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

PUBLIC MEETING MINUTES

American Geophysical Union
2000 Florida Avenue NW, Washington DC, 20009

October 15 - 16, 2015

NUCLEAR SCIENCE ADVISORY COMMITTEE
SUMMARY OF MEETING

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) was convened at 9:00 a.m. EST on Thursday, October 15, 2015, at the American Geophysical Union, Washington DC, by Committee Chair Donald Geesaman.

Committee members present:

Donald Geesaman, Chair	David Hobart	Patrizia Rossi
Vincenzo Cirigliano	Suzanne Lapi	Kate Scholberg
Abhay Deshpande	Jamie Nagle	Jurgen Schukraft
Frederic Fahey	Filomena Nunes	Matthew Shepherd
John Hardy	Erich Ormand	Raju Venugopalan
Karsten Heeger	Jorge Piekarewicz	John Wilkerson

Committee members unable to attend:
Michael Weischer

NSAC Designated Federal Officer:
Timothy Hallman, U.S. Department of Energy (DOE), Office of Science (SC), Office of Nuclear Physics (ONP), Associate Director

Others present for all or part of the meeting:
Cyrus Baktash, DOE ONP
Ted Barnes, DOE ONP
Denise Caldwell, National Science Foundation (NSF)
Julie Carruthers, DOE SC
Adrian Cho, Science Magazine
Emily Conover, American Physical Society
F. Fleming Crim, NSF
David Dean, Oak Ridge National Laboratory (ORNL)
Patricia Dehmer, DOE SC
Jerry P. Draayer, Southeastern Universities Research Association (SURA)
James Dunlap, Brookhaven National Laboratory (BNL)
Rolf Ent, JLab
George Fai, DOE ONP
Jehanne Gillo, DOE ONP
Glenn Fox, Lawrence Livermore National Laboratory (LLNL)
JoAnne Hewett, Stanford Linear Accelerator Laboratory (SLAC)
Ken Hicks, NSF
Andrew Hime, Pacific Northwest National Laboratory (PNNL)
Mary Hockaday, LANL
Barbara Jacak, Lawrence Berkeley National Laboratory (LBNL)
Josh Klein, University of Pennsylvania
Paul Mantica, Michigan State University (MSU)
Manouchehr Farkhondeh, DOE ONP
Bob McKeown, JLab

Brian Meadows, NSF
Bogdan Mihaila, NSF
Russell Moy, SURA
David Nguyen, University of Texas-Arlington
Allena K. Opper, NSF
Andreas Piepke, University of Alabama
Andrea Pocar, University of Massachusetts-Amherst
Robert Redwine, MIT
Don Rej, LANL
Lee Schroeder, LBNL / TechSource
Jim Shank, NSF
Brad Sherill, MSU
Michelle Shinn, DOE ONP
Jim Sowinski, DOE ONP
Alan Stone, DOE Office of High Energy Physics
John Warren, JLab
Scott Wilburn, LANL
Sarah Wilk, PNNL
Boleslaw Wyslouch, MIT

OCTOBER 15, 2015

OPENING REMARKS

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) was convened at 9:00 a.m. EST on Thursday, October 15, 2015, by **Committee Chair Donald Geesaman**. The meeting was open to the public and conducted in accordance with Federal Advisory Committee Act (FACA) requirements. Attendees can visit http://science.energy.gov for more information about NSAC. Geesaman highlighted the recipients of the 2015 Nobel Prize in Physics and those on the NSAC who participated in the prize winning research.

PRESENTATION OF THE 2015 NSAC LONG-RANGE PLAN

Donald Geesaman presented the 2015 NSAC Long-Range Plan (LRP) for Nuclear Science, *Reaching for the Horizon*. Details can be found at http://www.phy.anl.gov/nsac-lrp.

Twentieth century nuclear science is about probing nuclear matter in all of its forms and how technologies that support nuclear science can best serve society. Nuclear science has been guided by NSAC long range plans since 1979. The LRP was guided by a working group of nearly 60 members. It started in June 2014 and met several times leading up to today's presentation.

The 2007 Plan included recommendations for new construction. Since then, many efforts have taken a significant step forward.

Geesaman shared each recommendation from the 2015 Plan and the science possible with the fulfillment of each recommendation.

Recommendation one notes that progress since the 2007 LRP has reinforced U.S. world leadership in nuclear science. The highest priority in the 2015 Plan is to capitalize on past

investments such as the JLAB 12-GeV Upgrade, the Facility for Rare Isotope Beams (FRIB), Relativistic Heavy Ion Collider (RHIC), and the Large Hadron Collider (LHC). Compelling questions also include understanding the origin of matter and the nature of dense matter. Recommendation two describes the excess of matter over antimatter in the universe as one of the most compelling scientific mysteries. Observing neutrinoless double beta decay (NLDBD) in nuclei would demonstrate that neutrinos are their own antiparticles and would have profound implications for understanding the matter-antimatter mystery. Observing NLDBD would suggest that a new mechanism for mass generation other than Higgs is at work and could give evidence for leptogenesis to explain the preponderance of matter over antimatter in the universe.

Neutrino masses give other information. NLDBD results are desired on the same time scale as direct measurement, long baseline neutrino oscillations, and cosmology as tension between the results could point to other important issues. The U.S. could lead the most promising ton-scale experiments with international and multi-agency collaboration.

Recommendation three notes that gluons that carry the strong force bind quarks in nucleons and nuclei, and generate nearly all of the visible mass in the universe. Despite this importance, fundamental questions remain about gluons' role in nucleons and nuclei. Questions can be answered only with a powerful new Electron Ion Collider (EIC) giving unprecedented precision and versatility. This instrument is enabled by recent advances in accelerator technology. The EIC can address science questions proposed by the community and that have not been addressed by other international facilities, such as the Hadron-Electron Ring Accelerator (HERA) at DESY.

Recommendation four is to increase investments in small-scale and mid-scale projects, and initiatives to enable forefront research at universities and laboratories. This comes after a time where there has been little investment in projects of this size.

NSAC has been asked to identify scientific activities and recommend levels of resources. Geesaman shared that there is long-standing trust with the DOE and NSF and that they will seek to support NSAC recommendations.

The LRP proposes a theory initiative to underpin the goal of understanding how nuclei and strongly interacting matter in all forms behave and can predict their behavior in new settings. The initiative includes new investments in computational nuclear theory, the establishment of a national FRIB theory alliance, and expanding topical collaborations.

Another initiative is vigorous detector and accelerator research and development (R&D) for NLDBD and the EIC.

The LRP proposes developing a workforce trained in cutting-edge science as a vital resource for the Nation, and that NSF and DOE take steps to fulfill this goal.

U.S. research relies on offshore facilities. There are U.S. users of foreign facilities and a dependence on experimentation conducted by these facilities.

The LRP recognizes funding constraints and the need to make hard choices. It proposes sequencing projects in a natural way to support the lifecycle of a project. FY15 – 18 budgets are as proposed in the 2013 Implementation Plan. This is consistent with the FY16 Presidential Budget Request. The proposed ton-scale NLDBD effort would begin near the end of this decade after FRIB peaks. EIC construction would begin once FRIB construction ends. Budget recommendations are made with proposed modest growth in the DOE budget and similar growth

in the NSF budget. When NSCL transitions to FRIB the NSF budget will see decreasing costs for NSCL and a shift of funds is proposed to small and mid-scale projects.

A constant effort budget at the FY15 budget level would lead to more difficult decisions. In the scenario considered by the LRP, the constant effort budget can fund a sustainable nuclear science program but may present more difficult choices in five to six years' time.

DISCUSSION OF THE 2015 NSAC LONG-RANGE PLAN

There were no comments from the NSAC on the LRP.

Joshua Klein asked about the budget proposed in the LRP. **Geesaman** clarified that the figures reflect the actual Congressional FY16 budget. **Tim Hallman** added that constant effort is defined by government inflators with a rate of 2.1 and 2.6 percent.

Jurgen Schukraft commented as a member of the public and not as an NSAC member. He commended the way that the LRP has received input and formed consensus and commented that this approach is one of the reasons why nuclear physics in the U.S. is much better off than in Europe.

Filomena Nunes called for vote to accept the LRP, **Abhay Deshpande** seconded, and the NSAC accepted the LRP unanimously.

NATIONAL SCIENCE FOUNDATION MATHEMATICAL AND PHYSICAL SCIENCES OVERVIEW

F. Fleming Crim, Assistant Director for Mathematical and Physical Sciences (MPS), shared that the FY15 budget has concluded but is currently under continuing resolution. Work has been done on the FY16 budget.

NSF supports fundamental research. MPS supports 44 percent of NSF physical science research and 62 percent of NSF mathematics research. Since around 1970, there have been two NSF budget growth periods. The most recent was between 1998 and 2004. Since the American Reinvestment and Recovery Act (ARRA) around 2009, the NSF budget has been relatively flat.

MPS' budget has grown from $1250M in FY13 to $1300M in FY14 and is $1337M in FY15. It is the largest of NSF directorates. NSF's total budget for FY15 was $7344M with Research and Related Activities (R&RA) at $5934M. The FY16 request is $7724M. R&RA is $6186M.

Crim highlighted specific MPS investments for FY15. Some are formal initiatives that reach across Directorates. There are major investments with a lot of activity but these are only about six percent of the budget.

Proposed growth in mid-scale research is part of MPS' investment outlook from FY15 to FY16. The physics community has called for greater mid-scale investment, dating back to a National Science Board report in 2002 and subsequent reports.

Major Research Instrumentation (MRI) is defined as projects larger than the limit of $4M and smaller than the Major Research Equipment and Facilities Construction (MREFC) threshold which starts at $130M, equal to 10 percent of a Directorate's budget. There is a gap and opportunity for investment between $4M and $130M. Proposals for three divisions including PHY have demonstrated that there is pent-up demand for funding amounts in this space.

MPS previously funded projects in this gap. NSF MPS Physics (PHY) takes the approach that proposals should undergo merit review, be a great opportunity, and reflect community priorities. Projects can cost up to $15M and run over several years. There are currently five projects receiving about $2M per year.

Crim commented on the 2015 NSAC Long-Range Plan (LRP). MPS PHY supports recommendation one calling for capitalizing on investments from the 2007 Plan. MPS is interested in recommendation two, the ton-scale NLDBD. Recommendation three proposes a polarized electron-ion collider after FRIB and this reflects Jefferson Laboratory (JLab) and RHIC planning. Recommendation four for small-scale and mid-scale project support reflects an MPS priority amidst budget constraints.

Discussion

Karsten Heeger asked how nuclear physics may grow over next decade. **Crim** noted that early discussions about mid-scale work projected that there would be an appetite for this. PHY has about $40M for this area and that is MPS' target. MPS will not come near that level of funding in current budget scenarios but seeks to grow it each year. **Crim** would like to grow funding to just over $30M then $35M over the next few years with small percentage increases.

DOE OFFICE OF SCIENCE OVERVIEW

Patricia Dehmer, Acting Director of the DOE Office of Science (SC), shared that DOE is under a continuing resolution. DOE and SC also live with marks and language that were done for the FY16 budget. This presents some constraints and impacts programs, including SC Nuclear Physics (NP). SC is also thinking about the debt limit and debt ceiling.

SC's Cherry Murray has been nominated by DOE Secretary Moniz to be the Director of SC. Her hearing will take place next week. Dehmer elaborated on Murray's background. Many previous Directors have specialized in condensed matter physics.

The 2015 NSAC LRP has been briefed to staff from the U.S. House and Senate Appropriations Subcommittees on Energy and Water Development (HEWD, SEWD), respectively, by SC Associate Director Tim Hallman. Staff members asked many questions and showed significant support for the LRP. Staff can be difficult at times but were engaged and receptive of in-depth presentations of NLDBD, proton-spin, hot, dense nuclear matter, and the search for the path and site of the r-process. They were impressed with the level of community collaboration and support, the demonstration of accomplishments since the 2007 Plan, and that the 2015 LRP builds on the 2007 Plan. The LRP shows that the community has carefully thought about strategic direction and has avoided the need to make radical changes.

The LRP projects a steady budget growth of 1.6 percent per year above the level of inflation. This is a stretch for offices in SC in general as they have not grown at this rate. Looking back to 2006 and 2007, NP has done well and grown at around this rate, 4 percent per year in as-spent dollars. Dehmer believes that this is because NP and the nuclear physics community always have something exciting to show and that Federal stakeholders are attracted to exciting science.

Discussion

Geesaman appreciated acknowledgement that House and Senate committees have supported NP dating back to 2006 and 2007.

Klein noted that the rate of scientific inflation is important for U.S. science in general and asked if SC has a sense of the main driver of why that is higher than the general rate of inflation, especially when scientific funding in other countries seems to be flatter. **Dehmer** thinks that a main driver is increasing overhead costs at laboratories.

U.S. DEPARTMENT OF ENERGY NUCLEAR PHYSICS OVERVIEW

Tim Hallman, Associate Director of ONP, shared the NP mission and scientific challenges that are part of the work that DOE does in the field. The community supported by NP spans universities and laboratories across the U.S.

Completion of the FY15 LRP has been a grass roots process that originated with the community and space was allowed for all to give input.

The NSAC Isotope Strategic Planning Exercise was completed. A report was released on July 20. Recommendations included significant R&D funding increases, creating a stable isotope capability, increasing infrastructure investments and the operating base, and continued university facility integration. Isotope production is a program for all of DOE and important for NP.

The 12 GeV CEBAF Upgrade at JLab is 96 percent complete and a significant accomplishment for the NP and the community.

RHIC machine performance is continuing to set new records achieving greater luminosity and providing a foundation for a vital scientific program. RHIC is world-leading and is currently the only polarized ion collider in the world.

FRIB civil construction progress continues strongly, is 10 weeks ahead of pace, and is nearly 50 percent complete as of September 2015. The tunnel within the building is complete.

Hallman believes that NP has done well due to community partnership with DOE, effective planning by the community, and its ability to execute on the plans that it makes.

FRIB Theory effort and instrumentation concepts are getting underway to include a FRIB Theory Alliance.

ATLAS facility capabilities at Argonne National Lab continue to grow to meet research goals on the heels of upgrades. The GRETINA detector is being used to look at the gamma ray spectrum of the nucleus. One example of science being done is the Coulomb excitation of unstable nuclei with beams from CARIBU for structure studies of neutron-rich nuclei. ATLAS is envisioned as continuing to be a world-leading stable beam facility in the out years, complementary to FRIB.

NLDBD is an important recommendation of the LRP. There is a world-wide race to show the feasibility of a ton-scale experiment and why the neutrino mass is approximately nine orders of magnitude smaller than the masses of other particles. There is opportunity to support demonstration efforts and then down-select to a large ton-scale experiment. NP will be the steward of this experiment. Experiments are driving toward showing feasibility and movement toward understanding sensitivity limits.

The LRP also articulated that the construction of a future EIC is a priority following the completion of FRIB construction. This drives toward understanding Quantum Chromodynamics (QCD). Different approaches being used at RHIC and JLab are ultimately driving toward understanding what is happening in low momentum fraction in the proton and how the gluons behave and generate mass in the proton.

NP trends show that construction has consumed a larger portion of NP funds from FY08 through FY15. This has put pressure on other parts of the budget. Major Items of Equipment have gone to zero and research is constrained. NP recognizes that the research percentage needs to be built up once construction goals near completion. This echoes LRP recommendation four.

Future Mid-Scale Instrumentation support includes GRETA at FRIB, MOLLER at JLab, and sPHENIX at RHIC. MOLLER and sPHENIX have undergone successful science reviews and discussions about next steps are underway.

NP is addressing topical theory collaborations with a start of a new cohort of three initiatives in FY16. Three topics have been selected through peer review and community discussions.

The Isotope Program is supported by NP. It produces and distributes isotopes in short supply. There were more than 225 customers in 2015 with more than 400 shipments. **Jehanne Gillo** leads the DOE Isotope Program. This has brought about benefits such as pointing out new avenues for the use of isotopes in areas such as medical research. The field is opportunistic and takes advantage of other facilities that are supported for other missions. The effort seeks to identify ways to meet national needs and requires clever strategies. A workshop on November 9, 2015, will gather multi-agency participants to assess current isotope requirements.

An earlier study identified the need for a domestic stable isotope production capability. The current inventory is at Oak Ridge National Laboratory. It was produced between 1945 and 1998. Once isotopes in this inventory are used, the U.S. must rely on foreign supplies. Already, 11 isotopes have been exhausted. Research is examining how to build a Stable Isotope Production Facility (SIPF) at ORNL, and mitigate dependence on foreign production and fulfill DOE's isotope production mission.

The NP FY16 budget request is $625M. This is an increase of $29M over FY15 with the largest increases coming in Research and User Facility Operations, respectively. Increases address specific needs to include support for CEBAF and RHIC operations and facilities.

Hallman shared additional DOE NP news to include position openings and the acquisition of new personnel. An urgent need is the identification of a program manager for Nuclear Structure /Fundamental Symmetries.

A workshop produced the report "Nuclear Data Needs and Capabilities for Applications" and Hallman urged that NSAC read this report.

NP is leading a discussion on the establishment of a pan-Federal communication / coordination forum on Nuclear Data. Hallman encouraged that all participate to identify effective coordination.

Hallman announced that NP published a proposal deadline of December 31, 2015, for FY16 funding of proposals containing new scope by the Physics Research Division.

Discussion

Geesaman asked when NP will obtain a mission need decision for ton-scale NLDBD experimentation. **Hallman** felt that this deserves collective discussion in NP and suggested that this could take two or three years before there are results from demonstration projects. **Gillo** added that a first step is learning more from the NLDBD report. Getting a CD0 before the report would not make sense as it might require going back to make changes. The NSAC process is helpful to NP. A funding path needs to be identified. NP would have to think carefully about having a down-select first and supporting one project, or having a CD0 before a down-select and supporting many projects. The first step is getting results from the NSAC NLDBD Subcommittee report.

Jorge Piekarewicz highlighted the value of topical theory collaboration as it gives great value and also engages young researchers. In the LRP, there is hope that here will be sustained collaborations. **Hallman** noted that NP appreciated that there is strong support for topical collaborations in the LRP. The three shown at this time are what NP can accommodate at this time.

Andreas Piepke asked about ton-scale NLDBD down select timing, if NP has considered shortening the time frame by proposing a deadline for community input, and adding to this the

need to remain globally competitive. **Hallman** clarified that the timeframe is based on what he has learned through discussions and that NSAC will hear more from **Bob McKeown**. It is important not to preclude anyone who may be developing a viable technology and **Hallman** recognizes that the community wants to know more about the timeframe.

Lee Schroeder highlighted the need for discussion with DOE Advance Scientific Computing Research (ASCR) regarding exascale computing. **Hallman** shared that ASCR does this with other program offices to identify needs and has talked about engaging NP in June 2016.

Hallman replied to **Geesaman's** interest in knowing how the Nuclear Data Advisory Committee he discussed operates. It was suggested by John Wilkerson that the Nuclear Data Advisory Committee work more strategically and gather community input to identify opportunities that could and are not being addressed. Opportunities are addressed based on peoples' interest and availability. **Ted Barnes** clarified that this is a matter of looking at the most important opportunities that can be addressed within fiscal constraints. When new ideas emerge, the Nuclear Data Advisory Committee can assess what is going on and how to address opportunities. There were nine major recommendations brought about in the Nuclear Data review in 2014. These will be brought forward to the committee. **Geesaman** suggested that it would be helpful to know the recommendations from 2014. **Barnes** could share details with NSAC. **Hallman** responded to **John Wilkerson's** idea that the committee could be an NSAC subcommittee. This is new territory and would make the committee very formal. The approach is open to discussion. The committee is broad. It includes a large group who use nuclear data.

NATIONAL SCIENCE FOUNDATION NUCLEAR PHYSICS OVERVIEW

Allena Opper, Program Director for the NSF Experimental Nuclear Physics Program (PHY) shared that the NSAC LRP has emerged through strong collaboration between PHY and NSAC.

There are significant research accomplishments made possible through NSF funding. Florida State University research has identified new γ states in ^{19}O. At the University of Notre Dame, research in astrophysics is addressing unknowns in the Hoyle State. Transverse Wobbling and new collective motion is being examined and has been observed at Notre Dame. At NSCL at Michigan State (MSU), a major milestone has been passed – the Reaccelerator Facility is now operational and two experiments have been completed with that facility. The first experiment investigated single particle states in argon isotopes. The second experiment looked at fusion-fission reactions that may lead to a path to long-lived super heavy nuclei. NSCL's Low Energy Beam Ion Trap is contributing to nuclear structure, nuclear astrophysics, fundamental interaction and symmetry tests. Additional work at MSU determined that 30% of the ^{26}Al in the Milky Way comes from novae.

At the FROST experiment at JLab, more than 900 data points of double-polarization observable E have been taken. At Fermilab, the SeaQuest experiment is functioning as expected and will lead to improved d_bar / u_bar ratios in the proton very soon. The NSF-MRI funded muon trigger for PHENIX has led to an extremely large data set of W-bosons that are being combined with STAR data to constrain quark and anti-quark helicity distributions.

There are nuclear physicists involved in the new Muon g-2 work at Fermilab. The storage ring magnet has been installed. MiniBooNE has published its final neutrino interaction results.

MPS funding trends show a relatively flat budget since ARRA in FY09. PHY funding for FY16 is expected to be slightly higher than FY15 ($275M). The total for Nuclear Physics grew from $48M to $51M from FY14 to FY15. PHY funding is distributed among operations, M&O

for facilities, the 10 Physics Frontier Centers, for education and broadening participation, and six major areas of physics.

PHY operates under a solicitation and Opper shared deadlines for upcoming program areas. Proposers must follow the Grant Proposal Guide and checklist.

The Focused Research Hubs in Theoretical Physics (FRHTP) is a new funding opportunity. One hub in Fundamental Symmetries, Neutrinos, and their applications to Nuclear Astrophysics will be funded for five years at around $250K to $500K per year. This is intended to support postdoctoral research and hub-related activities. The proposal deadline is January 22, 2016, and Bogdan Mihaila manages this solicitation.

Major Research Instrumentation (MRI) received 24 proposals in FY15 and three were funded. The due date for the next MRI solicitation is January 13, 2016. Proposers should recognize their own internal proposal deadlines at their respective university.

Opper shared the listing of MPS / PHY personnel. She noted that Ken Hicks, Program Director for Experimental Nuclear Physics Program, will return to his home university in August 2016. A replacement is being sought.

Discussion

Opper shared with **Geesaman** that FRHTP is designed to give support for postdocs and hub-related activities. **Mihaila** shared that the focus for the hub was chosen as the LRP pointed out the need for research in this area and the need for small-team research collaborations in nuclear theory. The Nuclear Theory program portfolio balance in this area was also taken into consideration.

Piekarwicz was surprised that the FRHTP announcement called for proposals and the need for hubs, then selecting a topic of interest to NSF. **Mihaila** clarified that NSF tried to be specific and that the hubs are a new idea. There are similar NSF activities in the PHY. NSF supports the Institute for Theoretical Atomic Molecular and Optical Physics (ITAMP) at Harvard and the Center for Quantum Information and Control CQuIC at University of New Mexico. The Division felt that it would be beneficial to formalize this type of activity without making promises that it could not keep. The solicitation is open for any PHY program and is guided by community input. The FY16 solicitation is limited to Quantum Information Science and Nuclear Theory.

Filomena Nunes described the FRHTP as a great opportunity to increase the number of postdocs. There are similarities with topical collaborations and asked if the hubs would represent a single institution or more than one. **Mihaila** confirmed for **Nunes** that the hubs could represent a single institution or more than one. The community could define this and propose it to PHY.

Raju Venugopalan suggested that the hub concept does not invalidate the need for a peer review process. He hopes that PHY will consider this. **Mihaila** noted that everything that PHY does goes through peer review.

Mihaila clarified the difference between the DOE topical collaborations and PHY's FRHTP. DOE seeks to advance science through community collaboration. FRHTP is focused on postdoc support. A previous COV suggested that there is insufficient funding for postdocs.

McKeown noted that LRP recommendation four calls for an increase in mid-scale instrumentation support and he hopes that has a positive influence on that NSF funding. He then referred to an NSF committee that responded to the P5 report (produced by the DOE/NSF High Energy Physics Advisory Panel) that led to increased support in elementary particle physics

midscale instrumentation. **Opper** shared that the MPS Advisory Committee (MPS-AC) is a standing committee that provides advice and recommendations to the directorate. After the latest P5 report came out a sub-committee of MPS-AC was charged to advise MPS on how to respond to P5 to maximize science impact. The NSF mid-scale investments at LHC were in progress before the P5 report came out and were not a result of the MPS-AC subcommittee's work. She is not aware of plans to charge the MPS-AC with anything related to the LRP. The community has been responsive to identifying opportunities with specific funding levels and the LRP is very focused.

PRESENTATION OF CHARGE FOR THE DOE NP COMMITTEE OF VISITORS

Timothy Hallman presented a charge to the NSAC to conduct a DOE Committee of Visitors (COV) exercise to review the management processes of the DOE SC ONP. The COV will look at the processes used to solicit, review, recommend and document proposal actions and monitor active projects for DOE laboratory and university programs.

The review will include the evaluation of the efficacy and quality of processes used to solicit, review, recommend, monitor and document application, proposal and reward actions. It will include reviewing the quality of the portfolio, its depth and breadth, and its national and international standing.

The COV process occurs approximately every three years and responses go onto the DOE website. It serves to guarantee that DOE does its best to serve the community.

Geesaman shared that **Gail Dodge** at Old Dominion University has agreed to chair the COV. The site visit to DOE will be at the end of January 2016. The expectation is that the report will be available around the end of February 2016. An NSAC meeting will hear the report in March 2016. Several NSAC members' appointments will end in March. **Geesaman** does not believe that the schedule can be pushed to have an NSAC meeting earlier in the year.

Frederic Fahey asked about the schedule. **Geesaman** clarified that it takes about one month after the site visit to compile and finalize the report.

PRESENTATION OF THE NSAC NEUTRINOLESS DOUBLE BETA DECAY REPORT

Bob McKeown of JLab presented the NSAC NLDBD Subcommittee report. The charge called for giving guidance to DOE and NSF on implementing a second-generation experiment on NLDBD capable of reaching the sensitivity needed to know if the neutrino is a Majorana or Dirac particle under an inverted hierarchy mass scenario.

The charge came in April 2015 and proposed assessing ongoing R&D for a ton-scale experiment, identifying major R&D needed to demonstrate the down select criteria, and the time durations and resources needed for this.

McKeown explained the NLDBD process. Experimental issues can include the need for good energy resolution and low background to help observe a peak in summed beta energy.

More is known today about non-zero neutrino mass. The present limit from tritium decay is < 2 eV. The Higgs mechanism has been shown to be unlikely for neutrino masses, and that the "see saw" is the most common alternative.

Neutrino oscillation experiments measure the difference in squared masses. They have also determined the m1 is less the m2, but it is not known if m3 is the lightest or heaviest of the three neutrinos.

The Klapdor-Kleingrothaus claim of an observation of NLDBD from 2004 has been ruled out by recent results. New work in cosmology has also added to the understanding of neutrino mass.

Neutrino oscillation experiments continue, including the T2K experiment in Japan and NovA at Fermilab. Results from both show a preference for the normal hierarchy, but are not very definitive at the moment. This will become clearer as the experiments continue. There are new experiments planned to include PINGU, JUNO and RENO50 all trying to measure the mass hierarchy by the end of this decade.

The limits from Cosmology are also improving. K Azerbajian from the University of California-Irvine made a presentation to the NLDBD Subcommittee. In the next three to five years, improved results are anticipated.

McKeown explained the impact of possible sterile neutrinos. Several pieces of data seem to suggest evidence for an eVsterile neutrino. There are experiments being proposed to confirm and refute current interpretations.

If an eV mass sterile neutrino does exist, the normal ordering of neutrino masses can be explored by ton-scale experimentation. Previous plots that reflect current research could be altered by exploring the science case behind NLDBD.

McKeown also noted the opportunity for new physics possible through LHC experiments.

The subcommittee concluded that there is a unique role to be played by NLDBD in addressing the issue of the Dirac versus Majorana nature of neutrinos.

McKeown pointed out that the subcommittee's guidelines in its first report showed the design of an experiment in the ton-scale to address the inverted hierarchy. Conclusions about the design have not changed.

Background is a major issue. For a background-free experiment, background reduction from current levels is essential. R&D in this area includes factors such as deeper underground sites, improved radiopurity, better energy resolution, and better event characterization. The subcommittee noted this conclusion 18 months ago. McKeown shared that no experiments have gotten to this level yet. He offered an estimate of the background. The NLDBD rate is 0.4 / Tonne – year/region of interest (ROI). To be background free, the work must be < 0.1 / Tonne - year / ROI. The subcommittee identified this number as necessary to for successful ton-scale operation. A key issue is to scale up to ≥ 1 Tonne with low background.

The subcommittee requested details from the projects on the current status and plans of experiments, and the R&D required to be ready for a down select. Seven presentations were made to the subcommittee. Various methods are in use. Common goals are to show background reduction for next generation experimentation and to extend sensitivity. A timeline of construction to operation shows that operations can occur as early as the end of 2015 and as late as 2017. In two to three years, there will be more information from these projects. McKeown shared several next generation approaches being considered.

The technology assessment conducted by the subcommittee examined a status report for each current project, a summary of their R&D plans, and technical issues being considered. Technical issues were sent out to collaborations for fact checking and some have evolved since the issues were sent out. McKeown shared a brief summarization of the proposed U.S. R&D for each of the seven. The total resources needed for R&D is estimated at $11M.

The subcommittee proposes that with one more year of construction, all projects would be in an operational phase that would allow for taking data. All mid-scale experiments are making good progress in setting new NLDBD limits and testing out approaches to be extrapolated to ton-

scale installations. The subcommittee suggested that R&D efforts should be aimed at solving specific technical issues relevant to the down select decision. There are other R&D issues to be addressed that will require longer term investment to further understanding. Support is needed for shorter term R&D aimed at a near term future down select.

The subcommittee suggested that there are common R&D topics that will benefit several techniques. Funding agencies should consider ways to encourage groups to work together to address common goals.

McKeown pointed out that within nuclear theory, there are varying techniques for nuclear matrix elements. Applying modern techniques involves ab initio methods and gives better approximations for heavy nuclei. There is also a larger and broader group of nuclear theorists interested in working on this. They are interested in applying more diverse methods in a systematic way. The subcommittee believes that this approach has evolved since its last report 18 months ago. The subcommittee observed a trend toward increasing and the broadening of the community working on the theory and a move to more modern theoretical techniques. This is a welcome development that could reduce uncertainty in the nuclear matrix elements in the future.

On a global front, the subcommittee proposes that the U.S. maintain leadership in at least one experiment while being open to joining one or more internationally-led projects. Currently, the U.S. should maintain a nimble posture to make a timely decision in the near future.

McKeown shared current modifications being made to the subcommittee report.

Discussion

Patrizia Rossi asked about projects' timelines. **McKeown** noted that SNO+ PHASE 1 is moving forward but technical issues have limited their progress and the timeframe is a little fuzzy. The NEXT 10 group has been slower than anticipated. PANDA III is a new experiment in China that has funds to build something but is mostly just planned at this point. The Majorana Demonstrator is pretty close to early 2016 operational status. GERDA II is making progress. EXO200 Phase II has not been able to start due to an accident. The SuperNEMO Demonstrator in France has some U.S. involvement that seems to be a small collaboration. CUORE is in good shape to become operational in early 2016. KamLAND ZEN has been running but the operational phase will come to greater fruition with recent technical modifications in early 2016.

McKeown confirmed for **Fahey** that the timeline came from the presentations by each project and was confirmed by projects.

Rossi urged including data on the different isotopes being used by each project, isotope mass, and current levels of achievement. **McKeown** shared that this is a good suggestion and that the data should probably be sent to the projects for confirmation.

Nunes expressed concern that the timeline for operations activities is a little slow based on the projections shared in the report 18 months ago. She noted that some collaborations do not have a strong sense of what the background looks like, and proposed including more forceful language that urges projected numbers at a minimum that are needed to go forward. **McKeown** shared that there has been a reluctance to put together data that compares things and suggests a down select. The community is sensitive to how information is presented. Current project data such as R&D are not shown in the current report as it might suggest comparisons and force people to draw premature conclusions. Readers can find data in the report and make tables themselves but the subcommittee was not inclined to highlight this.

Fahey added that the term "down select" appears several times but there is no time frame proposed for a down select and if it would identify several projects or just one. **McKeown** recognized the concern and offered that at least one project suggested that there is no need to wait. The community could pose various responses to this. The subcommittee felt that waiting for one year or so would give more information from which to draw conclusions. At present, there is no precise algorithm on which to base a down select decision.

Nunes noted that KamLAND, as an example, is ready to run and that is very significant. Waiting two or three years before down select might diminish the U.S.' ability to lead in this area. **McKeown** noted that addressing ton-scale and the inverted hierarchy effectively would require KamLAND to do more work. Replacing tubes, for example, will not happen quickly. They will be ahead for a while but they will not suddenly go to the sensitivity needed to address the inverted hierarchy.

John Hardy shared that the timeline demonstrates the extent of international collaboration, Many do not care about the U.S. down select as they are funded by other places and do not rely on the U.S. One cannot down select until all of the partners in the game are identified. Real data is needed to differentiate promises from results. This will enable making real decisions.

Jamie Nagle suggested that the report describe how one could prioritize and show criteria for down select. Some projects may not adhere to criteria and address it by a certain point in time. It may be useful to do a review that takes a critical view. **Geesaman** shared that NSF and DOE's desired deliverable from the report was information and a prioritized list of R&D in each project. There is another panel that NSF will convene to make decisions on what R&D to fund based on concrete R&D plans. **Hallman** agreed that **Geesaman's** description is correct. **Opper** shared that proposals will be gathered and assessed. The agencies are coordinating efforts to address the NLDBD challenge and funding opportunities will be announced when details are worked out.

Nunes commented that the closing statement on theory at the end of the report should more strongly note that theory work will do better and that topical collaboration will enable progress. **McKeown** agreed, noting that more about topical collaboration was heard today. He suggested that the NSAC consider adding this.

McKeown responded to **Suzanne Lapi** that projects can share the R&D required to enrich isotopes exists and the technique has been demonstrated. Projects were also asked about pricing and that was in the last report. The fact that this was asked even though it is not in the charge is something that the subcommittee was concerned about. It should be considered in the down select. **Lapi** is concerned that isotope production was not mentioned in the report.

Hobart suggested that background reduction issues include other fields and communities.

PUBLIC COMMENTS

Andreas Piepke pointed out that the EXO200 project has been collecting data for three years and believes that it demonstrates the validity of its method. There is measurement of resolution and background, and associated things.

Andrew Hime asked if the study of common R&D themes could be sorted out by the subcommittee to identify a coordinated approach. **McKeown** shared that the subcommittee can encourage agencies to pursue a method and that pointing out the commonalities in the report has value for the community. Some coordination could lead to a better result.

ADJOURNMENT

The NSAC meeting was adjourned for October 15, 2015 at 5:00 by Chair Don Geesaman.

OCTOBER 16, 2015

The Nuclear Science Advisory Committee (NSAC) was convened at 9:00 a.m. EST on Thursday, October 16, 2015, by Committee Chair Donald Geesaman.

DISCUSSION OF ISOTOPE PRODUCTION

In response to a question on day one about the availability of isotopes, **Jehanne Gillo** told NSAC that DOE had asked **Wilkerson** to work with the community about the isotopes needed for NLDBD. A plan has been developed and submitted to the DOE. The DOE is engaging the community and learning about the role that the Isotope Program could play in supplying isotopes for their needs. **Hobart** asked if the capability can produce isotopes at the ton-scale. **Gillo** shared not yet. DOE is establishing a prototype production capability which will be the first of its kind in the U.S. DOE has obtained CD0 for an upgraded stable isotope production capability. **Wilkerson** acknowledged that one ton of xenon has been produced.

DISCUSSION OF THE NSAC NEUTRINOLESS DOUBLE BETA DECAY SUBCOMMITTE REPORT

Some NSAC members were recused from commenting on the report.

McKeown acknowledged the need to remove the word "small" from the sentence that there is "…small wiggle room…" in the section on cosmology.

Schukraft commented on the scientific development around experiments. **McKeown** clarified that there are experiments being mounted now to address sterile neutrinos. A timescale of around three years for some information is likely. **Heeger** added that there are experiments on the accelerator and non-accelerator side scheduled for 2016. There will be data around 2018.

Schukraft asked about the hierarchy. If a normal hierarchy comes out, then the scientific question will be less defined. He asked about down select. **McKeown** shared that if there is new information, then that changes the probability of identifying a signal and that would change the parameters around down select. Reexamination of the science case may be required. **Geesaman** added that considering the importance of the understanding the nature of the neutrino, there is little question that NLDBD experiments will proceed. The type of experiment may change as there is a less obvious target or due to funding constraints.

Wilkerson commented that the mass of the neutrino is not known. Most people expected small mixing angles but that is now known to be untrue. When looking at plots, the location of zero is unknown and experiments are needed.

Nagle proposed better framing around words such as "few". The report language changes with regard to timeframes and could be more specific or consistent. There is a need to be clear that the report is not prioritizing the experiments and share that agencies will have a process for prioritizing. **McKeown** and **Hallman** agreed that the report could clarify that the report proceeds a possible request for proposals.

Lapi highlighted the need to include the table showing the timeline for experiments. The report should describe isotope production acknowledging that progress is occurring.

Hobart recognized that this is an addendum report to the past report. He would like to see some justification for studying the NLDBD and that NSAC is not the only one looking at this. The report should include an acronym glossary. **Hobart** noted that the experiments' locations should be added. He offered to include information on the potential impact on subfields.

Hardy co-authored the report. He agreed on adding the experiments table and also adding a column indicating which ones care about receiving funding from the U.S. in order to give perspective prior to a down select. For instance, PANDA III is asking for just a small amount of R&D support.

Fahey commented on a bullet point that suggests identifying remaining R&D needs to be shown to inform down select criteria. Criteria is a strong word. It could be substituted with a paragraph recommending needs to be addressed. There is also a need for editing to ensure consistency in the report. **McKeown** noted that the charge for the report did not ask for criteria but did ask for guidelines. **Fahey** agreed that guidelines would be an acceptable approach.

Nunes suggested that the last paragraph of the Executive Summary be more crisply written and indicate that theory will deliver on this topic. The theory section should show that a proposal has been approved for funding

Schukraft suggested that the next draft could emphasize the relevance of international cooperation and competition. **McKeown** pointed out that the report notes international needs several times and agreed that this is an important thought.

Rossi agreed on including the table that shows all of the experiments. **McKeown** shared that the table is from a previous talk. PANDA III, in particular, has a plan but no more detailed information at this time. He acknowledged the need for a table.

Piekarewicz liked the crisp divide between the science case and the challenges. The science is compelling and the community is behind this, shown in particular by support for the LRP. It is also clear that NSAC colleagues are in support of this activity. He urged giving the process a chance and believes that results will come to fruition in two to three years.

Geesaman reviewed the list of changes that he heard. **McKeown** noted the need to include justification for doing the study.

Hobart added that the report shows that more information will be known in the coming years and asked if it should be indicated that there will a follow-up report by the DOE ad NSF. **Geesaman** does not know what the agencies will ask next of NSAC. **Hallman** commented that this is a standing subcommittee. He was impressed with how the last exercise had an impact on experiments' own self-assessments. DOE can use the standing subcommittee as appropriate.

Geesaman and the NSAC reviewed the letter of transmittal that would accompany the report.

PUBLIC COMMENTS

JoAnne Hewett from SLAC appreciated the recognition of NLDBD and its prominence in the LRP. She recognized the completion of the P5 Report by the high-energy physics community and the synergy between nuclear science and high-energy physics that has been created. The agencies should pursue down select as quickly as possible due to the importance of NLDBD.

CLOSING REMARKS AND ADJOURNMENT

Geesaman adjourned the meeting at 9:59 a.m. EST.

The minutes of the U.S. Department of Energy and the National Science Foundation Nuclear Science Advisory Committee meeting, held at the American Geophysical Union on October 15 – 16, 2015, are certified to be an accurate representation of what occurred.

Donald Geesaman, Chair, Nuclear Science Advisory Committee