate change, and large-scale nuclear accidents;
- Promote U.S. economic growth, jobs and energy security, which contributes to national security; and
- Maintain positive relations with foreign countries.

In 2008, Daniel Poneman said in the NEAC report, "Without U.S. leadership, it is far less likely that the international community will settle on international fuel-cycle arrangements that minimize the risks of nuclear proliferation. If the United States is not engaged in building new nuclear power plants, including new reactor design and fabrication, it will be left with an ever-diminishing influence in international discussions relating to future nuclear power and fuel-cycle arrangements. … Given the stakes to the United States and the high U.S. standards in safety, it is in U.S. national interest to play a leadership role in global efforts to address the safety, security, environmental, and proliferation implications of nuclear power."

The levels of nuclear issues include the global/geopolitical, U.S. objectives, U.S. Government interagency interests, DOE objectives, and NE responsibilities. However, NE is asked to service the needs of the global nuclear enterprise with no resources.

The key questions are:

- How should the United States structure its nuclear enterprise, engaging government, industry, universities and national laboratories to further U.S. geo-political and economic interests?
- How can we connect the prudent use of nuclear power to increasing concerns regarding change?
- How should Team USA help to define the framework for a reinvented nuclear America and help to bring about such an ambition?

At the same time, in accomplishing the above, one must not lose sight of any of the core objectives: strengthening of the non-proliferation regime; securing nuclear materials; increasing nuclear-energy safety; expanding clean energy; and job creation.

The primary responsibility of NE is to support the needs of DOE's R&D complex and export initiatives. There is no home for nuclear policy in NE. NE contributes to the policy discussions of all U.S. agencies and works with partners [i.e., the NRC, International Atomic Energy Agency (IAEA), Nuclear Energy Agency (NEA), etc.) on safety and security. It may be best to seek to be a part, not independent, of overall DOE policy and strategy.

NE needs to promote (1) international security and safety and the promotion of the "gold standard" for safety and performance, (2) education and training, (3) waste storage and fuel services (the BRC is one way to do it, but leadership is needed), and (4) international R&D collaboration and cost sharing.

NE needs to support administration priorities and Team USA. Team USA could bundle national assets to present an attractive package to other countries.

The President needs to lay out Prague II, building on the legacy of great U.S. leaders and their accomplishments: Atoms for Peace, Atoms for Prosperity, and Atoms for Progress. No one can lay out the needed agenda as can the President. The challenge is to get him on the record. The secretaries of State, Department of Defense, and Intelligence should be interested in this initiative.

Joe Perkowski was asked for a summary of issues to consider:

- NE as lead vs. team player
- Allocating NE resources to policy-supporting project management
- Enhancing U.S. domestic competitiveness in the manufacturing sector
- Consider the use of case studies (e.g., the Czech Republic success) to get Congressional subcommittee interest

Richter pointed out that the report left out the inspection, training, and regulation that will need to be provided to lesser-developed countries that decide to go nuclear. NE could provide the lead here.

Bunn suggested that most policy work should be moved elsewhere in the Department and leave the technical needs to NE.

Ion said that the problem is not enough money and too much legwork. Unless there is some focus in other agencies, the United States is racing toward diminished influence as China and others take the lead. If climate change is taken seriously, natural gas does not seem so cheap. The U.S. administration should look at what is happening to U.S. nuclear influence; the U.S. nuclear industry is struggling to stay afloat on the international stage.

Meserve said that the United States' nuclear policy efforts employ the IAEA and, as a United Nations (U.N.) organization, its funding goes through the Department of State. NRC's international activities are funded by the licensees, which serves to limit NRC flexibility. The way the United States interacts in international organizations, focusing on security and nonproliferation, suppresses safety; there is a need for balance in national efforts.

Martin pointed out that the United States used to hit on ELBaradei to emphasize safety. After Fukushima, his successor is much more focused on safety.

Bunn said that, after Fukushima, the direction of the U.S. leadership was that "we can do it better than the IAEA can." DOE is not well structured to deal with such international nuclear issues. There is one person on the National Security Council (NSC), one person at the NRC, and a small group at the Department of State. An institutional structure is needed to accomplish any of this.

Matzie asked what the U.S. value proposition was to get others to engage with us. The United States has the national laboratories, the gold-standard regulator, and the most creative technology for the nuclear industry's near-term needs. All of these need to be integrated in a unified strategy.

Juzaitis said that this Committee had agreed in its morning session that it would like to develop nuclear technology but there is not money available. The President's budget is declining for non-proliferation rather than increasing, as promised at Prague. We as a country do more to shut down nuclear technology than to expand it. This nation cannot build a mixed-oxide (MOX) plant because it would cost too much now because of our past plutonium policy. It has not shown the world how to deal with waste, and it does not have a simple answer to the fuel cycle. The risk of latency should be managed. How can one build test reactors and other sources of technological leadership? A test reactor and experienced leadership are needed. A vigorous R&D program in advanced reactors and in plutonium disposition is needed. There may be something there that meets the needs of both missions.

Michael Corradini was asked to present the report of the Reactor Technology Subcommittee.

Under the current NEAC Nuclear Reactor Technology Subcommittee charge, the Subcommittee met with NE-7 staff three times to review the reorganized structure and NE-7 program overview, the Advanced Reactor Technology Program, and the LWR Technologies and IRP programs. The first two meetings have already been reported to NEAC. The most recent meeting addressed SMR licensing support, LWR sustainability, and the IRP projects (focusing on the most advanced, the fluoride-salt IRP).

In LWR sustainability, the program goals are to (1) develop the fundamental scientific basis to understand, predict, and measure changes in materials and systems, structures, and components (SSCs) as they age in environments associated with continued long-term operations of the existing reactors; (2) apply this fundamental knowledge to develop and demonstrate methods and technologies that support safe and economical long-term operation of existing reactors, and (3) research new technologies to address enhanced plant performance, economics, and safety.

The Office addresses

- Nuclear Materials Aging and Degradation (MAaD) to develop a scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants
- Risk-Informed Safety Margin Characterization (RISMC) to develop and demonstrate a risk-assessment method that is tied to quantification of safety margins and associated assessment tools
- Advanced Instrumentation, Information, and Control System Technologies (I&C) to develop, demonstrate, and deploy new digital I&C technologies

There was a thrust area on Advanced Nuclear Fuels that is being moved to the Nuclear Fuel Cycle Program. In addition, there is a program on Systems Analysis and Emerging Issues to address high-impact emerging issues (e.g., the response to Fukushima).

The Light Water Reactor Sustainability (LWRS) Technical Integration Office was reviewed by the Industry Advisory Committee (IAC). IAC posited two opposing goals: (1) Support of life extension and the first and second license renewals of the operating plants and (2) provide systems, analysis tools and technologies generally attuned to improving and modernizing the operation of the fleet. How this dichotomy is settled affects R&D project selection throughout the program. The IAC suggests that the LWRS Office identify and engage owner/operator decision makers, explain LWRS to them, and get their input [recognizing that these positions would be different between merchant plants vs. regulated utilities (in the rate base and not in the rate base)]. The LWRS program will reassess priorities based on input received from decision makers, and make changes in funded activities based on that input, balanced with input from other stakeholders. (Different types of operators will have different answers to these questions.) The LWRS office plans to leverage its connections with industry senior-level management; additional decision-maker engagement activities are taking place in each area.

The Subcommittee encourages NE to consider these IAC recommendations.

The highest-priority pathway in the LWRS program is the MAaD Program, followed by the RISMC and I&C. The percentage of available funding to each of these three pathways depends on the actual budget. More than 60% of the funding has typically been allocated to the MAaD pathway to enable completion of high-priority activities. In high-budget years, that allocation is more than 50% because funds are available for additional activities in the RISMC and I&C pathways.

The Subcommittee concurs with this funding strategy at this time.

The Subcommittee did not come to a consensus on some details. The big impact is to focus on the MAaD effort. However, there may be practical limitations to doing more work in this area, given that finding suitable experimental materials may be limited. Risk-informed safety margin characterization is an important area, which should continue to

receive emphasis. However, this has not been done before, and NRC may not accept the approach and its use.

The I&C program needs to be refocused on implementation rather than on hardware and systems. (Matzie explained that the system has to fit together in a practical relationship.) Some Subcommittee members disagree with this characterization. Industry understands the incentives to do this work. The program is focused on implementation: How will partial replacement with digital I&C interact with remaining analog instrumentation? Program is set up to examine a wide variety of control-room configurations, which is what the real world is offering today. Other work (aid for outage management) is well received, with the folks in industry actually involved in the work; it could be important for economics. Today, the replacement of analog with digital is done on a piecemeal manner. Doing it all during one outage (or within 2 to 3 months) would avoid having a mix of analog and digital devices and would avoid some costs. Bunn added that, in the Subcommittee's view, too much emphasis was put on the design of the whole integrated digital system.

The technical focus area of "Systems Analysis and Emerging Issues" is broad. DOE/NE should focus on a few high-impact topics that are not being addressed by others, or it will have to compromise the program.

IRPs (which have to be multidisciplinary and multi-institutional) are part of the NE University Program (which includes R&D grants, fellowships, and infrastructure awards to University programs). IRPs are to provide R&D solutions that are most directly relevant to the near-term, significant needs of the NE R&D programs. IRPs are intended to develop a capability to address specific needs, problems, or capability gaps identified and defined by NE. IRPs may include a combination of evaluation capability development, research program development, experimental work, and computer simulations. This approach is relatively new. The IRPs engage multidisciplinary, multi-institutional partners for 3 years with funding of more than $1 million per year.

The Subcommittee recommends that NE develop a set of metrics to evaluate IRP benefits (and NEUP generally), involve the universities in research topic selection and NEUP work-scope definitions, and develop a strategy for continuing or graduating the successful IRPs (and NEUPs). If an IRP is a successful area, it makes sense to make it a graduating project.

The IRP Advisory Panel has issued three interim letters with observations and initial recommendations. The Subcommittee concurs with the Advisory Panel's observations and findings.

The first IRP seems to be well-organized and has enormous student participation and a very good system-analysis basis. However, in the remaining time, the FHR concept needs to focus on major scientific challenges for the overall concept (e.g., tritium control and advances in molten-salt chemistry, corrosion, and heat-transfer.

DOE-NE needs to develop a strategy to transition successful IRP (and NEUP) research into the base program (i.e., program extension).

Kazimi asked what the value of NEUP was and whether the maximum value was obtained from the program. He asked whether there should be wider room for new ideas to come from universities.

Sackett stated that a lot of good research gets done, but the results lie unknown. The process can be better explained and utilized. It is a very good program.

Matzie said that the Chinese are moving quickly, and this IRP needs a more precise agreement with the Chinese before they pick our pockets of 2 years of research and the nation loses its leveraged position.

Juzaitis said that, in terms of transition, the IRP concept is important because it puts the students and faculty into the mainstream of what is important to a national program. A programmatic environment that has a long-term (10 to 20 years) technical strategy is needed to produce a broader program that can be built on and to make the transition successfully from an academic program to an advanced development program. What does an advanced reactor technology program look like? Three years is good for an academic program, but not for an agency program. For an agency program, it is not long enough. The IRP is a great start; the question is, what will the program look like when it transitions to an advanced-technology program? The challenge there is on the budget side.

Corradini said that the domestic student involvement is huge. The students see a connection between their studies and an industrial career.

John Sackett was asked to comment on the Facilities Subcommittee's views of the other subcommittees' reports.

How does our nation improve its international standing? What facilities does it have that will promote real advances? There has been a lot of discussion of DOE facilities. The assessments have supported the underlying science. What needs to be better supported at universities? Looking ahead 20 years, much infrastructure will be in modeling and simulation. However, those techniques need validation and verification. The university community is being asked about what facilities it has (e.g., thermal hydraulics) that would contribute to validation and verification of modeling and simulation. The Subcommittee is formulating specific questions to ask and an approach to elicit useful responses instead of a catalog of capabilities.

There has been a grand experiment for 5 years, the National Science Users Facility, a virtual laboratory. But the current 125 participants are self-selected (e.g., the MIT reactor). This family of facilities has provided leadership, and it makes efficient use of facilities. The Subcommittee hopes to envision a national science users facility complex on, say, thermohydraulics. Who would participate, and what facilities would they be able to contribute are outstanding questions. The Subcommittee hopes to come back with a report on the types of facilities, extant facilities, and willingness to cooperate. It hopes to have specific recommendations at the next meeting.

Richter pointed out that the proprietor does not control the selection of users. It has to be an independent group that sets the priorities. Otherwise, the program just furthers the host institution's goals. Another thing is that you are talking 20 years in the future, and it is difficult to see how the facilities existing today are going to be used 20 years from now. DOE and NE need to determine how to support the development of advanced-technology facilities and the evaluation of users' requests. If the facility has more than 2 or 3 times the requests than it can accommodate, another facility is needed.

Lyons presented his brief comments on the meeting. He understands the rationale of restarting TREAT; there is a plan to do so under development. It would be good to build a test reactor; what design to build would be the difficult choice, requiring input from universities and national laboratories. There are agreements with several countries on R&D for fast reactors. There is an international network on molten-salt reactors. Terrapower is making heavy use of almost all the national laboratories. The 50-50 split of

funding is set in statute (along with other splits). Moving toward an Atoms for Peace II or Prague II is important. PCAST has suggested a quadrennial energy review; an office may be devoted to it. It has the potential to more effectively integrate DOE, the National Nuclear Security Administration (NNSA), and DoD. DOE should leverage its connections with industry leaders. The Office is aware of the need to couple NEUP and the program areas and to move successful NEUP programs into core programs. Right now, the NEUP is programmatically justified; if it were not, it would likely be cut. The R&D roadmap needs to be reviewed; Shane Johnson is heading this up. The protection of intellectual property is a touchy point that is the subject of a lot of effort by DOE. Areas where a NEUP program in the academic community would provide verification and validation of modeling and simulation have been talked about.

Sal Golub said that the project management software of DOE has been used to track work across the whole NEUP program.

William Boyle said that, in regard to the research to deploy a prototype in the next 10 years, the goal is, in actuality, a sustainable fuel cycle in the near future. The budget is not available to build a prototype, although the Department would like to do so.

Ion said that the IRP programs are good and fit in the overall strategy. The United States should concentrate on a single system and retain leadership on that system. The worst thing would be to spread funds around; a focus is needed. It would be good to put forward the U.S. value proposition. Use the 60th anniversary of Atoms for Peace to promote its expansion. Lyons pointed out that there will be a coordinated 75th anniversary celebration of controlled fission and the 60th anniversary of Atoms for Peace.

Paperiello said that he did not see how a canister can be certified without knowing the environment it will be in. Where will it be put? Standardization is needed. Boyle replied that that is the chief challenge. Richter said that the Fuel Cycle Subcommittee recognizes that the environment was unknown. The storage facility will last for 40 years. The Subcommittee's thought was to accommodate the interim needs and buy those 40 years. One needs standardization.

Ion left at 3:00 p.m.

Barron said that, if waste-fund money could be spent, he would support the related recommendation, but DOE does not have the authority to use those funds. Richter said that, if Barron believed that this recommendation is premature, the Subcommittee would agree to drop it.

Chu asked how the nuclear community was going to deal with the spent fuel that is sitting around at many sites. Guidance is needed for ongoing activities rather than the current hodge-podge. She asked whether it was known whether these materials in dry-cask storage could be moved to interim storage. She asked whether future casks can be required to allow transport. Boyle said that some of the current casks have been designed for dual-use. Lyons added that the contracts with utilities do not state what kind of cask is to be used. The Department does not want to reopen those contracts. Boyle said that it is not positive that DOE has the authority to tell the utilities unilaterally what kind of casks to use.

Richter suggested deleting the first recommendation under nuclear waste. He also accepted the replacement of "prototype" with "appropriately sized test reactor."

Corradini moved to accept the remaining recommendations of the Fuel Cycle Subcommittee; Barron seconded. The vote was unanimous to accept the recommendations as amended at the meeting.

Paperiello stated that the SMR program is the opportunity to develop a more economic reactor than today's reactors. SMRs leverage O&M costs over the years.

Matzie said that the national nuclear agenda needs to be coordinated to free up money among many agencies.

Christensen said that the loss of the scholarships and fellowships should not halt DOE's investment in the next generation of scientists and engineers. The Department of Education is process-focused, not outcome-oriented.

Corradini said that the American Nuclear Society will help educate the new Secretary, who is hinting at the reorganization of nearly all of DOE. He asked, who should have a voice in what R&D should be done? Industry has to have a major voice if the lifecycle is 60 years. If one is talking 10 to 20 years, the national laboratories and universities should have the lead. All the actors should be gotten together. There are two IRPs, three national laboratory projects, and two industry projects. They need to be integrated.

Sackett pointed to the potential restructuring of the agency, the fact that policymakers around the country are making choices, and that the financial community is doing the same thing. They are asking if the nation can afford restructuring the grid. DOE could bring the investors and state regulators together with one voice.

Martin commented that the Director General of the NEA addressed an extraordinary meeting of the International Subcommittee. What was said was that nuclear was where the most important improvements could be made by more integration at the top. The Secretary of Energy needs to bring to the table his counterparts at State, NSC, DOD, etc.

Richter said that what Congress is talking about with the Department of Education is STEM. Martha Krebs got told by Congress that primary and secondary education is not within DOE's province. Advanced stuff has to go with the people who drew advanced research because one learns only by doing.

Sattelberger said that there is a program in the Office of Science called Energy Frontier Research Centers. They are funded for 5-year cycles, which term gives them time to do important work. He agreed that NE needed test facilities.

Barron said that the Department needs to figure out what the next game-changing reactor will be. It also needs to figure out why it is more expensive today to build a nuclear reactor than to build a natural-gas-fired plant. Is it quality, scale, or regulatory burden? There are a lot of factors that could be sorted out.

Juzaitis said that cheaper nuclear with safety and security is needed; otherwise, there would not be enough impact on the climate front. The United States needs to work with China, Japan, Korea, etc. on dry-cask storage.

Dana Christensen and Michael Corradini left at 3:30 p.m.

Bunn noted that experts have said that nuclear is going to become more expensive in the future than it is today. Nonproliferation is important, and NNSA has the controlling role here. NE could have a role in working out alternatives in, say, dry-cask storage. The Chinese are very interested in this issue.

Sattelberger and Juzaitis left at 3:33 p.m.

Chu said that the Committee has been asked to review the current program. There are a lot of interrelated issues. Can the Committee as a whole spend a meeting on the big issues of core fundamental things and revisit those ideas year after year?

Chu left at 3:36 p.m.

Kazimi noted that there have been attempts to boost modeling and simulation to shorten the path to a choice. But those methods need a lot of verification. TREAT would be a good facility to have. A few canisters should be taken apart to gain empirical information. The way University Programs is run is too mission-driven. The Nuclear Energy Research Initiative (NERI) brought forward a few, good, new ideas. Lyons pointed out that NERI was legislatively directed; NEUP is not.

Meserve said that the reality is that the budget is austere and is likely to continue that way. There will likely be a continuing resolution for the next year. The stalemate in Congress will continue. Climate change is a serious problem and will need to be dealt with; nuclear is part of the answer. The center of gravity of nuclear is moving to China, Russia, and India. If the United States is going to have influence on nuclear safety and security, it needs to be more engaged and have more robust program than it now has.

Lyons thanked all the Committee members for their work and suggestions. He said that the Office will try to find ways to move through some of these incredible challenges.

The meeting was adjourned at 3:45 p.m.

Respectfully submitted,
Frederick M O'Hara, Jr.
Recording Secretary
June 25, 2013