Department of Energy–National Science Foundation
Nuclear Science Advisory Committee
July 16, 2015
Doubletree Hotel
Bethesda, Maryland

Minutes

Committee Members Participating:

Abhay Deshpande
Frederic H. Fahey
Donald Geesaman, Chair
John Hardy
Karsten Heeger
David Hobart
Suzanne Lapi
Jamie Nagle
Filomena Nunes
Erich Ormand
Jorge Piekarewicz
Patrizia Rossi
Kate Scholberg
Matthew Shepherd
Raju Venugopalan
Michael Weischer

Committee Members Absent:

Vincenzo Cirigliano
Jurgen Schukraft
John Wilkerson

Other Participants:

Lawrence Cardman, Associate Director, Physics Division, Thomas Jefferson National Accelerator Facility
Leland Cogliani, Associate, Lewis-Burke Associates
Patricia Dehmer, Acting Director, Office of Science, US DOE
Jehanne Gillo, Director, Facilities and Project Management Division. Office of Nuclear Physics, Office of Science, U.S. DOE
Timothy Hallman, Associate Director of the Office of Science for Nuclear Physics, U.S. DOE
Kenneth Hicks, Director, Experimental Nuclear Physics Program, NSF
Bradley Keister, Deputy Director, Physics Division, NSF
Frederick O'Hara, NSAC Recording Secretary, Oak Ridge Institute of Science and Education
Allena Opper, Director, Experimental Nuclear Physics Program, NSF
Bradley Sherrill, Director, National Superconducting Cyclotron Laboratory, Department of Physics and Astronomy, Michigan State University

About 30 others were in attendance in the course of the meeting.

The meeting was called to order by the Chairman, Donald Geesaman, at 8:04 a.m. He had the Committee and audience members introduce themselves.

Patricia Dehmer was asked to present the perspective of the DOE Office of Science (SC).

The FY16 budget request is on the Hill awaiting a joint conference. The FY 17 budget is in formulation. Both budgets have projects for SC in the range of $0.75 billion to $1 billion, and advisory committees have played a major role in getting those projects into the budgets. What advisory committees do has an important impact on the budgeting process.

In its current state, the FY16 House Mark and Senate Mark of the SC budget have large differences in program funding that tend to cancel out; both would allocate about $5.1 billion to SC, about $4.7 million less than the President's Request. In the Senate markup, there are $174.9 million for the Relativistic Heavy Ion Collider (RHIC) operations at Brookhaven National Laboratory, $8.4 million above the FY15 budget and $2 million above the President's Request. This is not an anomaly. SC has 30 operating research facilities, and some make their cases to Congress better than others do.

Program planning in SC considers mission needs and scientific opportunities. Mission need is set by the Executive Branch priorities, within which (1) administration priorities are guided by deliberations at the National Science and Technology Council (and working groups), Office of Science and Technology Policy (and working groups), other administration-convened ad hoc working groups, and interagency coordination and (2) departmental priorities are determined through DOE and program strategic plans and the *Quadrennial Technology Review/Quadrennial Energy Review*. Congressional-branch priorities are reflected in legislative authorities and annual appropriations.

Within the myriad of scientific opportunities, program priorities are set via the engagement of community experts and stakeholders through federal advisory committees' reports and recommendations along with DOE-sponsored scientific and technical workshops/reports and non-DOE scientific and technical workshops/reports.

Between 1978 and 2015, there have been major shifts in program funding within SC, with individual offices' funding growing and declining from year to year. The Office of Advanced Scientific Computing Research (ASCR) has seen the greatest percentage growth. The Office of Basic Energy Sciences (BES) saw its greatest dollar growth in the 1990s and 2000s because of facility construction that resulted from National Research Council (NRC) and National Academy of Sciences (NAS) reports. The Office of Biological and Environmental Research (BER) has seen a constant level of funding. The Office of Fusion Energy Sciences (FES) now has a small portion of funding relative to what it had 25 years ago. The funding of the Office of High Energy Physics (HEP) expanded rapidly during the period of Superconducting Supercollider construction and then declined significantly with program closures (i.e., the B Factory and Tevatron) and the off-shoring of high-energy physics research. And the Office of Nuclear Physics (NP) has grown and will continue to grow with strong advisory committee support.

Each of these offices has generated major charges to their federal advisory committees which haveproduced major reports.

The Advanced Scientific Computing Advisory Committee (ASCAC) was charged to (1) determine the potential synergies between the challenges of data-intensive science and exascale computing; (2) determine the ten principal research challenges and the technical approaches required to develop a practical exascale computing system; and (3) review the Department's draft preliminary conceptual design for the Exascale Computing Initiative (ECI), a huge initiative across DOE and the federal government that is ramping up funding in FY15 and FY16.

The Basic Energy Sciences Advisory Committee (BESAC) was charged to provide advice on the future of photon sources in science, considering both new science opportunities and new photon-source technologies. It produced a report that completely changed the budgeting and priorities of the Office. That report became a poster child of advisory committee reports. BESAC was also charged to revisit the BESAC 2007 "Challenges" report, considering progress achieved, impact of the challenges on energy sciences, funding modalities, and new areas of basic research not described in the original report.

The Biological and Environmental Research Advisory Committee (BERAC) works in a slightly different manner from the other advisory committees. It recommends initiatives for field-based research (conducted by the so-called Integrated Field Laboratory or IFL) that capture a multidisciplinary approach and build on observations and modeling to (1) define the criteria for selecting sites for future BER field-based research and (2) prioritize the sites identified or described. Since 2013, BERAC has been building on its major report on IFL, and the most recent report is on Grand Challenges for Biological and Environmental Research: A Long-Term Vision.

The Fusion Energy Sciences Advisory Committee (FESAC) has been charged to (1) assess priorities among and within the elements of the Magnetic Fusion Energy Sciences Program; (2) develop a strategic plan for the Fusion Energy Sciences Program, assuming several different funding scenarios, which was delivered December 2014, and raised a lot of controversy (as a result, FES is holding a series of workshops engaging wide areas of the scientific community); and (3) assess the connections between research supported by the Fusion Energy Sciences Program and other scientific disciplines and technological applications (a new charge issued in February 2015).

The High Energy Physics Advisory Panel (HEPAP) has a standing subcommittee, the Particle Physics Project Prioritization Panel (P5) that was charged to develop an updated strategic plan for U.S. high-energy physics that can be executed over a 10-year time scale in the context of a 20-year global vision for the field. Delivered in May 2014, that strategic plan has produced a significant change through recommendations to globalize efforts and expand programs. The implementation of that recommendation is progressing faster than anyone anticipated. It is currently driving budget activity at a level of more than $1 billion. This report and the BESAC light-source report have been developed by wide communities in short order with major impacts. HEPAP was also charged to assess the accelerator R&D efforts supported by the HEP program.

The Nuclear Science Advisory Committee (NSAC) has two main thrusts: the DOE Isotope Program and the nuclear science scientific program. NSAC’s reviews have facilitated changes in the way the Isotope Program is managed and its visibility and importance. NSAC’s report in response to the 2014 nuclear physics research opportunities and priorities long-range-plan charge letter (due in fall 2015) could have great impact on the Office’s program.

SC’s advisory committees have real impact on operations of the Office. Their reports play a major role in budget planning and adoption. The report NSAC delivers in October 2015 can have a tremendous impact on the progress of nuclear science.

Geesaman said that he believed that the slow but constant growth of the Office of Nuclear Physics resulted from long-range planning being taken seriously by the community. It will continue to be taken seriously. He asked if any progress were being made in the facilities plan that SC was preparing several years ago. Dehmer replied, yes. Some aspects have been overtaken by advisory committee reports and the help of the scientific community as facilities are terminated in a disciplined way and new facilities are identified by advisory committees. Geesaman surmised that a facilities plan report was not going to be published. Dehmer said, no. The administration decided not to do that.

Venugopalan asked Dehmer to comment on National Academy of Sciences (NAS) reports. Dehmer said that, during the past 20 years, NAS reports have played a major role but cannot take the place of advisory committee reports. The NAS recommended light-source investments, but those investments did not happen until advisory committees recommended them.

Piekarewicz asked what drives the long-range plan. Dehmer replied that the science has to be compelling and the recommendations have to be actionable. Dozens of reports end up on the shelf unused because they do not have these attributes.

Timothy Hallman was asked to give DOE NP's perspective on the frontiers, challenges, and opportunities for U.S. nuclear science.

DOE NP has three broad scientific thrusts: Quantum chromodynamics (QCD) seeks to develop a complete understanding of how quarks and gluons assemble themselves into protons and neutrons. Nuclei and nuclear astrophysics seeks to understand how protons and neutrons combine to form atomic nuclei. Fundamental symmetries of neutrons and nuclei seeks an understanding of fundamental interactions.

DOE supports about 90% of nuclear science research in the United States with three national user facilities: RHIC, the Continuous Electron Beam Accelerator Facility (CEBAF), and the Argonne Tandem Linac Accelerator System.

CEBAF at the Thomas Jefferson National Accelerator Laboratory (JLab) is in the final phases of a major upgrade in energy from 6 GeV to 12 GeV. That upgrade is 94% complete and has been funded since FY12. It is expected to complete within the baseline schedule and on budget. With the completion of the 12-GeV CEBAF upgrade, researchers will address the search for exotic new quark–antiquark particles to advance our understanding of the strong force; evidence of new physics from sensitive searches for violations of nature's fundamental symmetries; and a detailed understanding of the internal structure and dynamics of the proton. A tremendous number of instruments are now installed. Some data are coming from the first beams. The GlueX detector is doing extremely well, producing data that will allow detailed comparison with theory.

With the new CEBAF energy range, JLab is poised to explore some exciting science questions:

- What is the role of gluonic excitations in the spectroscopy of light mesons, and can these excitations elucidate the origin of quark confinement?
- Where is the missing spin in the nucleon, and is there a significant contribution from valence-quark orbital angular momentum?
- Can a novel landscape of nucleon substructure be revealed through measurements of new multidimensional distribution functions?
- What is the relation between short-range nucleon-nucleon correlations and the partonic structure of nuclei?
- Can evidence for physics beyond the Standard Model of particle physics be discovered?

Looking to the future, the proposed MOLLER [Measurement of Lepton–Lepton Elastic Reactions] apparatus had a successful science review. NP is working to define the next steps to continue progress. Beyond that, another major new instrument being proposed for JLab is the SoLID [Solenoidal Large-Intensity Device] detector for deeply virtual Compton scattering.

Continued research is being conducted on the RHIC discovery of the densest, most strongly interacting perfect quark–gluon liquid matter. "Jets" of energetic particles that traverse the new form of matter in relativistic heavy-ion collisions are completely disrupted, unlike in proton-proton collisions. This is evidence of new physics and of a new form of matter being produced. RHIC machine performance continues to set new records. No other facility worldwide can rival RHIC in range and versatility as a heavy-ion collider. Moreover, it is the only polarized proton collider in the world. There are many remaining questions for RHIC. It has revealed a *terra incognita*, and the investigation needs to be completed: What is known about the initial state and its rapid development? Where is the missing spin in the proton? What do gluons contribute? Advanced instrumentation added during a proposed upgrade would help complete the mission. This upgrade completed a successful science review in the spring of 2015.

In QCD, the study of the high-density gluon field that is at the center of the mass of the proton, the spin of the proton, the dynamics of quarks and gluons in nucleons and nuclei, and the formation of hadrons from quarks and gluons requires a high-energy, high-luminosity, polarized electron–ion collider.

Coulomb-excitation results show that isotopes can be separated and identified, including some that have never been seen. For example, barium-146 is predicted to be octopole deformed. The observed coincidence gamma spectra verify the theory.

The Facility for Rare Isotope Beams (FRIB) is under construction. Groundbreaking was held on March 17, 2014. The tunnel is constructed, and progress has been spectacular. FRIB will immediately increase the number isotopes with known properties from about 2000 observed during the past century to about 5000 and will provide world-leading capabilities for research on nuclear structure, nuclear astrophysics, and fundamental symmetries. The FRIB instrumentation effort is just getting under way, and the excitement is palpable. The Gamma-Ray Energy Tracking Array (GRETA), SEparator for CApture Reactions (SECAR), and the High-Rigidity Spectrometer are the major initiatives, and they are gearing up for a major theory alliance. GRETINA [little GRETA], which was developed at Lawrence Berkeley National Laboratory (LBNL) and moves around the country, enables a new window on the synthesis of elements in stellar reactions.

Major emphasis will be placed on neutrinoless double-beta decay. This line of research has implications for why masses of neutrinos are so much smaller than those of other particles. Major theory is being challenged by experiment, as researchers address the science questions:

- Is the neutrino its own anti-particle?
- Why is there more matter than antimatter in the present universe?
- Why are neutrino masses so much smaller than those of other elementary fermions?

The most sensitive experiments to date have attained results for a half-life greater than 10^{25} years. To reach the inverted-hierarchy region requires sensitivities of 10^{27} to 10^{28} years. The current efforts are demonstration projects to see how to achieve that sensitivity. A number of those experiments should show their sensitivity limits in the next few years. An NSAC subcommittee will determine the essential R&D to demonstrate down-select criteria for a ton-scale experiment. Following that, there will be a joint NSF–DOE peer review convened by NSF to provide guidance on prioritizing R&D needs prior to the downselect.

Nuclear theory underpins everything: it gives a path forward and explains experimental results.

The Isotope Program produces and/or distributes radioactive and stable isotopes that are in short supply, maintains the infrastructure required to produce and supply isotope products, and conducts R&D on new and improved isotope-production and -processing techniques; 19 key isotopes are produced, and 21 isotopes are under development. The program also serves a very important role in coordination and communication to identify isotope needs and how to meet them. When the program came to NP, it had no R&D component. The R&D has been restarted, allowing production of alpha emitters that can be used in cancer therapy. There are other success stories also.

The NP budget is currently divided among funding for the Small Business Innovative Research/Small Business Technology Transfer (SBIR/STTR, about 2.5%), research (about 29%), facility construction, stewarding the future and all of the major items of equipment(about 18%) ; the remainder supports operations of facilities (about 51%). More investment in research and instrumentation is needed. The FY16 request reflects a strong commitment to research within the overall NP budget, an increase of about $13.5 million over FY15. Buying power is down, and this increase is needed to use the tools that have been constructed. Increased funding in FY16 supports NP's national scientific user facilities, the isotope-production facilities, and other NP facility commitments. The House mark would reduce funding from $595.5 million in FY15 to $591 billion in FY16, a great challenge. The President's Request is very robust for NP; Congressional support is crucial.

Since 1979, the NP long-range plans have identified the scientific opportunities and recommended scientific priorities. The scientific opportunities are rich, extending from microseconds after the creation of the universe to today.

In summary, The CEBAF and RHIC programs are both unique and at the "top of their game" with compelling "must-do" science in progress or about to start. Long-term, an electron–ion collider is envisioned to be the facility that provides exciting opportunities for the entire experimental QCD research community. A very high priority for the NP community is not losing U.S. leadership in the science of neutrinoless double-beta decay. Essential R&D for candidate technologies must be completed in the next 2 to 3 years prior to a downselect for a ton-scale experiment. A concomitant challenge will be ensuring inclusiveness and fairness for all demonstration efforts in progress and completing the downselect in a timely way so as not to endanger U.S. leadership in this science. A high priority in the Office is increasing investment in research and instrumentation as a percentage of the total NP budget.

Heeger asked what the SBIR program was. Hallman replied that SBIR shows up in the NP budget as a "tax", a percentage of budget (except construction) devoted to innovative projects conducted by small businesses. The Act that authorizes it is renewed periodically by Congress.

Piekarewicz noted that junior people need to participate in the field. Hallman answered that there is a plateau in postdocs. DOE agrees that junior scientists need to be supported. The Office does that through Early Career Awards (5 years of funding). Research funding needs to be increased; *that* will attract students. He noted that Dehmer is also the Associate Director of the Office of Workforce Development. That Office has several programs for students.

Bradley Keister was asked to present an overview of the NSF's Physics Division (PHY).

NSF awards are being closely scrutinized by Congress to see if the awards made are consistent with its mission. The organization chart reflects people that deal with cross-cutting programs, construction, and a variety of smaller programs.

PHY hosted a committee of visitors (COV) in February 2015 with 33 members. The COV reports to the advisory committee of the Directorate for Mathematical and Physical Sciences (MPS), and PHY got a positive review. The report and the division's response are available online.

Over 50% of the Division's funding goes to investigator grants, with the remainder allocated to centers and facilities.

The Advanced LIGO [Laser Interferometer Gravitational-Wave Observatory] project is now completed, potentially increasing observations of gravity-wave events from one to tens per year.

The Large Hadron Collider (LHC) is now running at 13 TeV . NSF supports researchers at ATLAS [A Toroidal LHC ApparatuS], CMS [Compact Muon Solenoid], and ALICE [A Large

Ion Collider Experiment]. It is participating in the LHC phase 1 upgrade (LHCb) and is the only U.S. supporter.

The National Superconducting Cyclotron Laboratory (NSCL) ReA3 (re-accelerator) is now ready for science. GRETINA, a mobile facility, is to arrive in July 2015.

IceCube gets a contribution from PHY. The IC86-2014 run was completed in May of 2015, detecting 90,000 neutrinos and 90 billion muons. The management of IceCube is to be recompeted. Further information is available online.

There are now ten physics frontiers centers. They are funded for up to six years each; and have are recompeted every 3 years. About 65 proposals were been submitted in the most recent competition. There is not a strong incumbency advantage. New this year, the division funded a new center: NANOGrav [North American Nanohertz Observatory for Gravitational Waves] at the University of Wisconsin–Milwaukee, which will look for gravitational waves in a manner complementary to LIGO.

The FY15 budget request was $263.70 million. The FY15 operating plan was $274.99 million, higher than the FY15 budget request. Proposal and award processing for FY15 are under way; no details are available. The FY16 budget request is $277.37 million. The House and Senate have marked up the FY16 budget. The House has for the first time specified funding levels for individual directorates. The Senate has left program funding to NSF and its divisions.

The Office of Management and Budget (OMB) along with the Office of Science and Technology Policy (OSTP) have set the administration's priorities. Priorities apply across the Executive Branch. Priorities affect the year-to-year changes in the budget process. These priorities guide the distribution of funding to agencies and programs.

Wiescher noted that several aspects of the PHY list of research interests should overlap with NP. He asked if this were decided from current funding or other reasons. Keister replied that the issue for Homeland Security and Climate is how much is applied research, and does one want to go in that direction? Hallman added that all federal agencies get this information, and DOE also stresses these priorities in its budget narratives. Keister added that this communication of priorities goes to the Office of the Director, and divisions define initiatives to the director.

Deshpande asked how the committee reports were informed about the leading-edge research. Keister replied that the OSTP has analysts that interact with agency leaders. Hallman added that they also have experts on the OSTP staff to advise the analysts.

Nunes asked whether high-performance-computing funding was increasing in the NSF. Keister said that PHY already has a program in high-performance computing. Other divisions do not but are developing such programs.

Nunes asked whether the NSF has had a decrease in support for young talent through its support of small investigators. Keister answered that he did not know of any such study. Opper said that the data come from the principal investigators' (PIs') reports on how money is spent. In total, the number of postdocs has been stable during the past years. Keister noted that one of the variables considered in reviewing proposals is how much goes to students, how much to postdocs, and how much to everything else.

Allena Opper was asked to give an overview of NSF nuclear physics.

The NSF's Directorate for Mathematical and Physical Sciences (MPS) is composed of six organizations: Astronomical Sciences (AST), Chemistry (CHE), Materials Research (DMR), Mathematical Sciences (DMS), Physics (PHY), and Office of Multidisciplinary Activities (OMA). Funding for PHY peaked in FY09 with the receipt of funding from the American Recovery and Reinvestment Act of 2009. It hit a low in FY13 with the sequestration and is just now recovering to FY12 funding levels. PHY is the second-highest-funded division in MPS. The FY15 NSF Nuclear Physics funding was $49.69 million. Within that total, the program funding was $23.043 million. Funding for the NSCL was $22.5 million plus $0.5 million added to meet additional needs. (The President's Request for NSCL for FY16 is $23.5 million.) The total Nuclear Physics funding reflects a base increase of about 2% plus $1.3 million added to the experimental program for neutrinoless double beta-decay research that had been moved into the program. These figures do not include Major Research Instrumentation (MRI) projects.

The distribution of funds across program areas has been consistent during the past 3 years. NSCL funding is stable. The experimental nuclear physics community has a very high success rate (about 60%) for its proposals, probably due to pre-vetting and collaboration. This is a bumper year for proposals to the Experimental Nuclear Physics Program. About 40 awards will be made, totaling about $7 million.

A solicitation for investigator-initiated research projects is currently on the street. All proposals submitted to PHY programs must go through this solicitation. The deadlines are October 28, 2015, for particle astrophysics; November 13, 2015, for experimental nuclear physics and theoretical nuclear physics; December 3, 2015, for computational physics; and February 3, 2016, for accelerator science. Proposers must follow the *Grant Proposal Guide*, its checklist, and instructions that are specific to a given solicitation.

PHY-specific instructions include: PIs who have anticipated additional concurrent sources of support should clearly explain the differences between this proposal and other awards regardless of the agency of origin. There must be no overlap in scope. The proposal review process will include an assessment of the proposers' ability to carry out the proposed research in light of these other commitments. PIs with similar proposals for different agencies will be expected to withdraw all other applications should one of them be funded. A list of collaborators that do not fit in the biosketches should be included as a supplementary document. Letters of support should not be submitted with an NSF proposal. Instead, letters of collaboration are allowed. Letters of collaboration should follow the suggested single-sentence format.

The MRI solicitation closed on January 22, 2015. The reviews are completed, and awards are being made. For FY16, the due date is January 13, 2016. New solicitations may have some changes .

The proposal deadline for career awards is July 23, 2015. One should contact the program officer for information/advice ahead of time.

As pointed out in the *Grant Proposal Guide*, there should be a discussion of broader impacts in the Project Summary. These discussions are taken very seriously, and if one does not include them in this summary, the proposal will be returned without review. There must be a discussion of broader impacts in the main part of the project description, as well. A subheading is needed to make them identifiable. There should be a discussion of broader impacts in the Results of Prior Support section, as well. A record of contributing to the broader benefits of society gives reviewers confidence in proposed activities; and it is required.

NSF and DOE are working in a coordinated, unified way to optimally utilize resources in support of the neutrinoless double-beta decay research funded, similar to the process used in the recent joint effort on the second-generation dark-matter experiments. That process included independent calls for proposals with coordinated requirements and a joint review.

The personnel in MPS and PHY have not changed since September 2014. Ken Hicks plans to return to Ohio University in August of 2016, and a replacement is being sought.

Deshpande noted that assessments of broader impacts seem to be required in two places in a proposal. Opper agreed; one is in the proposed efforts and the other in the description of prior accomplishments (which can be up to five pages in length).

Nagle asked if people at small institutions or junior faculty failed to meet the requirements because they are not well-connected. Opper replied that all the requirements are in the *Proposal Guide*. Sometimes, a proposal is returned to the PI for minor changes and resubmission. Keister added that most failures to meet requirements are made by PIs at major universities and by experienced PIs.

Nunes asked about theoretical-nuclear-physics proposals. Opper replied that the data have not been filed for this year, yet. In general, there was a major jump in proposals this year. It is believed that people are submitting proposals to both DOE and NSF.

Weischer asked how much of an impact previous annual reports of proposals have on a proposal's success. Opper said that the proposals (and only the proposals) go out to three reviewers. Those reviewers can go out and look for earlier publications, but they are not made aware of them by NSF. Hicks stated that about one-third of annual reports are returned for lack of information or other reasons.

Geesaman asked about proposals that depend on resources at other institutions and how those proposals should communicate that the host facility will be ready for use. Opper replied that the letter of support from the other institution will state that the resource will be made available.

Nunes asked if young PIs should be encouraged to submit to both DOE and NSF. Opper replied, yes; they should apply to whatever agency offers opportunities. Hallman noted that this happens often in early career awards. The agencies decide independently whether the applicant meets the agency's requirements. Applicants cannot be funded by both agencies, however; they must choose between any competing offers. Opper noted that the program managers at the different agencies tend to coordinate with each other.

Ormond asked how the agency chooses between making more smaller awards or fewer larger awards. Opper replied that one looks at the significance of the science. If a large award is proposed but not all portions review well, the agency can "scrub" the funding to reflect the reviews, in conjunction with the proposer.

A break was declared at 10:28 a.m. The meeting was called back into session at 11:03 a.m.

Lawrence Cardman was asked to present an updated report from the NSAC Isotope Subcommittee.

An updated version of the report has been distributed. It is hoped that all the concerns voiced at the previous NSAC meeting have been addressed.

The Subcommittee had been charged to conduct a new study of the opportunities and priorities for isotope research and production, resulting in a long-range strategic plan. It was also to identify and prioritize the most compelling opportunities for the DOE Isotope Program to pursue during the next decade and to articulate the potential impacts of those opportunities. It was to indicate the resources needed to pursue those opportunities. And it was to articulate the progress that has been made since the prior NSAC Isotope Subcommittee published its recommendations.

The text of the draft report reviewed by NSAC at its prior meeting has been cut from 137 to 118 pages, jargon has been reduced, readability has been enhanced, simplifications were made, redundancy was reduced, and less-important material was relegated to appendicies.

Recommendation 1 was left unchanged: the Subcommittee recommends a significant increase in funding for research and development.

Recommendation 1.a, to continue support for R&D on the production of alpha-emitting radioisotopes, has a major addition: Since the 2009 recommendation, the effectiveness of this novel therapy for cancer treatment has been demonstrated with Food and Drug Administration (FDA) approval of the alpha emitter radon-223 for metastatic bone cancer from hormone-refractory prostate cancer.

Recommendation 1.b, support R&D into the production of high-specific-activity theranostic radioisotopes, had a justification added: Medical procedures that can be tailored to an individual's unique response will be more effective and will lower the cost of healthcare.

Recommendation 1.c, continue support for R&D on the use of electron accelerators for isotope production, had a reason added to it: Many isotopes that have ideal properties for applications in nuclear medicine and national security cannot currently be produced in the quantities and purity required.

Recommendation 1.d, support R&D on the development of irradiation materials for targets that will be exposed to extreme environments to take full advantage of the current suite of accelerator and reactor irradiation facilities, had a sentence added to it: It is paramount that the production of critical isotopes be performed in a way that ensures public safety and protects the environment.

Recommendation 2, completion and the establishment of effective, full-intensity operations of the stable-isotope-separation capability at ORNL, had technical details deleted and a justification added: Without this effort, the United States is dependent on foreign sources for materials critical to the health and safety of the nation. This ongoing effort should continue until the separation capability has been fully established, the intensity goal of throughput comparable to a calutron (about a 100-mA ion current) has been achieved, and the separator is available for routine use. To achieve the goal for separator throughput, the Isotope Program is investing in the development of new ion-source technology. This facility will provide a reliable U.S. source of high-purity stable isotopes in small quantities, many of which are currently available only from Russia and will require, among other things, the allocation of a base operations budget for the separator.

Recommendation 3's wording was clarified: We recommend an increase in the annual appropriated budget to realize the opportunities associated with high-impact infrastructure investments and to maintain a stable funding base for reliably operating and continually improving facilities. Specific opportunities for the period covered by this long-range plan include … .

Recommendation 3.a, infrastructure for isotope harvesting at FRIB, received a modest clarification: The technical and economic viability of this proposed capability should be developed and assessed promptly.

Recommendations 3.b, 3.c, and 4 remained unchanged, as did the section on evaluation of progress toward realizing the 2009 report recommendations and the section recommending $19.5 million per year of incremental appropriated funding.

In summary, the Subcommittee found that NP has done an outstanding job of managing the Isotope Program since the 2009 transition and has set in place a structure and procedures that form a firm foundation for the future. The Office should be encouraged to pursue the path that it has laid out. There are many opportunities to further enhance the ability of the Isotope Program to "increase the domestic availability of isotopes appropriate to the DOE Isotope Program portfolio and deemed to be critical for the nation." It is anticipated that the strengthening of the

Isotope Program will be rewarded with continued progress in science, medicine, and industry and by a further strengthening of national security.

Geesaman noted that, at the previous meeting, there was general approval of the report and its recommendations even though theCommittee asked for some substantial modofications which had now been accomplished. He asked if discovery science support would be impacted bythis program in the course of budget development. Hallman replied that the Isotope Program budget has thus far been kept separate from the discovery science budget, in part because the mission of the Isotope Program is larger than just NP; it includes DOE and the entire government. The research portfolio requests are being increased across NP

Nagle asked whether the 15% figure cited was driven by dollars or percentages. It is ambiguous in this document. Sherrill said that the 15% (of the total budget) is not the driving factor, but the dollar amount is. He added that the amount recommended is *close* to 15% of the total budget.

Deshpande noted that, if Fig. 15 were increased in size, it would be more readable.

Geesaman asked each member to respond to the revised draft report.

Deshpande said that this version is much clearer and improved.

Fahey said that he could live with this version. It emphasizes the right topics. He appreciated the efforts in alpha emitters and the R&D aspects emphasized in this report. A reliable, cost-effective method of producing medical isotopes is needed.

Hardy said that the draft report does what it needs to do, and he was prepared to accept it as is.

Heeger congratulated Cardman on completing this report, now approved. It is a useful and detailed reference.

Geesaman interjected that the members from Los Alamos National Laboratory (LANL), Oak Ridge National Laboratory (ORNL), and Michigan State University have to recuse themselves from voting on this report.

Hobart liked the use of sidebars to explain technical details for the nontechnical reader.

Lapi said that it is readable and all the previous issues have been dealt with.

Nagle said that the Executive Summary could benefit from adding a budget chart. He questioned the effectiveness of including the last paragraph of the Executive Summary at that point.

Ormand said that the draft report was a good job; the Office did a good job in structuring the management of the program, also.

Piekarewicz said that it is a much better report and is now acceptable.

Rossi said that she fully approved of the program.

Scholberg agreed with the comments of the other Committee members. The recommendations are clear.

Shepherd thanked the Subcommittee for revising the report. He supported its content and recommendations.

Weischer declared that the report is very good on both the technical and managerial sides.

Hallman said that this report is an asset to the Office and to DOE, as well.

Geesaman noted that three additional changes have been requested: clarify the 15% comment, move a budget chart into the Executive Summary, and work on the last paragraph of the Executive Summary. With the understanding that these three issues would be successfully dealt with, he asked for a vote whether or not to accept the report. The vote was unanimously in favor by the members who did not recuse themselves. Geesaman committed to writing a letter of transmittal.

Nagle asked if a shortened version would be prepared. Geesaman said that he did not see that a shorter version was needed. Gillo agreed.

A break for lunch was declared at 11:30 a.m. The meeting was reconvened at 1:26 p.m.

Susan Seestrom was asked to report on the current status of implementing the goals of the National Nuclear Security Administration (NNSA) material management molybdenum-99 program.

The Subcommittee met in May 2015 with representatives from the NNSA, Organisation for Economic Co‑operation and Development (OECD), the NAS study group, both active cooperative-agreement partners, and one potential new partner. A session was devoted to input from the broad stakeholder community.

Technetium-99m, which is widely used for nuclear-medicine diagnostic imaging, is produced from molybdenum-99, all of which is produced by the fission of uranium-235. The U.S. Government would like to reduce the use of highly enriched uranium (HEU) and to shift to other sources for producing molybdenum-99. The medical community fears that this could lead to shortages of Mo-99 and/or a significant increase in price. This issue was addressed in the 2009 NAS study, but some supply-chain disruptions have occurred between 2005 and 2014. There is currently no U.S. supplier of molybdenum-99, leading to interest among potential molybdenum-99 producers. The current producers are Malinkrodt (the Netherlands), IRE (Belgium), NTP Radioisotopes (South Africa), CNL/Nordion (Canada), and ANSTO (Australia). The Canadian facility will halt operations in 2016 unless there is an emergency; whatever the case, it will shut down entirely in 2018; currently, it produces most of the molybdenum-99 in the world.

There are three paths to molybdenum-99 production: low-enriched-uranium (LEU) fission, neutron capture, and accelerators (γ,n).

NNSA currently has cooperative agreements with two partners: Northstar Medical Radioisotopes and SHINE Medical Technologies/Morgridge Institute for Research. Each cooperative agreement is awarded under a 50-50 cost-share arrangement, consistent with the American Medical Isotopes Production Act and Section 988 of the Energy Policy Act of 2005. The cooperative agreements are currently limited to $25 million each.

Full-cost recovery is the goal to put Mo-99 production on a level playing field internationally. Since 2014, the OECD has assessed progress toward full-cost recovery as “slow.” The Canadian Government has announced the possibility of providing molybdenum-99 during the period 2016 to 2018 if a worldwide shortage developed, although a trigger mechanism has not yet been defined.

NNSA has taken a leadership role in the interagency working group developing the uranium lease and take-back program. All partners and the trade association consider this program important. The projected dates of production from the active cooperative-agreement projects have incurred delays ranging from 1 to 2 years since the 2014 review because of slow FDA approval and the difficulty of raising funds, although the partners have made some significant progress. NNSA is evaluating a proposal from a third partner.

The Subcommittee’s general conclusions are:

- NNSA has worked diligently and proactively over the course of the program based on the specific requirements of the Act, especially considering the many complex factors outside NNSA’s direct control.

- NNSA is working with the international community to achieve full-cost recovery and thus a level playing field for new U.S. producers.
- NNSA is trying to accelerate the development of new domestic suppliers; funding seems to be an issue.
- The possibility of a shortage of molybdenum-99 between 2016 and 2018 has substantially increased since the prior review in 2014.

The OECD has estimated the supply of and demand for molybdenum-99 from 2014 to 2020. Increases postulated by that estimate indicate that a method could come online and not be competitive in 2020 because of the changes in the production landscape.

None of the partners met the original goal of producing 3000 6-day Curies by 2014. Only one partner anticipates producing any molybdenum-99 in 2016. Dates of anticipated molybdenum-99 production have slipped 1 to 2 years since the prior review. The existing partners have, nonetheless, made progress during the past year, with a number of important milestones met. The NNSA strategy does not appear to have been modified to take into account the delays being encountered by the partners or the slowness in moving forward full-cost recovery by the global community. The strategy also has not been modified to account for the possibility that the Canadian facility could serve as an emergency supplier in this timeframe. The uncertainty in defining the uranium leasing and take-back program remains an issue. Previously, the Subcommittee concluded that the strategy was reasonable but not complete because it did not address all possible risks in the program. These recent developments reinforce that conclusion. In some cases, the risk-mitigation actions have become increasingly responsive; but in some cases, the risk management could be enhanced.

In 2014, the Subcommittee recommended that NNSA should look carefully across the domestic production part of the molybdenum-99 program in view of present facts to focus resources on the most promising cooperative agreements. On the basis of the slowness of progress toward implementation of full-cost recovery internationally, NNSA should consider relaxing their present $25 million cap on investment in any project. This change could increase the likelihood of eliciting a successful domestic producer of molybdenum-99.

The NNSA program has paid attention to the 2014 assessment. Since the review, NNSA has stopped national laboratory work related to inactive cooperative-agreement projects. NNSA stated in this review that they have carefully considered the issue of increasing the $25 million limit or otherwise increasing funds available to partners; the options are still under consideration.

Because the production dates have been pushed back and progress toward full-cost recovery has been slow, the Subcommittee concludes that the NNSA actions in response to the 2014 report have been less than adequate.

The Subcommittee has four specific recommendations:

- DOE should increase funds available to individual cooperative agreement projects sufficiently enough to significantly accelerate their ability to rapidly establish domestic production by increasing the $25 million cap or by increasing the NNSA cost-share fraction during the R&D phase of projects. This would require the Secretary of Energy's approval.
- DOE must support NNSA in the continued efforts to advocate for the timely establishment of the uranium lease and take-back program. The publication of a draft of the model contract is an urgent need, and NNSA has taken very credible actions to move the interagency working group's program definition forward. However, high-level

agency engagement will be essential in reducing this risk by ensuring model contracts are finalized as soon as possible.

- NNSA should document a contingency plan to ensure a supply of molybdenum-99 from Canada within a few months if a significant shortage of molybdenum-99 appears imminent. This plan should include details on working within the U.S. Government and with Canadian producers/Government to address the definition of a trigger mechanism for molybdenum-99 production at the National Research Universal reactor and to ensure that valid import and export licenses for HEU are in place prior to the need for them. This contingency plan should be available by the next NSAC review.
- NNSA should develop a contingency plan to adapt the program should OECD and the Nuclear Energy Agency continue to determine that the global community is not making adequate progress toward full-cost recovery for domestic production to be economically feasible. This contingency plan should be available by the next NSAC meeting.

The Subcommittee added one member to gain expertise in radiopharmacology, and several members recused themselves because of conflicts of interest.

Nunes commented that the recommendations are crisp, and the justifications compelling. She asked what the Subcommittee did to come up with the $10 reimbursement per dose based on HEU-produced molybdenum-99. Seestrom replied that this is not an NNSA issue. The reimbursement is set by the Centers for Medicare and Medicaid Services (CMS); they set how these procedures are compensated for. This is for just a small percent of procedures done in the United States. The private insurers generally pay the full amount. They may not always do that, though.

Heeger asked if these recommendations were in a particular order. Seestrom said that they were. Heeger asked what could be done to ameliorate the short-term shortage. Seestrom replied that the only offer to make up the short-term shortage is Canada's. That is why NNSA should work with Canada to define a trigger and to work out procedures. Geesaman noted that, because that backstop is there, private companies may have difficulty raising capital. Seestrom answered that there is a window of opportunity during this short-term shortage to introduce new products and to carve out market share.

Rossi asked why NNSA has not raised the cap. Seestrom replied that the NNSA may not have raised the cap because companies that have raised the necessary capital do not want less-capitalized companies to become competitors.

Hardy pointed out that, in Recommendation 2, no risk is specified. Such a risk should be specified.

Fahey asked if the production data included the 2-year delay in bringing production back up. Seestrom said that it does for all methods of production for some modes of delay. It does not for some specific types of delays. Geesaman said that the risk of oversupply could drive some of the companies out of business. Seestrom responded that a Korean and a Polish project have not been included in the survey of sources. None of these have started reactor construction, yet.

Deshpande asked if there were an optimum cap. Seestrom answered that that question was put to NNSA; the answer was that there is not such a cap.

Hobart noted that the difficulty of separating molybdenum-99 from other fission products is not factored in. Seestrom stated that that was beyond the scope of the study. Geesaman added that the charge only refers to molybdenum-99.

Hardy noted that a glossary of acronyms would be helpful.

Nagle said that the Subcommittee needs to decide the priority of the different risks (e.g., the risk of increased deaths during a shortage versus the risk of a failure of a business because of oversupply). Seestrom replied that the Subcommittee wanted to recommend actions that were within the law and were doable. Lapi said that the Subcommittee drove home how important the diagnostic tests were. It could get numbers on that, but that is outside the scope of the study. There are alternative tests that may not be as effective. Fahey added that, in general, the people who get these tests are at a high risk of death. Nagle suggested that maybe the cost share is so marginal that it will not affect the outcome. One cannot tell. If one backs the Canadian extension of production, one undercuts the development of other sources.

Venugopalan suggested moving Recommendation 3 to number 1. He was concerned about the ordering of recommendations in respect to the timeline. If there is a catastrophic shortfall, there would be catastrophes; so any and all suppliers would be important. Seestrom said that there *is* urgency, and there are long-term needs. Venugopalan asked whether, if the report stresses the urgency of the short-term needs, that might prod on a domestic supplier? Geesaman commented that the Subcommittee discussed this issue because of the ambiguity in the Act about supply and production. One can argue that there is a window of opportunity, or one can argue that it offers a period to prepare for market entry in 2018 or 2020. That is why the Subcommittee emphasized the Canadian extension and the lease-and-take-back program.

Fahey said that a diversity of sources was desirable and pointed to the Icelandic volcano eruption in 2010 that halted air traffic in northern Europe for days, an occurrence that dramatically affects the shipment of a radioisotope that has a 3-day half-life. Seestrom pointed out that the Canadians have offered to step in for the short term and that the international situation is neutral on the financial aspects. That notwithstanding, the first recommendation is essential; the United States needs more than one domestic source.

Heeger said that the Executive Summary should stress that these recommendations are the best course of action but did not take into consideration all possible influences and settings. Seestrom offered that it is desirable to have a viable *domestic* producer. Hallman added that this puts the response to the charge in context.

Ormand was confused about the relaxation of the cap and stated that the argument for a cap is weak. He said that an example of why one would want to set a cap would be helpful. Seestrom agreed that the Subcommittee does need to strengthen that discussion. NNSA says that it would not be fair to change the rules midstream, and they do not have enough funding to give everybody the extra money.

Scholberg said that the tone of the report is uneven. It implies that the Subcommittee thinks that the NNSA has done a good job, but there are places that mention jarring failures. Seestrom agreed; the NNSA was doing all that they can do but are still not succeeding.

Geesaman asked each committee member to make a statement about the report.

Weischer said that this is a complicated issue.

Venugopalan said that this is a complex issue, and the Subcommittee has done a good job.

Shepherd said that the recommendations are crisp and target what is very important. He noted that it is difficult for a company to invest when it is competing with subsidized entities.

Scholberg said that the recommendations are clear and to the point.

Rossi liked the report.

Piekarewicz said that this has been a heroic effort, and he appreciated it.

Ormand said that the Subcommittee had done a good job. The report captures all the issues.

Nunes said that she supported the report.

Nagle said that a stronger statement on risk is needed, perhaps in a closing paragraph in Recommendation 1.

Lapi thanked Seestrom for her hard work, which is evident in the report.

Hobart noted that the report does not clearly articulate the magnitude of negative impact to the U.S. if there is a shortage in the production of molybdenum-99.

Heeger said that the Executive Summary should be able to stand alone.

Hardy pointed out that there is no other topic on which nuclear science interacts with the general population more than this one. The Committee needs to do this right; it has to be careful and neutral.

Fahey said that the report was well written. A couple of sentences on uncertainty are needed, however.

Deshpande said that this is a legible report; it needs an acronym glossary and a line or paragraph on the uncertainties of the program. Otherwise, he approved it.

Geesaman asked if asked if the Committee were ready to accept the report with the understanding that these changes and corrections would be made to the draft.

Piekarewicz moved that the Committee accept the report, subject to the changes discussed. Scholberg seconded. The motion passed unanimously with one abstention.

Geesaman opened the floor to public comment. There was none.

Geesaman opened a discussion on the progress on the Long-Range Plan. The long range plan working group resolution meeting was held at Kitty Hawk, North Carolina, on April 16–20, 2015. The text of the final version will be available in early August. Work on figures and other details will follow. The next NSAC meeting on October 15, 2015, will be where the Long-Range Plan will be rolled out. Starting in late August, work will begin on a short version of the report based on the Summary and Recommendations. This is not likely to be ready by the NSAC meeting.

Deshpande noted that most of the Committee members had contributed their "best figures." Geesaman said that he had all of those figures and will discuss them with the design team.

The floor was opened to public comment. **Leland Cogliani** of Lewis-Burke Associates and a former congressional staffer asked to address the Committee. He said that the congressional subcommittees believe that the NNSA molybdenum-99 program is on track. That is obviously not true. The relevant subcommittees should be updated on that program. There are many issues that are not progressing as planned. Congress believes there are no significant problems or barriers. Seestrom commented that some production is happening, but not the 3000 6-day curies per week that was planned. One entity will produce 600 6-day curies per week in 2016. Cogliani suggested that Congress be made aware of the long-range plan. A preliminary two-page summary would be very helpful in informing Congress.

There was no other public comment.

CLOSING REMARKS AND ADJOURNMENT

Geesaman adjourned the meeting at 3:09 p.m. EST.

The minutes of the U.S. Department of Energy and the National Science Foundation Nuclear Science Advisory Committee meeting, held at the Doubletree Hotel in Bethesda, Maryland on July 16, 2015, are certified to be an accurate representation of what occurred.

Donald Geesaman, Chair, Nuclear Science Advisory Committee