NUCLEAR SCIENCE ADVISORY COMMITTEE
to the
U.S. DEPARTMENT OF ENERGY AND
NATIONAL SCIENCE FOUNDATION

PUBLIC MEETING MINUTES

DoubleTree by Hilton Hotel
8120 Wisconsin Avenue, Northwest, Bethesda, MD 20814

April 24 and 25, 2014

NUCLEAR SCIENCE ADVISORY COMMITTEE
SUMMARY OF MEETING

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) meeting was convened at 9:00 a.m. EDT on Thursday, April 24, 2014, at the Doubletree Bethesda Hotel, Bethesda, MD, by NSAC Chair, Donald Geesaman.

Members present:

Donald Geesaman, Chair
Ani Aprahamian (2014 APS ex-Officio)
Robert Atcher (SNM ex officio)
Vincenzo Cirigliano
Paul Mantica (2014 ACS ex-Officio)
Jamie Nagle
Allena Opper
Jorge Piekarewicz
Patrizia Rossi
Kate Scholberg
Jurgen Schukraft
Matthew Shepherd

Members absent:

Erich Ormand
Raju Venugopalan

NSAC Designated Federal Officer:

Timothy J. Hallman, DOE Office of Science (SC), Associate Director of Science for Nuclear Physics

Others present for all or part of the meeting:

Cyrus Baktash, DOE SC, Office of Nuclear Physics
Gerald Blazey, OSTP
Ted Barnes, DOE SC, Office of Nuclear Physics
Elizabeth Bartosz, DTRA/TASC
Denise Caldwell, Physics Division, NSF
Julie Carruthers, DOE, SC
Rod Clark, Lawrence Berkeley National Laboratory
Corey Cohn, DOE, SC-2
Claire Cramer, OMB
David Dean, Oak Ridge National Laboratory
Patricia Dehmer, DOE SC, Deputy Director for Science Programs
Abhay Deshpande, Stony Brook University
Gail Dodge, NSF
James Dunlop, Brookhaven National Laboratory
Rolf Ent, Jefferson Lab
George Fai, DOE SC, Office of Nuclear Physics
Manouchehr Farkhondeh, DOE SC, Office of Nuclear Physics
Konrad Gelbke, NSCL/FRIB
Jehanne Gillo, DOE SC, Office of Nuclear Physics, Facilities and Project Management Division
Joel Grimm, DOE SC, Office of Nuclear Physics, DOE Isotope Program
Kawtar Hafidi, DOE SC, Office of Nuclear Physics

Dick Kouzes, Pacific Northwest National Laboratory
Suzanne Lapi, Washington University Saint Louis
Helmut Marsiske, DOE SC, Office of High Energy Physics
Robert McKeown, Jefferson Laboratory
Bogdan Mihaila, NSF
Hugh E. Montgomery, Thomas Jefferson National Accelerator Facility
Filomena Nunes, Michigan State University
Dennis Phillips, SC DOE, Office of Nuclear Physics, DOE Isotope Program
David Radford, Oak Ridge National Laboratory
Robert P. Redwine, Bates Linear Accelerator, Massachusetts Institute of Technology
Lee Schroeder, Berkeley Lab/Tech Source
Susan Seestrom, Los Alamos National Laboratory
Jim Sowinski, DOE SC, Office of Nuclear Physics
Stephanie Sparks, DOE SC-2
Parrish Staples, National Nuclear Security Administration, DOE
Alan Stone, DOE SC, Office of High Energy Physics
Thomas Ullrich, Brookhaven National Laboratory
Michael Wiescher, University of Notre Dame
Scott Wilburn, Los Alamos National Laboratory
Sherry Yennello, Texas A&M University

APRIL 24, 2014

OPENING REMARKS

The DOE/ NSF Nuclear Science Advisory Committee (NSAC) meeting was convened at 9:09 a.m. EDT, at the Double Tree by Hilton Hotel in Bethesda, Maryland, and accessible via webcast. The meeting was open to the public and conducted in accordance with the requirements of the Federal Advisory Committee Act.

NSAC Chair Donald Geesaman remarked that the committee membership was smaller than normal due to the annual cycle of appointing new members. He invited committee and audience members to introduce themselves. He then announced that the order for some of the presentations had been changed, and that the first talk would be the DOE Office of Nuclear Physics (NP) overview.

DOE OFFICE OF NUCLEAR PHYSICS OVERVIEW

Dr. Timothy J. Hallman, Associate Director of Science for Nuclear Physics (NP) at SC, said the talk would focus on the Fiscal Year 2015 (FY15) President's Budget and exclude science updates due to time restrictions. The NP mission is discovering, exploring, and understanding all forms of nuclear matter. Key scientific challenges include:

- The existence and properties of nuclear matter under extreme conditions, including that which existed at the beginning of the universe
- The exotic and excited bound states of quarks and gluons, including new tests of the Standard Model

- The ultimate limits of existence of bound systems of protons and neutrons
- Nuclear processes that power stars and supernovae, and synthesize the elements
- The nature and fundamental properties of neutrons and the neutrino and their role in the evolution of the early universe

Hallman discussed highlights of the FY15 NP Budget Request. Research at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory capitalizes on increased luminosity and new micro-vertex detectors to probe the properties of the perfect Quark-Gluon liquid using charm and bottom quarks. Construction continues for the Facility for Rare Isotope Beams to study nuclear structure and nuclear astrophysics. At Thomas Jefferson Laboratory, the 12 GeV (gigaelectronvolt) Continuous Electron Beam Accelerator Facility (CEBAF) upgrade to study the quark structure of nucleons and nuclei achieved CD-4A, Accelerator Project Completion. ATLAS beams using the Californium Rare Isotope Breeder (CARIBU) advanced the understanding of nuclear structure and the origin of the elements in the cosmos. NP will continue to support research, development, and production of stable and radioactive isotopes important for science, medicine, industry, and national security. Research dollars will decrease, relative to FY14.

In 2015, the budget request for SC is up by 0.9 percent, while the NP budget increases by 4.3 percent, from $569M enacted in FY14 to $594M in the FY15 request. Relative to the 2013 NP appropriation of $507M, the FY15 request is significantly higher. 2013 was a "down-turn year," and the increase in 2014 included construction of a facility for the study of rare isotope beams. The budget for NP subprograms has increased since FY10 but not as much was anticipated at the time the 2007 long-range plan was developed. Construction funding for the Facility for Rare Isotope Beams (FRIB) is strong, but the other NP funding lines (facility operations and research) are basically flat. Major items of equipment (MIE) expenditures are disappearing completely in 2014. NP has achieved much of what was envisioned in the last long-range plan. However, the budget is highly constrained, and that is a reality to be faced as SC considers funding over the next five or ten years.

Research at the Jefferson Lab touches many areas of the nuclear physics program. The 12 GeV CEBAF upgrade at the lab is 87 percent complete. The project was re-baselined in September 2013 with a total project cost of $338M and completion in September 2017. Researchers will search for exotic new quark anti-quark particles to advance our understanding of the strong force and for evidence of new physics from sensitive searches for violations of nature's fundamental symmetries. The upgrade will also enable a detailed, microscopic understanding of the internal structure of the proton, including the origin of its spin and how this structure is modified when the proton is inside a nucleus.

Looking more closely at the Medium Energy budget for FY15, the research line appears to be down by $857,000. In the 2014 appropriation, SC was mandated by Congress to provide full funding of grants less than $1M. The full funding change affected the program in 2014. In 2015, the impact of that mandate will decrease from $10M to $6M. So, the negative research trend lines for NP subprograms are artifacts of the fact that the upfront, full-funding burden is decreasing from FY14 to FY15. In reality, funding for research is flat.

In the area of medium energy, the TJNAF request of about $96M will support 45 operations staff full-time equivalents (FTEs) transitioning from the 12 GeV upgrade project back to the base operations budget as the project ramps down. The needed funding for operations has been partially offset by redirecting funds from other activities such as equipment, accelerator improvement project (AIP) and general plant projects (GPPs).

At the Relativistic Heavy Ion Collider (RHIC), scientific discovery continues. RHIC discovered a completely new state of matter—a perfect quark-gluon liquid. The RHIC science campaigns planned in the next three to five years will (1) determine, with precision, the properties of this perfect liquid; (2) search for new discoveries such as the postulated Critical Point in the phase diagram of quantum chromodynamics (QCD); (3) explore the gluon and sea quark contributions to the spin of the proton using RHIC, the only collider with polarized beams; and (4) explore and develop intellectual connections and broader impacts to other subfields.

One example of progress at RHIC is the STAR Heavy Flavor Tracker, a tool to probe the structure of quark-gluon plasma with heavy quarks, which serve as sensors of the internal forces that govern the structure of the "perfect" liquid QGP, and will map the phase diagram to determine where the quark-gluon liquid cools into a gas of elementary particles and search for a critical endpoint. RHIC is the only accelerator in the world capable of such work due to its flexibility, i.e., energy range.

The Heavy Ion budget request for FY15 also appears to be down for the same reasons (full, up-front funding). The focus is on the collection and analysis of RHIC data using newly completed scientific instrumentation to better understand the initial conditions in heavy ion collisions as well as participation in experiments at the LHC. The RHIC Operations budget is maintained at the FY14 level, about $165M, which supports 2,770 beam hours (approximately 22 weeks and 68 percent utilization). Funds for experimental equipment, accelerator R&D, and materials and supplies are reduced in FY15 in order to optimize instrument running levels.

ATLAS at Argonne National Laboratory (ANL) uniquely provides low energy research opportunities in nuclear structure and nuclear astrophysics. The Facility for Rare Isotope Beams, FRIB, is a future facility under construction. The March 17 groundbreaking was exciting and included the participation of two senators and a couple of representatives from Michigan. The total project cost for FRIB is $730M, of which $635.5M will be provided by DOE and $94.5M will be provided by Michigan State University. The project completion date is June 30, 2022. Start of civil construction was authorized January 22, 2014. Excavation activities began in late February 2014.

NP is also the steward for the study of neutrino-less double beta decay. With techniques that use nuclear isotopes inside cryostats, often made of ultra-clean materials, scientists are "tooling up" to study whether neutrinos are their own anti-particle. NSAC has been charged to identify the criteria for a next generation double beta decay experiment. The "down-select" process has begun on research efforts to demonstrate feasibility. The work pace has been challenging, but has resulted in significant progress towards demonstrating feasibility. The instrument will be underground to decrease background in measurements.

In low-energy NP, research funds appear to be down due to the same artifact as discussed previously. The focus is on nuclear structure and nuclear astrophysics research

at ATLAS, preparation for FRIB, commissioning of the Majorana Demonstrator, the neutron program at the Fundamental Neutron Physics Beamline (FNPB) at Oak Ridge, completion of fabrication of the Cryogenic Underground Observatory for Rare Events (CUORE) in Italy, upport for the Gamma-Ray Energy Tracking Array (GRETINA) and the KATRIN experiment. Operations at the ATLAS national user facility are optimized at 5,900 hours of research beam time (95 percent of optimal operations). Funding will be maintained for operations of the 88-inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL), which is funded jointly with the U.S. Air Force and the National Reconnaissance Office; and for continued equipment disposition at the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL.

Nuclear Theory underpins everything in our science. Theory poses scientific questions that lead to the construction of facilities. It helps make the case for and guide the design of new facilities, their research programs, and their strategic operations plans. It provides a framework for understanding measurements made at facilities. Topical collaborations (fixed-term, multi-institution collaborations established to investigate a specific topic) have been successful and, resources permitting, the model will be continued. Regarding the budget reductions to NP research: Theory will feel the greatest impact, as most of the grants are less than $1M. Funding for the Nuclear Data program will increase in order to address a critical staffing issue.

The DOE isotope program mission is threefold. First: it is to produce and/ or distribute radioactive and stable isotopes that are in short supply, associated byproducts, surplus materials and related isotope services. Second: it is to maintain the infrastructure required to produce and supply isotope products and related services. Third: it is to conduct research and development (R&D) on new and improved isotope production and processing techniques, which can make available new isotopes for research and applications. There has been a lot of progress in this program since it came over in 2009 from the Office of Nuclear Energy (NE) to the Office of Nuclear Physics. When the program was within NE, there was not a research component. It was re-organized within NP. All of the recommendations from the first NSACI Subcommittee have been addressed. The Isotope Program has been a very successful program so far. NP is going back to the community for guidance in developing a new strategic as a dedicated NSAC exercise. Some of the recent activities in the Isotope Program include (1) increased portfolio of isotope production sites; (2) increased availability of research isotopes and more affordable; (3) introduction of peer review into mode of operations; and (4) improved communication with stakeholders, federal agencies, industry, and the research community.

Alpha particles are energetic enough to destroy cancer cells but are unlikely to move beyond a tightly controlled target region and destroy healthy cells. Alpha particles are stopped by a layer of skin—or even an inch or two of air. Previously, the only way to get isotopes like ^{225}Ac was to harvest them from natural decays. Because of the isotope research program, and a breakthrough last year, LANL (Los Alamos), BNL (Brookhaven), and ORNL (Oak Ridge) will be able to produce as much ^{225}Ac in a few-days' runs as used to be produced, world-wide, in a year. This is a tremendous success story and direct consequence of the Isotope Program. Overall funding for this research is flat.

For Construction, the FY15 budget is up a net $26M, from $80.5M in FY14 to $106.5M in FY15. A decrease of $9M is due to the re-baselined profile for the 12 GeV CEBAF upgrade at TJNAF, approved in September 2013. An increase of $35M supports the baseline profile for the Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU), approved in August 2013.

Recent NP program activities include the following. To maintain a high-impact, competitive research portfolio, NP conducted a comparative review of research efforts at laboratories and universities. Five sequential international panel reviews were held in May and June 2013 for: Nuclear Structure/Nuclear Astrophysics; Heavy Ions; Medium Energy; Nuclear Theory; and Fundamental Symmetries. Panel grades and comments were returned to principal investigators (PIs). An action plan was developed to terminate ~20 percent of the lowest-ranking competitive awards, to re-compete those resources, and also to address some impacts of congressional direction on the full funding of grants. There will be one additional competitive round for proposals received up to May 1, 2014.

The NSAC is currently preparing responses to three charges from SC:

1. To provide guidance on an effective strategy for implementing a possible second generation U.S. experiment on neutrino-less double beta decay (NLDBD) capable of reaching the sensitivity necessary to determine whether the nature of the neutrino is Majorana or Dirac. The NSAC intends to get a report out on this item following the April 2014 meeting.
2. To form a Subcommittee to assess the effectiveness of the National Nuclear Security Administration-Global Threat Reduction Initiative's Domestic Molybdenum-99 (^{99}Mo) Program, in accordance with direction given to the DOE in the National Defense Authorization Act for FY 2013. The NSAC intends to get a report out on this item following the April 2014 meeting.
3. To form a subpanel to examine potential gaps in training and workforce critical to the NP/SC mission.

Upcoming charges to NSAC are:

1. To form a new subpanel to conduct a new study of the opportunities and priorities for isotope research and production resulting in a long range strategic plan for the DOE Isotope Program.
2. To conduct a new Long Range Plan exercise to study the opportunities and priorities for U.S. nuclear physics research and recommend a long range plan that will provide a framework for coordinated advancement of the nation's nuclear science research programs over the next decade. This charge is a very important, very serious, and is an intensive exercise.

Hallman presented a number of items of NP news and events. There was a successful Office of Project Assessment (OPA) review of the 12 GeV CEBAF upgrade from April 8-10, 2014. The project is continuing well, but needs to maintain cost and schedule vigilance per the new baseline. NP is already beginning to formulate the FY16 budget. Regarding NP program office staffing: they have selected a candidate to be the Instrumentation Program Manager. There was some strategic restructuring of the "day-to-day" operation of the Isotope Program; Marc Garland will work directly with NIDC Management; this represents a move to address the complexity of that program. The SC

Director nomination is still awaiting confirmation. SC is transitioning rapidly to PAMS, the electronic program management system intended to improve efficiency and financial tracking practices. A RHIC operations review was conducted by the SC Office of Project Assessment (Lehman review). The main conclusion was that RHIC operations are appropriately-sized, high quality, and cost effective. Additionally, an NSAC implementation exercise revisited the 2007 Long Range Plan (LRP) for a constrained fiscal outlook; and, the NP Isotope Program held its second workshop on isotope federal supply and demand.

NP will conduct a competitive review of all new proposals responding to the Office of Science (SC) annual Funding Opportunity Announcement (FOA) received until May 1, 2014. The review will take place in the June-July 2014 timeframe in order to inform FY15 NP Research Division awards, subject to the availability of funds. Applications received during the period of May 2 – September 30, 2014, may not receive consideration for funding until FY16. The planned competitive review will address topics and proposed activities within the portfolio of the NP Physics Research Division. Research efforts that are not included in this review are the Accelerator R&D Program, the Isotope Program, the Nuclear Data Program, the NP SciDAC Program, Topical Collaborations in Nuclear Theory, and international collaboration awards.

The future of nuclear science in the U.S. continues to be rich with science opportunities. For the long term, an electron-ion collider may be the optimum path toward new opportunities in QCD research. The U.S. continues to provide resources for and to expect U.S. world leadership in discovery science illuminating the properties of nuclear matter in all of its manifestations. It will resource the tools necessary for scientific and technical advances which will lead to new knowledge, new competencies, and groundbreaking innovation and applications. Nuclear Science will continue to be an important part of the U.S. science investment strategy to create new knowledge and technology innovation supporting U.S. security and competitiveness.

Discussion of NP Overview

Donald Geesaman asked a question about slide 28, on the Construction budget. The FY15 request for construction for the 12 GeV CEBAF upgrade was cited at $16.5M. Farther down on the slide, the dollar amount is quoted as $21M. A box on the slide points to the $9M decrease from FY14 to FY15 and notes that the FY15 funding line supports the re-baselined profile for the 12 GeV CEBAF upgrade at TJNAF.

Timothy Hallman answered that the $16.5M was for the 12 GeV CEBAF upgrade construction cost, and the $21M cited elsewhere on the slide for FY15 reflected the total project cost.

Robert Redwine asked for more details on the comparative review.

Hallman said that as a result of the comparative review, 80 percent of most competitive grants will continue as normal, with a mail review and three reviewers as had always been done. Funding for the lowest-scoring 20 percent of grants will phase out. Some of those recipients can re-apply. The competitive review, open until May 1, 2014, is different from the comparative review in that it is open to the most exciting proposals. All the others will undergo mail review, as per normal, with three reviewers.

Comparative & competitive reviews are healthy for the field but are not done every year, maybe once a decade.

Geesaman followed up by asking about DOE national lab programs in other areas.

Hallman said the quadrennial research reviews at the labs would continue. Heavy ions will be first.

Jurgen Schukraft asked whether the new review will be across regions in NP, and might its results change funding levels between subprograms.

Hallman answered that the competitive rankings would occur within the subprograms; that subprograms would not compete against one another. However, if we receive a stellar proposal, and the NP program will be better served by supporting it, we would consider that. Overall, though, the review will result in competition for resources within, not across, subprograms.

Paul Mantica asked for more information about the impact of the full, upfront funding mandate.

Hallman said there would be adjustment of the terms of some awards for minimal effect. He also indicated the impact of the full, upfront funding mandate will decrease with time.

Filomena Nunes from the audience asked whether Hallman could share any details about the FY16 budget, where the field is headed for the future.

Hallman said, "no."

NSF MATHEMATICAL AND PHYSICAL SCIENCES UPDATE

F. Fleming Crim, Assistant Director of the NSF Directorate for Mathematical and Physical Sciences (MPS), next provided an update on MPS. He was pleased to announce that Dr. France Cordova was sworn in as NSF Director on April 2. In other exciting news, the DOE Facility for Rare Isotope Beams (FRIB) groundbreaking had occurred. NSF is committed to a smooth transition from the National Superconducting Cyclotron Laboratory (NSCL), at MSU, to FRIB. Two Senators and four Representatives attended the groundbreaking; MSU has been a very strong partner in this effort.

NSF funding since 1970 has been essentially flat with a few increases. The peak in 2009 is due to the American Recovery and Reinvestment Act (ARRA) funding. In constant 2012 dollars, from 1999-2004, there was real growth in the NSF budget. One can see long periods of constant funding punctuated by periods of real growth. While the community should think about near-term funding (being flat), out somewhere in the future, there will likely again be real growth in the budget for science. The community should consider how we would invest it. Such growth may depend on how good we are at telling our stories.

The total NSF budget request for FY15 is 1.2 percent greater than the FY14 enacted appropriation. Research and related activities funding lines are flat. The $80M increase was for the graduate research fellowship program. Also, because the General Services Administration (GSA) has acquired a new place for NSF to live—NSF will

move to Alexandria in a few years—there will be an increase in the budget to allow for that move.

The NSF Directorate for Mathematical and Physical Sciences (MPS) contains the following subprograms: Astronomical Sciences (AST), Chemistry (CHE), Materials Research (DMR), Mathematical Sciences (MS), and Physics (PHY). The overall MPS budget was down, from $1.3B in FY12 to $1.25B in FY13. All subprograms saw budget decreases from FY12 to FY13. The MPS budget increased by four percent between FY13 and FY14. And between FY14 and FY15 (request), the MPS budget is down 0.3 percent. This latest request may be a better predictor of what funding will be for FY15 because of the two-year budget agreement.

Major NSF physics investments are really in individual investigator and small group research programs. However, the slide "MPS Major Investments" indicates the larger budget line items. $20M is budgeted for SEES: Science, Engineering, and Education for Sustainability. Designing Materials to Revolutionize and Engineer our Future (DMREF) includes the Materials Genome Initiative and represents the interface of biological and mathematical sciences. BioMaPS and CNS (Cognitive Science and Neuroscience) participate in the President's Brain Initiative. Computational and data-enabled science and engineering are within CIF21. FY15 shows DMREF and CIF21 apparently decreasing, but NSF expects to put as much money as it already has because it has received strong proposals in those areas. We tried to provide as much flexibility as possible, so the subprogram funding levels shown really represent a "floor." We lowered the floor for DMREF and CIF21, but cross-cutting initiatives often have components that align with the heart of what we are trying to do, and we try to fund those initiatives.

The "Midscale" investment line is defined as projects from $4M (for projects exceeding the major research instrumentation funding threshold) up to $40M. A lot of scientific opportunity exists in that window, but there is a funding mechanism hole. Astronomy and physics began midscale efforts in 2014. In 2015: materials innovations platforms (i.e., materials research) will invest at a midscale level. MPS is trying to be more systematic and eventually grow midscale efforts.

About 5.8 percent of the MPS budget is tied up in NSF-wide initiatives. These include Cognitive Science and Neuroscience, Cyber-Enabled Materials, Manufacturing, and Smart Systems, Cyberinfrastructure Framework for the 21st Century, Science, Engineering, and Education for Sustainability, and Secure and Trustworthy Cyberspace. These cost $75.6M, or 5.8 percent of the MPS budget. In F14, that was 7 percent. NSF is trying to provide flexibility to individual budgets.

Crim discussed a few issues and community priorities, such as the conversion from NSCL to FRIB. He expressed pleasure at the progress of that transition. The midscale instrumentation effort has been driven by input from the community. Community priorities are important for NSF to understand intellectual themes as programs are shaped.

One example is in accelerator science. NSF has begun an accelerator science program on the order of a midscale-funded project. This as another place where there are big opportunities and where NSF needs to be supporting fundamental science. NSF wants to support the science that allows transformative activities in accelerator science.

Long range planning activities are critical to NSF. Input from the community, particularly efforts that establish priorities, is very important. The future of the isotope program is important.

Discussion of the NSF Mathematical and Physical Sciences Update

Geesaman asked for guidance on long range planning. We don't want to do anything to jeopardize transition-of-efforts, but on a time scale of ten years, we want there to be new, NSF-supported initiatives that follow directions we try to set in the long-range plans. We want advice: what is the feeling on joint initiatives with DOE, such as the Large Hadron Collider (LHC), neutrino experiments, instrumentation for RHIC, or for FRIB? What are the ways we can encourage or target NSF investments in new initiatives without damaging a smooth transition of effort?

Crim said NSF is committed to smooth transitions for joint initiatives. Thinking about partnerships is something he hopes the planning committee will consider carefully. Embrace them. He noted that NSF wants to make a unique contribution in those partnerships, rather than simply "topping off" a partnership with funding. The strongest partnership has a distinct science component for both agencies. For example, DOE is a smaller partner for the Large Synoptic Survey Telescope (LSST) camera, at $160M. NSF is building the telescope itself (along with private funding), at $430M. Aspects of dark energy science are important to DOE because support of that area moves the agency toward a science objective. Similarly, NSF wants its money to move a project toward a defined science objective. At LHC, we are funding LHC-B. We fund individual investigator grants, individual detectors, but we want to really own something and have a defined scientific contribution.

Schukraft asked was the $430M the total for the telescope, or just the NSF part? And can mid-scale projects be jointly funded by DOE?

Crim said we have really thought of these mid-scale initiatives as NSF projects, but that doesn't mean we would rule out DOE participation.

Denise Caldwell said for mid-scale projects, we handle those proposals the same way as for any project that we support together with DOE. We are really interested in a specific science question. If the proposal warrants it, and there is justification for doing it together, we would do that for mid-scale as well.

Crim said it is not something we have baked into the midscale program either, but it is not forbidden.

Ani Aprahamian asked if NSF physics funding looked lower than in the recent past.

Crim said the mathematicians took a bigger hit than the physicists. Physics recovered better than mathematics, but they took almost the same hit as NSF mathematics. Sequestration moved us from the baseline: when we dealt with sequestration, we had constraints to maintain facilities and ongoing program commitments. We maintained those commitments for cross-cutting initiatives. It might have been seven or eight percent of our budget; that is the margin. So if physics wasn't playing as heavily in cross-cutting programs as other science disciplines, they were disproportionately hurt. Crim came to NSF in 2012 and sees that as his baseline, but looking further historically, such as ten years ago, physics had a disproportionate

increase. There are differing perspectives as to what is our "baseline." There is no hidden message about a slight on physics.

Geesaman invited the audience to ask questions. No one had a question. The discussion concluded at 10:24 a.m.

NSF NUCLEAR PHYSICS OVERVIEW

Gail Dodge, Director of the NSF Experimental Nuclear Physics program, began by saying that the NSF Research and Related Activities (R&RA) funding line was flat from FY14 to FY15 (request). The NSF Physics (PHY) division FY15 request is down by $2.6M, a 1 percent decrease: essentially flat relative to FY14. Detailing the FY15 PHY funding request, she said that the Research account is where we have our programs. Although physics is flat, we are down in Research by $6M, or 4 percent. The Research Resources account is where mid-scale and accelerator science is increased. The sum of those two reflects money available in NSF physics for research programs. The National Superconducting Cyclotron Laboratory (NSCL), at Michigan State University (MSU), saw funding increases from $21.5M in FY12 and FY13 to $22.5M in FY14 and FY15.

The total for Research and Research Resources was down in FY13 (to $172M, from $198M in FY12) but up in FY14 ($179M), and flat for FY15 ($174M). Funding for programs like nuclear physics is expected to be roughly flat. NSF is committed to mid-scale support and wants to see that effort grow, even in a flat budget. Mid-scale support will be a priority going forward.

Dodge discussed Nuclear Physics subprograms, noting they do not include particle astrophysics. From FY09-13, one can see some small shifts, but overall, the program is funded at $19.9M in FY13 (this includes Theory). The Physics Division is projecting flat funding in the future. Program officers are trying their best to manage the Nuclear Physics program with the long-term view in mind, to protect it as much as they can. They try to make sure they do not put undue pressure on future-years' support. The Major Research Instrumentation (MRI) program has been very good for nuclear physics. In the last two years, nuclear physics has managed to get big chunks of money from the MRI program.

Covering personnel matters: France Cordova was sworn in as the NSF Director on April 2, 2014. Fleming Crim is the Associate Director for MPS. Denise Caldwell is the Physics Division Director. Brad Keister is Deputy Division Director. Bogdan Mihaila is now a permanent staff member with responsibility for the Nuclear Theory program. Jim Whitmore and Jean Cottam serve as particle astrophysics program officers. Gail Dodge is the nuclear experiment program officer; she will return to Old Dominion University in August. Alice Mignerey is serving as a part-time nuclear experiment program officer.

NSF is seeking to fill two personnel positions in the area of experimental nuclear physics. A permanent (or visiting scientist, engineer, or educator [VSEE]) position closes May 6, 2014; and a rotator position (Intergovernmental Personnel Act [IPA] assignee) is sought in this area. Dodge or Caldwell would be happy to speak with anyone interested in the jobs.

For accelerator science: the Physics Division is accepting proposals to a new program in accelerator science. Proposals have been received for consideration in FY14.

There has been a robust response to this new program. National labs can be involved, as collaborators, but the idea is to fund university groups, like the nuclear experiment program. The program description is posted (13-7243).

In the area of mid-scale instrumentation: three divisions are planning to start mid-scale programs. The Physics Division has established a mid-scale instrumentation fund. The intention is to fund projects above $4M (the MRI limit). This funding is not available for "operations," so program funds will have to be used to run the experiment. Investigators cannot apply to the mid-scale program directly; all proposals must go through the nuclear physics program or other subprograms. A priority of the division (and the directorate) is to increase the resources available for mid-scale instrumentation. For example, a $5M proposal would be submitted through the regular route: one doesn't apply directly to mid-scale, but the project would be handled as appropriate for its size. It would be wise to call NSF to inform staff of plans and get feedback before submitting such a proposal.

NRT, the NSF Research Traineeship Program, replaced the Integrative Graduate Education and Research Traineeship (IGERT) program. It is intended to fund areas where there needs to be improvement in graduate education. Awards are $3M over five years, and support needs to be sustainable, so that the university would pick up support into the future. It is an innovative way to approach graduate education in an area. The program is designed to encourage the development of bold, new, potentially transformative, and scalable models for STEM graduate training that ensure that graduate students develop the skills, knowledge, and competencies needed to pursue a range of STEM careers. A priority research theme is data-enabled science and engineering, although proposals are encouraged on any other crosscutting, interdisciplinary theme. Letters of Intent (optional) are due May 20, 2014, and full proposals are due June 24, 2014.

Bogdan Mihaila is our program officer in computational physics (Physics and the Information Frontier).

The Physics Frontiers Centers (PFC) program supports university-based centers and institutes where the collective efforts of a larger group of individuals can enable transformational advances in the most promising research areas. JINA, the Joint Institute for Nuclear Astrophysics, is an existing PFC. The Frontier Center competition is now entering its final stages. Reverse site visits will be in May. The rationale for these centers is that the whole is greater than the sum of the parts.

Discussion of the NSF Nuclear Physics Overview

Patrizia Rossi asked about application rules for the accelerator science program.

Crim said the program was aimed to primarily support university professors. Anticipated proposals might request support for a postdoctoral fellow or graduate student. National lab personnel could apply as collaborators. This particular program should not be something to which only DOE national lab staff apply; it is intended to seed university science.

Rossi asked what is the difference between this and the R&D for accelerators program.

Crim answered that NSF does not have an accelerator R&D program. The NSF program is to support fundamental science in the area of accelerators.

Schukraft asked about flat funding, and the ups and downs, and whether the fluctuations reflected competition between overall priorities?

Crim answered that yes, the funding increases and decreases reflected NSF priorities as a whole.

Someone from the audience asked whether the strong grant application response came from certain scientific areas, or was it strong across a broad spectrum of topics.

Dodge said in terms of subfields in accelerator science: NSF had received a broad spectrum of proposals. The response reflected a strong need in community for this kind of funding

DOE OFFICE OF SCIENCE UPDATE

Dr. Patricia Dehmer announced that Professor Marc Kastner, Dean of Massachusetts Institute of Technology's School of Science and Donner Professor of Physics, has been nominated for SC-1 and was awaiting Senate confirmation. Professor Franklin "Lynn" Orr, a director of the Precourt Institute for Energy at Stanford University, had been nominated for S-4.

Regarding the SC FY15 budget request, the Nuclear Physics program is up 4.3 percent from the FY14 enacted appropriate level. The overall increase for DOE SC is 0.9 percent. Clean energy was a priority. The NP community should be extremely happy with the 4.3 percent increase, as that level of funding will allow NP to go forward with construction and complete ongoing activities.

SC made investments in research, facility operations, and construction. In the area of research, funding was increased in three areas, all related to high performance computing and modeling and simulation. There also was increased support for exascale (through the early 2020s) and data intensive science. Basic Energy Sciences (BES) saw a $25M increase for computational materials sciences. Of all computer codes at the National Energy Research Scientific Computing Center (NERSC), virtually all codes have U.S origins except, ironically, for the two main codes used for materials science; both come from Europe. This effort was paired with increases for high performance computing. The total is $24M, including for BES. $30M will go for biological research. Support for advanced climate modeling is driving toward a 10-kilometer resolution capability. High performance computing and modeling/ simulation got increases. All other research budget lines were flat, relative to 2014.

Within the SC budget for construction: several large projects are nearing successful completion, on time and within budget; new projects are initiated to address science and infrastructure needs. For NP, the 12 GeV CEBAF upgrade is nearing completion. Activities at Jefferson Lab focus on beam development and commissioning of the new machine. The Facility for Rare Isotope Beams is in early civil and technical construction.

More specifically for facility operations: most of the scientific user facilities are operating at or near optimal levels—including the Leadership Computing Facilities (LCFs) and the light sources that together host more than half of all users at the facilities. In the area of advanced scientific computing, NERSC and the Leadership Computing

Facilities at ANL and ORNL are operating optimally. NERSC will move to the Computational Research and Theory Building at LBNL. Funds for the LCFs support the preparation of planned 75-200 petaflop upgrades in the FY 2017-2018 timeframe. For Basic Energy Sciences (BES) facilities: four light sources, two neutron scattering sources, and five nanoscale science research centers are operating optimally. The National Synchrotron Light Source II (NSLS-II) transitions to operations, and NSLS-I ceases operation. With the Spallation Neutron Source (SNS) operating at full power and nearly fully instrumented, operations at the Lujan Neutron Scattering Center will cease. An SC goal is to make sure existing facilities operate well.

The distribution of users at the approximately 30 SC facilities has changed from 2007-2013. **Dehmer** had prepared a chart for a facility priority goal exercise indicating that in 2013, there were approximately 28,000 users of SC facilities. In 2013, about three-fourths of users went to BES and computing facilities. Light sources showed significant growth between 2007 and 2013. High-energy physics saw few users in the U.S. because of the closure of the B Factory (SLAC) and the Tevatron (FNAL). Some facilities are in upgrade mode; SC wants to make sure those facilities operate well.

In the area of construction: several large projects are nearing successful completion, on time and within budget. New projects are initiated to address science and infrastructure needs. In BES: the NSLS-II is transitioning from early operations to full operations; construction funding ended in FY14. The planned CD-4 date is June 2015. The Linac Coherent Light Source II (LCLS-II) is in its second year of construction. ITER (International Thermonuclear Experimental Reactor) is funded at a slightly lesser level than in 2014, due to construction issues. Funding supports continuation of in-kind hardware, cash contributions to the international organization, and the USIPO (the U.S. ITER Project Office). For high energy physics construction: the Long Baseline Neutrino Experiment continues R&D and is waiting for results of the P5 (Particle Physics Project Prioritization Panel) report before the administration will put significant funding toward it. In nuclear physics, the 12 GeV CEBAF upgrade is nearing completion and FRIB is starting construction.

As part of a priority- and goal-setting exercise, **Dehmer** said that she had presented to the Secretary of Energy's Advisory Board (SEAB). There was a misconception that DOE builds facilities and never closes facilities. One of Dehmer's charts depicts a summary of new starts and terminated facilities that she said surprised people inside and outside SC. In BES, most light sources and other construction have been priority investments over the years. Users were not going to the Tevatron to do work. Therefore, BES closures tended to be neutron facilities. The Advanced Neutron Source closed before construction, after $1B was spent on the design. All new construction, going forward, should be based on strong community input and support from SC advisory committees such as the NSAC. All had intensive community workshops, sometimes from the National Academy of Sciences. We convinced the SEAB that SC is thoughtful about construction.

A historical chart showed the relative percentage of funds for each office in SC over the years. Growth of computing, BES, and BER now consume more than 60 percent of major SC program funds. Fusion, large in the 1970s and '80s, is a hold-over of the push for the peaceful use of atomic energy. Nuclear physics has stabilized due to strategic planning and thoughtful recommendations from the community. High energy

physics funding is flat due to a failure to deliver a plan on the future of science in that area.

Going back to a 2003 presentation called, "Facilities for the Future of Science: a 20-Year Outlook," **Dehmer** explained that the effort was requested by then-DOE director Ray Orbach. Since we are halfway through the 20-year period considered in the 2003 analysis, Dehmer decided to review SC's progress. She described the recent exercise in which SC considered upgrades to or construction of facilities. Many (30) facilities were evaluated as part of that exercise.

Dehmer then moved on to discuss the workforce development charge to the six SC advisory committees. The Administration consolidated a lot of fellowships and other education programs in the FY14 budget request. DOE has mission-specific workforce needs in STEM fields. The DOE laboratories are a unique resource for training in STEM R&D. STEM workforce development activities in SC should include: (1) an evidence-based statement of the workforce need; (2) a statement of program goals; (3) a diverse applicant pool and unbiased selection; and (4) tracking of outcomes and evaluation of success. SC should consider consolidating electronic applications, data collection, and tracking activity in a single place to achieve efficiency.

Dehmer asked the six federal advisory committees provide "evidence based statements of workforce need." She asked the NSAC to consider:

- Disciplines not well represented in academic curricula;
- Disciplines in high demand, nationally and/or internationally, resulting in difficulties in recruiting and retaining people at U.S. universities and at the DOE national labs;
- Disciplines identified in the previous two bullets for which the DOE national labs may play a role in providing needed workforce development; and
- Specific recommendations for programs at the graduate student or postdoc levels that can address discipline-specific workforce development needs.

She requested that the NSAC submit a letter describing its findings no later than June 30, 2014. The results would guide future activities and investments.

NSAC Discussion of DOE Office of Science Update

Geesaman referenced a 2012 National Academies study regarding nuclear chemistry and asked if that would be appropriate to feed into the response to the charge.

Dehmer answered that it could be used, but she didn't think analysis was done on specific programs. SC would need evidence.

Geesaman said one of the real challenges is the short time scale: it makes it challenging to have compelling, documented evidence.

Dehmer said she deliberately gave a short response time because the committees are already burdened with charges and reports. She recommended the formation of a subcommittee of the whole to provide the report. The task was not intended to be a book report.

Geesaman pressed by saying it was a challenge that the NSAC members, as experts, could provide a perspective, but an evidence-based response was a high standard.

Dehmer said her hunch was that a few things would bubble to the surface. It is straightforward to poll the DOE national labs or current facilities and ask what is the

situation. She said that she knew the labs poach from each other all the time, and Europe poaches from the U.S.. She is looking for a few things that bubble to surface and evidence to support those few points.

Rossi commented that since 2007, the total number of DOE facility users had increased. Thirty percent are international users, and the composition of users continues to evolve. HEP and NP tend to have more international users than the other areas of SC.

Aprahamian asked why educational support had become an issue.

Dehmer explained that DOE needed to consolidate the education programs to eliminate duplication. If a mission agency wishes to spend dollars on training, that training needs to align strongly with workforce needs. Dehmer has no problem with that as long as OMB and OSTP concur. SC had done considerable work to restructure programs to try and make it work.

Someone in the audience asked a question about facilities: how DOE sets priorities for which ones to support across the six subprograms.

Dehmer answered that comparisons across programs would be made by DOE leadership.

Ted Barnes of the NP program office commented that regarding high performance computing and its bright future, ASCR science fellowships for graduate students would continue.

Dehmer further commented on the computational science graduate fellowship. In 2014, Congress added $10M to allow for a smooth transition for education program changes. Some programs were terminated. Money was infused into computational science education, supporting twenty new fellows for a four-year timeframe. In addition, within its workforce development programs, SC has programs for undergraduates to go to the DOE labs, and graduate students to go to labs; SC will begin skewing them to computational science. ASCR has $2M for traineeships and will support postdocs in training centers. Currently, there is a cohort of 20 students that will go forward.

CHARGE TO NSAC TO PRODUCE NEW LONG RANGE PLAN FOR NUCLEAR SCIENCE

Hallman read the charge to Geesaman for the NSAC to develop a long range plan (LRP).

Commenting on the charge, **Hallman** said that the long range planning process within the DOE community has had a long tradition of partnership between sub-disciplines within the community and with the agencies, as early as 1983. There have been a number of plans since then: 1989, 1996, 2002, and 2007. Each has been important to guide the scientific directions, and as emphasized by Crim, for setting priorities. Making the case and articulating the scientific community's vision involves setting priorities. That makes the plan credible. There has been a long tradition in nuclear science of effective partnership between the research community and the agencies.

It will be a challenging exercise. In DOE NP, facility operations are 50 percent of the budget. NP research is at a historic low: 28 percent; that is not sustainable in the out years, and major projects, are almost 19 percent of the budget.

Hallman warned the group not to be a fractious community. Once the vision and plan are articulated, the NP community must all get behind it and support it.

NSAC Discussion of DOE Office of Science Charge: Long Range Plan

Aprahamian compared this charge to past LRP charges: this one is very specific, as it contains a flat funding scenario. That takes away some of the leeway of what the community can suggest.

Hallman said there is some leeway. Planners should ask two questions: first, what are the priorities in a flat-funding scenario, and second, what resources would be needed to carry out the vision which the community sees as compelling. Leaders should, articulate the compelling opportunities, say what the vision is and what resources are required to achieve that vision. They should also indicate priorities under constrained resources.

ISOTOPE CHARGE TO THE NSAC

Next, **Hallman** read the isotope charge from SC to the NSAC. He noted that the isotope program has a different character than the NP basic research program: it receives federal appropriation dollars, but it also sells commercial isotopes at full cost recovery, so it is also a business. SC leaders felt that the character and scope are sufficiently differentiated from the NP basic research program that it needed its own charge.

The charge asked the NSAC to study the opportunities and priorities for the program over next decade (2016-2025). The charge letter requested that the isotope subcommittee submit an interim report and then a final report by March 2015.

NSAC Discussion of Isotope Charge

Geesaman asked why this charge, why now.

Hallman answered that NP has a sense that there has been a lot of progress; SC is looking for input from the community on what the new opportunities are and directions the program should be heading. The isotope program is dynamic: continually changing as are the needs of the nation, production capability, and the situation with the commercial sector. SC wants a fresh look at the issue, with guidance from the nuclear physics community on compelling opportunities and articulation of priorities: where to concentrate most heavily in case of constrained resources.

Geesaman asked, regarding other aspects of the isotope program that were relevant: is there anything SC leaders have in mind on which the isotope subcommittee should report?

Hallman answered that SC was looking for guidance from the research community on how to add value: should we change the way we do business, and/ or better support research? Think not only about production, but how this program could be even more effective.

Suzanne Lapi, in the audience, said that the last report had a lot of recommendations. **Hallman** replied it was the first time we looked at the isotope program and the subcommittee went well beyond the priorities and delved into details,

such as program staffing levels. This charge is more standard in approach, but we wanted to give opportunities to look at more things – such as how we conduct business, supply and demand – that go beyond what we traditionally pursue.

Jorge Piekarewicz asked whether the community was knowledgeable enough to respond to this charge.

Geesaman said in the last charge, the subcommittee worked very hard to get representatives from isotope end users, including society, pharmacists, doctors, producers, and industry. He acknowledged that Piekarewicz was right: they would need to get the broader community together to consider a span of aspects on the subject.

Aprahamian had a question for **Jehanne Gillo**: did the previous report state a risk to the country if the U.S. did not restore the ability to produce stable isotopes?

Gillo said yes. We have made investments in R&D on stable isotope production. Last year, we started with investments on a pilot plant at Oak Ridge National Laboratory to reinstate domestic capability of stable isotope production.

Someone in the audience asked, regarding the topic of neutrino experiments and beta decay: does that fall under the isotope charge or the future planning charge?

Hallman answered that they could be coupled

Gillo added that the isotope would have to be in short supply if the isotope program were to be involved

Hallman noted that if an isotope is commercially available or in adequate supply, the DOE isotope program would not deal with that.

UPDATE ON WORKFORCE CHARGE TO NSAC

Geesaman said that **Jolie Cizewski** of Rutgers University was serving as the chair who would respond to the workforce charge and showed the names of those serving on the subcommittee formed to address it.

The group addressing the charge had worked to identify disciplines that need more work force training at the graduate postdoctoral levels for SC mission needs. The committee needed to consider: disciplines not well represented in academic curricula; disciplines in high demand and potential difficulties in recruitment and retention; and disciplines where the DOE national labs may play a role in providing workforce development. The committee should also consider specific recommendations for graduate student and postdoc programs to address discipline-specific workforce development needs. The subcommittee was asked to provide a letter to SC to report on findings and recommendations by June 30, 2014. The findings would guide future activities and investments. **Geesaman** noted that the charge had a very short time scale and needed to be addressed within the month for the NSAC to be able to consider it.

The subcommittee would provide a summary of findings by mid-May and a draft to the NSAC on June 1, 2014. The final letter would be reported to Patricia Dehmer by June 30, 2014.

NSAC Discussion of New Charges – Continued

Geesaman reconvened the meeting and stated an interest in discussing the NP long range plan. NSAC members already know they are part of the working group. It will probably take a month to balance issues, including field diversity issues. The community, he hoped, would start organizing this summer, or in August and September. Normally one would have activities at the DNP fall meeting, but this year may be complicated because the DNP will be holding a joint meeting with the Japanese Physical Society; the schedule has already essentially been set. However, there is time in the fall to have more activities.

Geesaman said the NSAC would ask for written input from the town meetings by the end of January. Meantime, writing assignments for the draft report will be made so people can come to resolution meetings after reviewing the input with draft text for the report. He envisioned a resolution meeting in late March or early April. Then, the NSAC could discuss whether to continue deliberating until the summer of 2015.

One of the things that makes the long range plan different is the gravity of it. We take our budget guidance very seriously. There will be a budget above 'constant effort' that we'll put forward. Careful judgment will have to be applied as to how optimistic or pessimistic we are in that budget. The final report will be due in late October.

Geesaman continued by saying that a question that comes up each time is what sort of report we are writing. Would it be a comprehensive description of the field, or something at a higher level that is glossier, directed at SC and congressional staff? He said that he would be listening to the reaction to the P5 (particle physics priority planning panel) report and how it presents the future of that field.

Responding to the long range planning charge, the committee will need to discuss the impacts of the field, interagency and international partners, and synergies with other major research disciplines.

Aprahamian expressed concern over the quick deadline for the report

Piekarewicz said that nuclear- and astrophysics will overlap in content with fundamental symmetries but will likely be two separate meetings. We envision members of the Division of Nuclear Physics executive committee at each of the town meetings.

Geesaman reconfirmed that each would accompany a white paper. **Aprahamian** said yes.

Mantica offered to help/ organize with ACS. There is a San Francisco meeting in August; the program is already completed. March 2015 is the next meeting.

Aprahamian said that the issue of innovation has come up several times; since SC doesn't directly fund applications *per se,* but the executive committee felt that it was an important aspect of what we do, so we should include it.

Geesaman agreed, saying the report needed to discuss the impacts of NP on other disciplines.

Jamie Nagle said he was nervous that the executive committee is editing the community inputs that come from the town hall meetings. He asked whether the LRP executive committee was playing the role of NSAC, in that it is putting things together, assembling findings.

Aprahamian clarified to say she did not intend for the executive committee to evaluate any of the content. She wants someone on the executive committee to come to

town meetings to ensure everything gets done in a timely manner. However, the committee representative would provide no editorial activities after town halls, such as deleting or adding material.

Someone commented that the long range plan should focus on innovation, benefits, and societal applications of NP. It should relay both history and future. In the past, such products were very useful in talking to Congressional staff, especially points covering broad impacts and economic benefits. It should tell a great story, aimed at a person who is not necessarily an NP expert.

Another member of the audience urged Aprahamian to consider the representation on the executive committee and to include the outstanding junior faculty and postdocs in the program who perhaps have outside influence and/ or experiences. Select people on the panel who currently have minimal voice now but will have a particularly strong interest in how choices are made and in the future of NP.

A representative from Berkeley asked whether high performance computing should be included as a separate town meeting.

Geesaman said there could be a Theory town meeting. He asked if there were individual themes that would come out in a Theory town meeting. It is an issue that theorists and experimentalists should think about.

Another audience member said the report should be focused on the science.

Geesaman said he worried about postponing final consideration until June, and wondered if the resolution meeting would be a Thursday through Sunday type activity.

Nagle asked if there would be a subcommittee meeting later in the fall after the American Physical Society's Division of Nuclear Physics (DNP) meeting.

Aprahamian said she would prefer to convene a meeting earlier: as soon as people can get organized. She suggested a late summer or September meeting – before the DNP meeting.

Nagle asked what drives the urgency.

Aprahamian reasoned that written material should be done in December. The final report was due in March 2015. The committee must start this week.

Geesaman suggested relaxing a little, that he didn't think that written material would need to be complete by the end of January. The time in November and December would be very useful.

Schukraft said the town meetings had been successful in the past. He asked how far could one push the electronic aspect of that: meaningful participation via video teleconference.

Aprahamian replied that electronic meetings may work for up to 50 or 70 participants, and that it was something she would consider.

Aprahamian asked **Nagle** whether he had a specific issue with the schedule.

Nagle said that it might be harder to get participation of students if the stakeholder input meetings are held right away and without much advance notice.

Someone from the program office noted that if workshop costs exceed $100K that DOE approval will be needed.

Aprahamian said that the deadline for DNP had already come and gone.

Hallman said there was further consideration of that meeting and that the deadline may have been extended for the DNP meeting.

An audience member noted that the High Energy Physics (HEP) community just went through this massive Snowmass process. It might be good to find out how to optimize our chances for success, given their experience. They had virtual town meetings. He encouraged **Geesaman** to contact Steve Ritz of the HEP community. That group's culture and sociology are different, but learning from their experience is something to think about.

Kate Scholberg added that she had experienced virtual meetings with a large number of participants that were effective; it depends on the technology used to arrange the meeting.

Mantica said that virtual meetings may inadvertently discourage young people who may be more reluctant to speak up.

Geesaman said he is still just beginning to think of the chair of the Isotopes subcommittee. He asked whether there were any further comments on the isotopes charge. There were none.

REPORT ON NEUTRINOLESS DOUBLE BETA DECAY

Robert McKeown (TJNAF), Subcommittee Chair on Neutrino-less Double Beta Decay, said he would present elements of a draft report that he hoped were close to final. The charge letter requested that an NSAC subcommittee provide guidance to DOE and NSF on an effective strategy for possibly implementing a second-generation U.S. experiment on neutrino-less double beta decay (NLDBD) capable of reaching the sensitivity necessary to determine whether the nature of the neutrino is Majorana or Dirac. The NSAC should solicit input from the High Energy Physics Advisory Panel (HEPAP) and the nuclear science community in formulating the membership of the subcommittee.

Subcommittee membership included representatives from the high energy physics community; (four members) Peter Fisher, Kate Scholberg, Tom Shutt, and Hank Sobel. Two of them, Fisher, and Shutt, are members of HEPAP. Scholberg is a member of the P5. Several theorists are on the subcommittee as well. **McKeown** described the elements of the charge.

McKeown summarized the scientific motivation for neutrinoless double beta decay experiments. He outlined the current experimental issues: since the two electrons carry all energy available in decay, the sum of their energies would add up to an endpoint energy. To observe this readily, one would need good energy resolution, observed via a very narrow peak on the energy plot with a low background. If one had finite resolution in the experiment, it degrades the quality of the experiment. This decay provides a very weak signal.

For the last 15 years, physicists have known that neutrino oscillations occur, and neutrinos have non-zero mass. This is a change from thinking of the 1980s: that at least some of the neutrinos have non-zero mass. Physicists have observed oscillations in detail in quite a few experiments: KamLAND in Japan, Daya Bay in China, and the Super-K experiment in Japan. All support the theory that neutrinos oscillate with sinusoidal curves that one observes in quantum mechanics. One can measure these parameters, and we know the three angles associated with the oscillation matrix, and Δm_{ij}^2. We have

limits on the absolute neutrino mass. We would like to know are those values close to zero, or are they separate from zero.

Looking at tritium beta decay, one needs very good resolution to measure a finite neutrino mass. The KArlsruhe TRItium Neutrino (KATRIN) experiment, in progress in Germany, will have significant US participation over next four or five years. In cosmology: we are able to set limits on the sum of mass of neutrino states. As cosmology CMB experiments improve, this number may drop to 0.06 eV, as one can see in literature.

If one plots the masses of the other fermions, leptons, and quarks, they are very different from the neutrino masses by orders of magnitude. The masses of the former particles are thought to come from the Higgs mechanism. But one needs to fine-tune the Higgs mechanism, and it is an unnatural scenario for neutrino masses, so the "see-saw" mechanism for neutrino masses is the most common alternative, requiring them to be Majorana neutrinos. Then one would naturally expect that double beta decay would occur; we just don't know the mechanism.

Masses of neutrinos, mass states, are commonly shown on a plot depicting the mass hierarchy. You can see a delta m squared solar [$(\Delta m^2)_{sol}$], and a delta m squared atmosphere [$(\Delta m^2)_{atm}$]. The mass hierarchy could be a normal or an inverted hierarchy. The inverted hierarchy scenario is just as likely as the normal hierarchy scenario. The half-life depends on a phase space factor, a nuclear matrix element and a combination of the masses. If you make a measurement of this half-life, and get with your theorist friends to calculate the phase space and nuclear matrix element, then you get this m double beta squared. This mixing matrix has been measured in oscillation experiments. In 2004, the Klapdor-Kleingrothaus experiment claimed to have seen neutrino-less double beta decay. In this plot of the allowable values of m double beta vs the mass of the lighted neutrino is shown; the colored bands indicate the allowed regions with the variation of U_{ei} due to unknown Majorana phases and uncertainties in the mixing angles. We have no information as to what the Majorana phases are; there are two of them. Each one can vary from zero to two-pi. When we talked to experimentalists in the field, we told them they had to give us what they could do for the half life, and it was up to us to interpret the experiment.

The Klapdor-Kleingrothaus claim is shown on the m double beta versus the minimum neutrino mass. Experiments on Earth limit the sum to 2 electron volts (eV). Cosmological experiments limit the mass sum to 0.260 eV. Three regions of the famous plot were discussed, including the quasi-degenerate region and the inverted and normal hierarchy regions. They separate into two separate regions at low minimum mass depending on whether the normal or inverted hierarchy is true. In 2004, German physicists published a paper saying they saw a bump in their double beta decay spectrum; it was unconvincing, and the field doubted the results. However, it generated interest in the field, and many of the current generation of experiments were motivated by trying to check on this claim. Now that we know the mixing angles, we know where the bottom of the inverted hierarchy allowed region is: 17 or 18 milli eV. If one builds a large enough experiment, it is technically feasible to detect below that region. If one could do that, one could prove the inverted hierarchy or could rule out the inverted hierarchy. Or, if neutrinos are not Majorana in nature, one could prove such a plot is not relevant. It

seems like a reasonable goal to make a statement on the nature of neutrinos. That is why you want to get an experiment sensitive enough to get to the 15 milli eV number.

McKeown reported that it was the assessment of the subcommittee that the pursuit of neutrino-less double beta decay addresses urgent scientific questions of the highest importance, and that sufficiently sensitive, second-generation experiments would have excellent prospects for a major discovery. Furthermore, the subcommittee recommended that DOE and NSF support this subject at a level appropriate to ensure a leadership position for the U.S. in this next phase of discovery-caliber research.

The subcommittee collected information on current and "next generation" projects occurring within the physics community in this area, providing a query template to 11 collaborative groups. Questions included, "tell us half-lives, not m double beta," and "What units did you use?" Most didn't follow it. The input was more open-ended; it is just a guess as to what the background will be for a next generation project. There also is variability in believability and reliability of the information received. Nine presentations occurred for the February open meeting at SURA headquarters in Washington, D.C.. There was a large range in variability in validity of assumptions that went into different projects. We found a way of dealing with this: to simply present the status of those projects without getting into those details. We were not charged to rank them, just to assess the field.

Xenon-136 is an attractive isotope for double beta decay and has been used since the 1980s. Germanium crystals have been used for a long time; was used for the 2004 claim. Germanium has very high resolution. There are two projects (in Europe and the U.S.) that will eventually merge. The use of Tellurium Oxide bolometers is also a very nice technique. Crystals have bolometers. One can see temperature change with double beta decay – it is really amazing. There are doped liquid scintillators (KamLAND): one puts a balloon in with Xenon-doped scintillators and can observe beta decay. Or, Tellurium 130 can be used in a similar way. Foils with tracking chambers give detailed information, but it is hard to get a lot of mass with the foils.

Current projects the subcommittee considered include: CUORE, MAJORANA, GERDA, EXO200, NEXT-100 SuperNEMO, KamLAND-Zen, SNO+, and LUCIFER. The experiments use ^{130}Te, ^{76}Ge, ^{136}Xe, ^{136}Xe and ^{82}Se. The primary goals are to demonstrate background reduction for the next-generation experiment and to extend sensitivity to $T_{1/2}$ to about $1x10^{26}$ years. For each current project, the subcommittee provided a list of perceived strengths and challenges. Big numbers are with Tellurium and Xenon; behind those is Germanium. Several of these experiments will probably get there within three to five years. In its report, the subcommittee wrote something about these projects and plans. It will include a list of perceived strengths and challenges and does not foresee anything too controversial there. Regarding the task to provide comments on next generation projects: the subcommittee's findings are currently not formulated well enough.

The notional timeline of projects under construction and in operation is based on information respondents provided in the survey. Six experiments are under construction, with most completing by 2015. EXO200 and KamLAND Zen are already up and running. SUPERNEMO is the foils-based experiment. It is currently at just a few kilograms; it would be into the future before they get into 100 kg. KamLAND needs higher purity; there is a good chance they will take the lead. They have 800 kg of Xenon

and if they put 600 at a time and cleaned up their balloon, they would be in the lead. Quite a few experiments will be coming online in the next year or two. It will be two to three years before we will have a lot more information about these experiments to do a hard-nosed assessment of these different technologies. At that point one could assess the future prospects with much higher reliability than today.

For its assessment, **McKeown** said the subcommittee recommends that the "current generation" experiments continue to be supported, and that the collaborations continue to work to resolve remaining R&D issues in preparation for consideration of a future, "second generation" experiment. New techniques that offer promise for dramatic reductions in background levels should also be supported.

McKeown talked about goals and criteria for inverted hierarchy coverage. The half life depends on phase space, matrix elements (and the calculations and techniques can be controversial) and m double beta. He showed a plot of half-lives ranging from 10^{26} to 10^{28} for various isotopes. Highlighted are Germanium, Tellurium, and Xenon – scalable options. Right now, we are at the bottom of the plot, measuring half-lives less than 10^{26} years. In five years, the subcommittee predicts experiments will be able to detect half-lives above 10^{26} years. One needs to get up to 10^{27} or 10^{28}, a factor of 50 to 100 improvement, to get there (to the desired half life range), and that's a lot. There is quite a bit of variation in predictions of where you have to get to, representing a factor of 50 beyond where we are going to be 5 years from now, depending on isotope. The major experimental issue is the background. If one had a background-free experiment, the lifetime sensitivity goes as the detector mass multiplied by running time. One would need a five ton supply of isotope. Suppose the experiment has background; now, there is not enough isotope to realistically run the experiment. Thus background reduction is key. The experimental apparatus must be located deep underground for this reason. One must have radiopurity. Several factors contribute to better energy resolution and better event characterization.

Further, the subcommittee recommended that the following guidelines be used in the development and consideration of future proposals for the next generation experiments:

1) Discovery potential: Favor approaches that have a credible path toward reaching 3σ sensitivity to the effective Majorana neutrino mass parameter $m_{\beta\beta}$=15 meV within 10 years of counting, assuming the lower matrix element values among viable nuclear structure model calculations.
2) Staging: Given the risks and level of resources required, support for one or more intermediate stages along the maximum discovery potential path may be the optimal approach.
3) Standard of proof: Each next-generation experiment worldwide must be capable of providing, on its own, compelling evidence of the validity of a possible non-null signal.
4) Continuing R&D: The demands on background reduction are so stringent that modest scope demonstration projects for promising new approaches to background suppression or sensitivity enhancement should be pursued with high priority, in parallel with or in combination with ongoing NLDBD searches.
5) International Collaboration: Given the desirability of establishing a signal in multiple isotopes and the likely cost of these experiments, it is important to

coordinate with other countries and funding agencies to develop an international approach.

6) Timeliness: It is desirable to push for results from at least the first stage of a next-generation effort on time scales competitive with other international double beta decay efforts and with independent experiments aiming to pin down the neutrino mass hierarchy.

It is premature to set down quantitative criteria for near-term future proposals. The subcommittee will not recommend using the most optimistic matrix element, nor the most pessimistic one. Regarding staging: the subcommittee recommends this approach because it believes one cannot do it all in one step. Currently, the challenge is poor energy resolution Different isotopes could be supported by different international collaborations. On timeliness: we should not sit on sidelines and wait to see what happens. The U.S. needs to address the timeliness issue and have a process in place to make a decision in two to three years and move forward.

McKeown discussed additional theoretical issues. Other mechanisms are possible besides the light Majorana neutrino. A variety of techniques used for nuclear matrix elements (QRPA, NSM, etc.) give a range of results. Also a Majorana mass may not be the mechanism for double beta decay. Hidden in those matrix elements is a sensitivity to the axial vector coupling constant, G_A to the fourth power. Here, it is critical because 1.25^4 becomes 2.5.

The subcommittee offered a Theory recommendation. There is generally significant variation among different calculations of the nuclear matrix elements for a given isotope. For consideration of future experiments and their projected sensitivity, it would be desirable to reduce the uncertainty in these nuclear matrix elements.

The subcommittee recommends establishing a theory task force that aims at:

1. Developing criteria to establish and rank the quality of existing and future calculations,
2. Identifying methods to constrain the less tested assumptions in existing approaches.

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McKeown acknowledged those who helped and contributed. He said it was a tight time frame to get any more quantitative results.

NSAC Discussion of the Report on Neutrino-less Double Decay

Nagle asked for more details about the normal versus inverted hierarchy.

Pointing to a common figure that (slide 13) had been shown before, **McKeown** said there are two aspects to that figure. Key questions are: (1) Are you inverted or normal? (2) Where are you on the spectrum of that plot? It may gradually, via cosmology hopefully, become known. Perhaps toward the end of the decade we will get experimental evidence – such as the NOVA experiment, with some sensitivity. The JUNO reactor being built in China could give a clue; or IGLOO, an upgrade of ICECUBE for atmospheric neutrinos, may help answer some of the questions. Any of these experiments, by the end of decade, may give us some clue. The subcommittee feels

it is not a correct strategy to wait for that to play out; we should pursue the subject in earnest in meantime. If M_{min} is small, and one would have to build a much bigger experiment than we think, we will have to re-evaluate.

Shepherd asked, also regarding the Klapdor-Kleingrothaus claim plot on slide 13, if McKeown could discuss the width of the band.

McKeown said that on the plot, one could see that Majorana phases are varied from minus pi to pi. Mixing angles get varied.

Shepherd asked if **McKeown** could comment on the expected time scale for shrinking that band.

McKeown said that this lower limit depends on delta m squared atmospheric, which we know well enough. The biggest uncertainty is theta-one-two. The best chance for figuring out theta-one-two is JUNO in China. It is a $300M project, and China is committed to proceed. It will improve our knowledge of all these other parameters in neutrino phenomenology. There are prospects for reducing uncertainties: neutrino science is getting into a calibration phase. Nonstandard interactions are the "name of the game" in the neutrino oscillation business.

Schukraft asked about the 15 meV number – how **McKeown** arrived at the number, given it depends on the fourth power of G_A, and there are experimental background issues. Is it important for the final selection?

McKeown acknowledged Schukraft's point and confirmed that the mass of material one might need for a next-generation experiment varied considerably. Members of the subcommittee had differences of opinion. What does it mean, three sigma? That is the reason why five sigma seems too much, given the other uncertainties. It is kind of a compromise position for now; hopefully the Theorists will help us. Assigning a probability or confidence is difficult, given uncertainties.

Nagle said that it might be worthwhile to pursue the program, even with null results. If you picked a value of 0.15 meV, it says the results are one sigma bands. That is not a five sigma Higgs discovery. How compelling is the program if you cover a lot of the phase space. But it doesn't rule things out if you get a null result. The question is how to know if you're in the right ballpark.

McKeown Agreed. When you set yourself on a course, don't design an experiment that won't get you there due to limits of technology. Instead, design the experiment to get you there in incremental stages. It was more of a philosophical thing: don't box yourself into an experiment that is too limiting in the beginning.

Nagle posited that maybe that strategy is not aggressive enough.

McKeown replied that **Nagle** could get some sympathy from some of the committee members, who agreed. This was a "middle of the road" compromise position. It is a balance; it is where the committee ended up.

Rossi commented that we would have to wait three years for results. Are we factoring this into long range planning?

McKeown said Rossi was correct: a LRP would need to revisit this issue. For the subcommittee, the question was whether the scientific merit of the program is compelling or not. He thinks the LRP will answer how compelling it is, relative to other things. **McKeown** suspects in the LRP process, the subject will be revisited, and these issues will be re-debated.

Piekarewicz said he might not be as optimistic about such a task force. He asked what was role of Theory in helping.

McKeown said that an example used in the past for a similar situation was the solar neutrino problem. Theory tried to decide what numbers to pursue. Not sure if they are analogous situations. There exist calculations that are old, and superseded by new models, but people still use the old one. It seems reasonable to get the Theorists together, maybe they will come up with experiments to reduce the uncertainties.

Mantica asked for clarification of the charge.

McKeown said that reaching the normal hierarchy at low minimum mass was pretty much impossible in the near term. So one asks whether one can cover or get to 0.01 eV for the m double beta.

Geesaman said that John Wilkerson via webcast wrote that this discussion was in terms of light Majorana and neutrino exchange. There may not be a direct correlation to m double beta and some of these other techniques, cosmological or others.

McKeown said it is common for people to focus on this model, thus enters the see-saw mechanism, which is attractive. The Light Majorana scenario is attractive, but other things could cause zero neutrino double beta decay. Other models could be the answer, and one has to keep an open mind.

Geesaman said he had one more comment: if you observe neutrino-less double beta decay, you do know that lepton number is violated.

Schukraft commented that the subcommittee emphasized the background issue and highlighted resolution questions.

McKeown said for high-resolution experiments like Germanium, it was not an issue. But for a liquid scintillator like KamLAND, it is very problematic for those experiments. The next generation experiments should attempt to demonstrate background reduction.

Schukraft asked if any of the labs queried project to be background-free, in the future?

McKeown answered that some of them did project that they would be background-free. Some predicted low background numbers, and some projected zero background.

Continued NSAC Discussion of the Report on Neutrino-less Double Decay

Robert Atcher asked whether projected costs had been considered in the subcommittee's work, as some of the needed quantities would be very expensive.

McKeown agreed but said costs had not been specifically considered.

Aprahamian commented that she appreciated separating the experimentalists from the theorists in the committee's consideration; that she supported that strategy.

Schukraft said, when queried, that he found the report to be both interesting and balanced. He asked a question about what value of G_A was used in Slide 22.

McKeown answered, "1.25."

Vincenzo Cirigliano commented that he was unsure whether one should apply quenching to double beta decay.

Schukraft asked a question about G_A.

McKeown answered that pessimistic G_A calculations take one way off the plot. This is why we need the theorists to try to quantify parameters.

Schukraft commented that he agreed that we should continue with research and development (R&D) and agreed also with coming back to consider the field in two to three years.

Geesaman said, hearing no further comment, that he assumed the committee unanimously accepted the report. The meeting was adjourned for the day at 4:23 p.m..

April 25, 2014

PRESENTATION OF THE REPORT ON THE NNSA DEVELOPMENT OF ^{99}Mo DOMESTIC SUPPLY

Geesaman convened the morning proceedings at 9:03 a.m. EDT. He said the group's discussions would move from yesterday's topics of measuring longest life times in the universe, and now to an issue important to the public health of the nation.

Susan Seestrom of Los Alamos National Laboratory and subcommittee chair, had led the study on ^{99}Mo.

Regarding the charge: there is interest in the government of reducing enriched uranium for nonproliferation. The U.S. medical community that utilizes medical isotopes is concerned there would be a shortage. Legislation called the American Medical Isotopes Production Act of 2012 (AMIPA) resulted, and hence the charge to NSAC. The subcommittee studying the issue did not focus on business processes. AMIPA focused on low enriched uranium fuels and a post-use take-back program; the subcommittee did not review those areas. Subcommittee members had relevant expertise as isotope users, isotope producers, nuclear chemists, nuclear physicists, and reactor operators.

Regarding the subcommittee's action process: there were two in-person meetings. The subcommittee was briefed by the Office of Economic Cooperation and Development (OECD) via phone. The FDA talked with subcommittee members about the process to license ^{99}Mo from different sources. The subcommittee talked with the Nuclear Regulatory Commission (NRC) as NRC approval would be needed. A second meeting included a half-day session to solicit community members to come talk to the subcommittee. Some sent written input.

There is widespread use of ^{99m}Tc for nuclear medicine diagnostic imaging, which is the daughter of ^{99}Mo. Today, ^{99}Mo is produced by the fission of ^{235}U. There is U.S. government interest in reducing the use of Highly Enriched Uranium (HEU). There was concern in the medical community that this could lead to shortages or a significant increase in price. The Organisation for Economic Co-operation and Development (OECD) estimated that there could be as much as a 27 percent cost increase in final consumer use of the product if there were a shortage. The issue was addressed in the 2009 National Academies study. Supply chain disruptions have occurred between 2005 and 2014. There is currently no U.S. producer of ^{99}Mo.

Molybdenum-99 is the parent product of ^{99m}Tc, a radioisotope used in approximately 50,000 medical diagnostic tests per day in the U.S. (over 18 million per year in the U.S.). Its primary uses include the detection of heart disease and cancer, the study of organ structure and function, and other applications. For a given medical procedure, about one percent of the procedure cost is due to the cost of the isotope. ^{99}Mo has a short half-life (66 hours) and cannot be stockpiled. Production is usually quantified in terms of activity six days after it is produced;. The U.S. demand is approximately 50 percent of the world market. The historic global demand is ~12,000 6-day curies per week. Since the 2009-2010 shortages, global demand has been ~10,000 6-day curies per week.

^{99}Mo is produced at only five processing facilities worldwide, in cooperation with eight research reactor facilities. Processing facilities are located in Canada (HEU), the Netherlands (HEU), Belgium (HEU), South Africa (HEU and LEU), and Australia (LEU). Research reactors used for irradiation are located in Canada, the Netherlands, Belgium, France, Poland, Czech Republic, South Africa, and Australia.

A National Academies study addressed the topic of switching from highly-enriched to low-enriched uranium targets

In the supply chain, reactor facilities irradiate targets to generate ^{99}Mo. Seven reactors use low-enriched uranium for fuel; the only reactor in the Northern Hemisphere is Canada. These reactors process ^{99}Mo and send to it to manufacturers. NNSA supports the development of low-enriched uranium targets; that issue wasn't the main subject of the subcommittee's review. Some reactor facilities are still using highly-enriched, low-enriched, or both types of targets; they are transitioning to low-enriched uranium targets and fuels. Generator manufacturers then send material to radio pharmacies that then send isotopes to hospitals. During shortages, pharmacies and hospitals postponed treatments. They employed alternative imaging like Rubidium-82 for cardiac perfusion. One result of the ^{99}Mo shortages was that demand decreased due to better utilization: the global demand decreased to 10,000-day curies per week instead of 12,000-day curies per week.

As a result of this history, there is no reward system for suppliers to deal with outage surge capacity. If one source goes down, the community can weather it; but if more than one supplier goes off-line, adequate ^{99}Mo supply to the medical community will be at risk. There is insufficient investment in the facilities, as four to six of them are 55 years old. Basically, the U.S. is dependent on old reactors in other countries. The U.S. wants to move to a system based on full cost recovery. That is a long process, and the time scale for the global community to move toward full cost recovery does not address the current risk of a shortage, because some facilities may shut down.

The mission of the NNSA Global Threat Reduction Initiative (GTRI) is to reduce and protect vulnerable nuclear and radiological material located at civilian sites worldwide. Its mission is to move away from using HEU. GTRI supports the DOE's nuclear security goal by preventing terrorists from acquiring nuclear and radiological materials that could be used in weapons of mass destruction or other acts of terrorism. GTRI works towards achieving its mission by converting research reactors and isotope production facilities from the use of highly enriched uranium (HEU) to low enriched uranium (LEU), removing and/or disposing of excess nuclear and radiological materials, and protecting nuclear and radiological materials from theft. Together, these efforts

provide a comprehensive approach to preventing terrorists' access to nuclear and radiological materials. ^{99}Mo is under the 'convert' pillar of the GTRI mission. GTRI works both domestically and internationally to achieve HEU minimization and establish reliable supplies of ^{99}Mo. The Nordion Canadian reactor produces 50 percent of the ^{99}Mo in the U.S. It is ceasing isotope production in 2016. A target for U.S. domestic ^{99}Mo projects is to fill the expected 2016 gap. GTRI, via the American Medical Isotopes Production Act (AMIPA), was directed to implement a technology -neutral program.

There are three approaches the GTRI program is using to produce ^{99}Mo. One is LEU fission based, using ^{235}Uranium. This approach will produce ^{99}Mo that is identical to that which is sent out to the radiopharmaceutical companies, with highly specific activity. A neutron combines with ^{235}U to create ^{99}Mo and other fission products. A second approach, neutron capture, occurs when a neutron is captured by the ^{98}Mo nucleus to produce ^{99}Mo. The third approach utilizes a high velocity electron from a particle accelerator to produce γ-rays. The photon interacts with ^{100}Mo nuclei and ejects a neutron from the ^{100}Mo nucleus, creating ^{99}Mo.

NNSA's objective is to provide support to accelerate existing commercial projects to meet the U.S. demand of ^{99}Mo produced without HEU. Based on the isotope risk, there are four cooperative agreements that NNSA had established. Details on status of the projects are business sensitive The companies include NorthStar Medical Radioisotopes, Morgridge Institute for Research/ SHINE Medical Technologies, Babcock and Wilcox, and General Electric-Hitachi.

There are two classes of risks. First, can the companies get the resources needed to produce the isotopes? Each cooperative agreement is awarded under a "50-50" cost-share arrangement, consistent with the AMIPA and Section 988 of the Energy Policy Act of 2005. The cooperative agreements are currently limited to $25M each to avoid continuing the subsidization of the industry, which is of global concern. Beyond the government funding provided under the cost-sharing arrangement, all costs incurred will be the responsibility of the commercial entity. Thus, companies must be able to raise upfront money. In the early stages, that is economically viable. However, a facility may need to build infrastructure that costs $200M, so that challenge may be cost-prohibitive to these companies. A second issue (subsidies) is that as per WTO guidelines the government should not supply more than 15 percent of money to build a facility. Another class of risks is the generation of low specific activity material, for which there will have to be new generators, and materials will need to be approved by the FDA,. NNSA has worked with the Department of Health and Human Services (HHS) and the folks who do Social Security reimbursements to competitively reimburse medical procedures using material produced with low enriched uranium. The NRC approval process can be lengthy for new faciliies.

Babcock and Wilcox, and General Electric-Hitachi were awarded cooperative agreements through the NNSA Albuquerque Complex under a Determination of Non-Competitive Financial Assistance in September 2009, following an evaluation by a merit review board of independent technical experts. In March 2010, GTRI issued a Funding Opportunity Announcement to select partners to develop LEU target technology and accelerator technology to produce ^{99}Mo. NNSA received eight proposals, and following their evaluation by a merit review board of independent technical experts, GTRI offered awards to three entities in September 2010. Of the four cooperative agreements partners

that were established, two stopped work due to lack of commercial partners or unfavorable business conditions.

NNSA sends money to national labs outside cooperative agreements to support long term R&D that will result in non-proprietary research. The subcommittee didn't review that aspect.

The subcommittee concluded that the medical isotope supply issue is a challenging problem. There is a complex international situation, with many factors outside the direct control of NNSA. It is plausible there will be a reliable U.S. supply of ^{99}Mo after 2016. There is risk associated with aging facilities. 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 development of new domestic suppliers; commercial funding seems to be an issue.

Only a small fraction of factors are within the control of NNSA for ^{99}Mo. Current facilities are old and outside the U.S. Full cost recovery will result in a level playing field. The time scale for an isotope supply drop seems to be the planned 2016 shut-down of the Canadian production. New domestic suppliers could fill the demand, but the problem is with money. In the envisioned arrangement, the commercial partners control the work. NNSA reviews the work they are doing, but they are not projects managed by NNSA. The subcommittee struggled with that difference as it carried out its review.

One question explored by the subcommittee is whether the NNSA GTRI goals for establishing a domestic supply of ^{99}Mo are sufficiently defined. The NNSA overarching programmatic objective is to accelerate the establishment of reliable supplies of the medical isotope ^{99}Mo produced without highly enriched uranium. This goal is not specific as to timelines or what constitutes "acceleration." There are specific and well defined goals for the commercial partners. For each of the four cooperative agreements, the goal was to provide 3,000 6-day curies of ^{99}Mo per week by 2016 (re-baselined from the original target date of December 31, 2013).

The current status is that none of the CA partners met the original goal to produce 3,000 6-day curies by 2014. Only one has a high probability of producing any ^{99}Mo in 2014, and two partners have paused their efforts.

A second question is whether the risks have been fully identified. In some cases the risks are more complex than indicated by NNSA. For example, the risk of market saturation could negatively impact potential new suppliers. There is also suspicion among potential suppliers that NRU, the Canadian reactors, might not cease production in 2016. The subcommittee saw no evidence that the Canadians will deviate from shut-down plans in 2016. The Australian Nuclear Science & Technology Organization (ANSTO) Open Pool Australian light water (OPAL) reactor is coming online with a new LEU based production capability, and other potential foreign sources have been proposed. Foreign entities could ignore the international protocols and market less expensive, HEU-produced ^{99}Mo. If all of the NNSA initiatives were successful, the market would be oversaturated. Having only a foreign source of a reliable, cost-effective supply of the stable Mo isotopes needed for production of ^{99}Mo by neutron capture or (γ,n) (^{98}Mo, ^{100}Mo), without a domestic supply, is also a potential risk. The entity that comes to the market with new technology to meet the 2016 shutdown has the best chance at a ^{99}Mo market share.

The subcommittee also evaluated whether the strategy was complete and feasible, within an international context. The NNSA strategy to achieve their vision is two-fold: (1) to help international suppliers transition to the use of non-HEU targets; and (2) to establish commercial non-HEU based production capability in the U. S. by addressing weaknesses in the global supply chain and by assisting commercial entities seeking to enter the market with new technologies. The subcommittee felt the strategy was feasible but not complete.

In summary, the subcommittee offered two recommendations: the NNSA should look carefully across the domestic production part of the ^{99}Mo program in view of present facts (such as progress on CA projects, economic environment for capital and projected operating costs) in order to focus resources on the most promising CA agreements. Second, the subcommittee assessed that, based on the slowness of progress toward implementation of full cost recovery internationally, the NNSA should consider relaxing its present $25M cap on investment in any project. This change could increase the likelihood of generating a successful domestic producer of ^{99}Mo as the international market continues to move toward a full cost recovery economic model, in order to get a stable system of supply and demand. This would address one of the major risks in the present program.

Seestrom concluded by thanking the subcommittee members, some of whom struggled with the complexity of the issue.

NSAC Discussion of the Report on the NNSA Development of ^{99}Mo Domestic Supply

Mantica asked for more information about the 50-50 cost sharing arrangement.

Seestrom said that it would require a legislative action. Of course, telling Congress what to do is not something the subcommittee wanted to state in its recommendations, and it was not within NNSA's ability to make that change.

Scholberg asked why the Canadian plants were shutting down.

Seestrom said that to rush aid the U.S. would just be subsidizing a potentially oversaturated short-term market for ^{99}Mo. A one-percent cost differential, for medical procedures, is reflected in using ^{99}Mo generated from HEU versus LEU. She said she could imagine a different government in Canada may change the plan, but with the current government, the plan is to shut down.

Nagle asked whether the subcommittee was assessing technical aspects but not business aspects of the issue, in its charge.

Hallman said that it was the program office's interpretation of the congressional language to look at the GTRI program health and not assess technical options for ^{99}Mo production.

Seestrom said that some subcommittee members had been technical reviewers on technology agreements and assessed that the technical feasibility was sound. For example, they looked at the NNSA requirement of 3,000 6-day curies, which had left some competitors out. However, after reviewing it, it appeared that the hurdles were economic, not technical.

Geesaman added that as a member of the subcommittee, he could attest that the subcommittee did look at technical issues. He didn't see any technology reason that any of the businesses wouldn't move forward. The hurdles are business issues.

Seestrom said that three of the cooperative agreement partners briefed the subcommittee, and it did not focus its review on technical aspects.

Nagle pointed out that the Missouri reactor uses HEU as reactor fuel.

Seestrom said the subcommittee only looked at contenders involving LEU targets. The U.S. wants the focus to be on LEU over HEU.

Nagle noted that the subcommittee used the word, "plausible" in describing a stable ^{99}Mo supply in 2016. He interpreted that to mean, "unlikely."

Seestrom replied that the subcommittee used "plausible" in terms of supply because U.S. hospitals can get ^{99}Mo from outside the U.S. in that timeframe. It also assessed that it was likely that only one supplier in the U.S. will make ^{99}Mo by 2016. That was the question NNSA is seeking to answer; the subcommittee believes there is a risk that none of these companies are going to supply a substantial part of U.S. ^{99}Mo demand by 2016, but that the U.S. will rely on international suppliers.

Atcher suggested some minor corrections.

Seestrom said she had fixed some of the typos. The Canadians are not going to produce ^{99}Mo after 2016. There will also be a drop in current production in France – the subcommittee was not sure whether French capacity will be reduced or offline as well.

Staples noted that between 2015 and 2018, the French OSIRIS reactor will stop producing ^{99}Mo. Approximately six percent of global supply comes from that reactor.

Aprahamian asked what the NNSA is doing regarding the FDA approval process for new business entrants.

Seestrom answered that the FDA process is most relevant for low specific activity material. There will be a new FDA approval process, and the FDA had been working closely with the DOE. There exists a broad working group that includes representatives from the FDA and NRC. NNSA and FDA are working together, but is hard to predict what FDA will want to see once an application has been made.

Staples added that the FDA and NRC are involved as independent regulators, and DOE has no authority to intervene in those processes. But an OSTP-convened group on radioactive process said it would support the NNSA's efforts.

Seestrom said she thought that a lengthy FDA process seemed unlikely. Regarding the NRC perspective: if one is going to build a facility, the bigger hurdles are processes to design and build the facilities. Commercial partners will have to generate proposals for FDA or NRC to consider.

Piekarewicz asked whether other isotopes could be used instead of ^{99}Mo.

Lapi said yes, there are others, but hospitals are at capacity or don't have the new techniques needed. New techniques will result in a small decrease in demand in the future, but ^{99}Mo is still important.

Geesaman commented that there are nonradioactive techniques like sonograms, with different imaging quality and effects. The Canadians recently published a survey of pluses and minuses of alternative technologies; so that issue has been investigated.

Seestrom said it makes no sense to incentivize industry if the medical community is walking away from ^{99}Mo as a diagnostic.

Schukraft asked whether the full cost recovery arrangement was the rule or an exception.

Seestrom answered that she didn't know, but that a true, full cost recovery arrangement for this isotope is a future aspiration.

Geesaman said that other isotopes such as iodine are produced via fission. The costs are cheaper than one would have for full cost recovery. They will be affected similarly via LEU targets and companies will have to process five times more material to get the same amount of iodine. In AMIPA, NNSA was asked to consider other isotopes. That consideration was not included in this committee's charge to review. Those iodine isotopes are not used as frequently as ^{99}Mo.

Atcher noted that, in terms of risk analysis, the leading company is dependent on stable Mo isotopes by either one of the production routes. Is there technology capacity to meet that demand?

Seestrom said that the subcommittee was concerned about the supply of those isotopes, and it called it out as a risk not adequately addressed. The higher production goal of 3,000 6-day curies needs highly enriched targets to be met. She said she did not see the analysis using international suppliers.

Atcher said that the Canadians initially thought they would have sufficient supply to do a "once-through" with targets. The subcommittee determined their supply would be insufficient for their own demand. There is talk of trying to recycle their ^{98}Mo targets. That issue needs to be pursued further as to what is realistic.

Staples said that NorthStar has sufficient supplies currently, but not enough for once-through capacity. Recycle is part of the company's planning.

Seestrom commented that the strategy is to get something to market quickly in order to get a piece of market share. However, a company may have no market share if no one is willing to use its product. There is a "chicken and egg" problem, in that these companies cannot get the money they would need to ramp up ^{99}Mo production if there appears to be no one using their ^{99}Mo.

Atcher said that 50 percent of ^{99m}Tc is used for cardiac imaging. These medical procedures are sensitive to the concentration of ^{99m}Tc in the reaction mixture. It is critical for NorthStar's new generator to produce ^{99m}Tc in the same concentrations as the Fisher product ^{99}Mo generators.

Seestrom, said that if the product is licensed by the FDA, that means the company is able to make equivalent substance.

Lapi confirmed that FDA approval means NorthStar is producing an equivalent-concentration substance.

Geesaman invited audience comments. Hearing none, he moved to take a break at 10:09. The discussion reconvened at 10:24.

Aprahamian clarified that the NSAC did not ask the subcommittee to take a stance on HEU versus LEU. She moved to accept the report, except for the statement that a regional approach for producing ^{99}Mo is viable in Canada but not for the U.S., and she said we already have regional approach for Fluorine and others, so she didn't see why a regional approach wouldn't work in the U.S. as well.

Atcher countered that the issue for the U.S. market is not that a regional model wouldn't work, it is that cyclotrons don't have sufficient energy to be able to produce it. One would have to pull out all the cyclotrons currently installed and put in new ones. It is not a distribution problem but an energy problem.

Atcher continued to say that several things had been brought to his attention by the medical field regarding this review. There are issues among people in the nuclear medicine community about the makeup of the committee and whether there was

sufficient expertise to evaluate these projects, particularly in radiopharmacy a second point that had been brought to his attention was that none are board certified radiopharmacists, so we don't understand the regulatory risks associated with some of these projects. Plus, the optics are that a majority of subcommittee members are funded by DOE; there exists the potential for people to 'tread lightly' because they get funding from DOE to support their research initiatives. **Atcher** has also had discussions with members of the community on whether there is any realistic chance that any of the four projects will be successful, given that two of the companies with experience in the field of nuclear science were the first two to drop out, indicative of the potential for failure.

On the issue of supply versus production, **Atcher** said that the Society of Nuclear Medicine tries to be clear that as suggestions for more production come forward, those options are also farther and farther away from the U.S. market. For ^{99}Mo, we lose 25 percent per day when it is in transit because of how fast the isotope degrades, so a closer source is desirable. For Australia: it takes a day to get to the U.S. market; for South Africa, which is proposing to engage now, there will be decay losses that will also confound a full cost recovery goal, because the loss of potent material during transit will have to be made up somewhere down the line. Also: after 9/11, the U.S. closed the borders to radioactive shipments, and the medical community had to petition for radioisotopes coming into U.S. It is important to prioritize consideration of the reliability of the ^{99}Mo supply. The advantage of having the Canadian supplier is they can literally truck ^{99}Mo to Massachusetts across the Chalk River. Something needs to be going on in North America, in terms of ^{99}Mo generation. One of the four industry candidates needs to be capable of supplying that material; there are great concerns in the nuclear medicine community. There was a time when the Missouri reactor produced ^{99}Mo via neutron capture, and time has passed since they were able to do that. Reactor reliability is an important factor. They are operating with HEU fuel. **Atcher** sits on the Science and Technology committee for the University of Missouri; there is a plan on their part to convert to LEU.

Cirigliano said he was struck by the report. He said that another recommendation was to try to trace back where the $25M comes from. How strict is that figure? Is that a contractually binding term?

Seestrom said it was not binding. It is on open market cost recovery. Regarding questions on why the government didn't offer to share more than 50 percent of costs: **Staples** and his team set that number. She said she would let him comment on the impact of raising that number.

Staples said the cost sharing terms were a recommendation the program office would take under consideration. That number is a "gray" marker for industry going forward, and $25M was reaction to the international community about subsidies and followed World Trade Organization guidelines. We didn't take a broad-brush approach as **Seestrom** mentioned. Companies have not shared estimates of anticipated financial losses of getting a large supply operation going.

Seestrom added that the subcommittee considered whether to recommend a loan guarantee program to give companies upfront money. After careful reading of OEC guidelines, it seemed consistent that one could do that. However, Congress would have to change the law, so the subcommittee stopped short of recommending it.

Geesaman asked **Cirigliano** if he had additional comments concerning the adoption of the report.

Cirigliano said that he supported the report but thought the previous concern regarding upfront funding concomitant with legal change should be more fully considered.

Mantica thanked **Seestrom** and the subcommittee, adding that they suitably addressed the charge. Recommendation number two should include the consideration of a 50-50 cost share arrangement. To make such recommendations about industry adoption of ^{99}Mo production is an extreme burden on the NSAC, as a scientific advisory body, especially with it being an annual requirement per legislation. When one looks at the speed at which this situation is progressing, perhaps the annual requirement is unnecessary. **Mantica** said that he agreed with the report.

Nagle thanked the subcommittee and said he was thinking about whether or not to accept the report. To him, there was not enough information available to make it clear whether this was a good plan. The charge was to consider and report on how the plan is being implemented, according to stated goals. The implementation is a set of cooperative agreements that don't clearly show that it is working. He added that it was not clear that was Congress' intent in having the NSAC look at this issue that it seemed more appropriate that they would be asking us to evaluate specific technologies. If Congress is asking us to evaluate business models, **Nagle** said he was not sure the NSAC has the ability to determine whether business efforts were going well or not.

Allena Opper agreed that the charge to the NSAC is awkward. This is beyond its ability.

Geesaman added that the subcommittee was not presented with any of the business models of any specifics of the cooperative agreements.

Opper said that, all things considered, the subcommittee responded well. She moved to accept the report.

Piekarewicz agreed with **Opper**. From the beginning, he was uncomfortable with making this evaluation. The subcommittee did the best that it could. He recommended sending the report forward.

Rossi agreed, thanking the subcommittee for undertaking a difficult job. She said she was a little uncomfortable, too, to make a judgment on the charge. However, given that caveat, especially for recommendation number one, it is very difficult to say which is the most promising cooperative agreement project, because the NSAC had no indication of what is most promising. The strongest industry candidate was still of concern, because they plan to rely on a generator that is not yet available. **Rossi** moved to support the report. She added that **Seestrom** and the subcommittee did a nice job of articulating the ^{99}Mo cycle from producer to user; she found that to be very clear, and it should be included in the report.

Scholberg agreed with what the other members said. She added that she had little expertise in this area and was inclined to support the report.

Schukraft said that his completely unqualified impression was that he would like to abstain from voting.

Shepherd agreed with the previous committee members' comments. After reading the report, he said that he had trouble evaluating the stated goals' likelihood in trying to incentivize a domestic ^{99}Mo producer. In the end, the NSAC was to comment

on whether implementation is feasible or not, but in what sense? Technology-wise? Market-wise? Whether it was feasible for the U.S. to have a domestic supply? He had the same questions as **Nagle**. Overall, though, he moved to accept the report.

Geesaman concluded that the majority of NSAC members accept the report, and that the NSAC will add members to subcommittee as **Atcher** suggests. He asked for further comments.

Hearing none, **Geesaman** directed **Seestrom** to make the discussed corrections, and send them back to the NSAC for final approval of the document. He said the group would move on, to the next time it had to do the report.

Staples said that we have all wrestled with this complicated problem – the technology versus economic standpoint. We have discussed this with Congress in the past week or two; congressional staff understand we have to be carefully positioned in commercial activity, as government. This Congress prefers more commercial and less government activity. Regarding the NSAC's discomfort: **Staples** said that all of the panels feel that way. It is difficult to balance whom has interest in the status quo versus those interested in patient care. Next year, the subcommittee might want to add patient care considerations.

Seestrom said, regarding **Schukraft's** comment: it is better than a 50-50 chance that Tc will be produced. No one is going to meet the time-scale goal, and 3,000 6-day curies are not in the cards for any projects under these circumstances. Would U.S. government activities generate a U.S. supplier? The answer is yes, but not on the desired time scale. The subcommittee looked at examples of technology reviews and scores from tech reviewers; it asked was something not funded in the initial call that dropped because companies couldn't technically do it by 2017. There wasn't anything. So what could NNSA do differently? Other than the two recommendations, everything else was outside the boundary of what the subcommittee could recommend.

NSAC Discussion of Letters of Transmittal for Neutrino-less Double Beta Decay and Mo-99 Charges

Neutrino-less Double Beta Decay

Geesaman asked whether there were any particular points that the NSAC wanted to emphasize in the transmittal letter. He read a draft of a basic letter, starting with the neutrino-less double beta decay topic. His beginning draft stated that the topic was an urgent scientific question of highest importance. It has excellent prospects of major discovery. DOE and NNSF both support this topic. There are difficult experiments to conduct. There should be included a brief background explanation. There should be guidelines for future proposals. He asked if the NSAC wanted to add anything else to the response letter.

Robert Redwine, from the audience said that, on the last sentence, instead of "attempt to quantify," replace the phrase with the more general "attempt to address," as more is going on, in addition to quantification.

There were no other suggestions. **Geesaman** said he would send the draft to the NSAC that night or the next morning for final review. He reiterated that the general sense was that that the draft was ok.

^{99}Molybdenum Domestic Supply

Regarding the ^{99}Mo letter: **Geesaman** said he had modified the second paragraph to correctly document the vote: that the NSAC accepted the report, 5 to 1, with 1 abstention. **Nagle** said to leave it as "5 to 2." **Geesaman** changed the language to "5 to 2."

Geesaman read the letter starting with the basic conclusions in paragraph two. He asked the NSAC whether it should include a statement such as "The charge specifically asked NSAC to review the process used by the NNSA, not the technical feasibility or business models of the cooperative agreement partners." The statement would clarify what the charge actually was.

Opper suggesting clarifying Geesaman's statement by changing, "business models" to "the economic viability of the partners".

Geesaman said he thought the original statement captured that. Then he added that, "the report is called for once a year." **Hallman** said yes, the report is asked for once a year by the Secretary of Energy.

Seestrom read the charge to confirm the once-a-year direction.

Geesaman asked the NSAC whether it wanted to indicate what it would do next. Should it state that it would continue to seek input from the community as this process evolves? He said the NSAC would want to make clear to the community that this is not the end of the discussion.

Seestrom said that **Geesaman** could state that this is an opportunity for agencies to fine-tune the charge, if this charge didn't generate the right responses.

Geesaman said he didn't think it was appropriate to suggest that the NSAC had been given "a bum charge."

Seestrom said that she sensed that some NSAC members thought it could be better worded.

Nagle asked whether there was some nice way to say it, such as "…to maximally utilize the expertise of nuclear physics community."

Gillo said that she heard mixed messages from the NSAC: some members said they had inadequate technical capability to answer the charge, but a few others said that they wanted to delve more deeply. The NSAC has limited visibility into NNSA's technical processes.

Geesaman asked if **Gillo** was ok with the two lines added, at the end, about input from the community. **Gillo** said yes.

Shepherd re-read the charge, emphasizing the phrase, "…programmatic goals for establishing a domestic supply." He asked to what extent the report had addressed supply versus production.

Geesaman said the answer was both and that everyone was well aware of the distinction. It is feasible that there will be a domestic supply. The risk is not having a U.S. supplier for all reasons articulated by **Atcher**.

Shepherd pointed out that the charge letter stated, "domestic production."

Geesaman added to **Seestrom**: "It should say 'supply." He thanked **Shepherd** for the correction.

Aprahamian noted that supply is available without international risk. The U.S. production was the risk.

Seestrom said we think there is a good chance there will be a sufficient U.S. supply. There are bigger risks in trying to accelerate the development of a domestic supplier. There may be risks in domestic production.

Geesaman made changes to that effect.

Hallman said that he had the impression that the GTRI mission was to ensure a domestic supply, rather than to accelerate domestic production. In the letter, "accelerate domestic supply" seems not what we are trying to accomplish.

Geesaman said he noted that was an issue to work on for this letter. He added that the final draft of the transmittal letter was not needed until the NSAC had approved the final report.

Geesaman then invited final comments from the NSAC and from the audience. There were none.

Geesaman expressed deep appreciation to **McKeown** for work on the double beta decay charge and to **Seestrom** for work on the ^{99}Mo charge. He said that the subcommittee chairs had put much effort into answering the charges. The agencies don't give simple problems. All the work they did was truly needed.

Geesaman said he was looking forward to working with the entire community as they develop the long-range plan. The community is positioned to make a strong case for its science and where the field goes forward, as well as why the field is important, more broadly, for the nation.

PUBLIC COMMENT

None

CLOSING REMARKS AND ADJOURNMENT

NSAC Chair Geesaman adjourned the meeting at 11:23 a.m. EST.

The minutes of the U.S. Department of Energy and National Science Foundation Nuclear Science Advisory Committee meeting, held at the DoubleTree by Hilton Hotel in Bethesda, Maryland, on April 24-25, 2014, are certified to be an accurate representation of what occurred.

Donald Geesaman
Chair, Nuclear Science Advisory Committee