

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

PUBLIC MEETING MINUTES

**Gaithersburg Marriott
Gaithersburg, MD 20**

April 3, 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 8:30 a.m. EST on Friday, April 3, 2015, at the Gaithersburg Marriott, Gaithersburg, MD, by Committee Chair Donald Geesaman.

Committee members present:

Donald Geesaman, Chair	David Hobart	Patrizia Rossi
Ani Aprahamian	Suzanne Lapi	Kate Scholberg
Robert Atcher	Jamie Nagle	Matthew Shepherd
Vincenzo Cirigliano	Filomena Nunes	Raju Venugopalan
Abhay Deshpande	Erich Ormand	Michael Weischer
Karsten Heeger	Jorge Piekarewicz	

Committee members unable to attend:

John Hardy Jurgen Schukraft

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
Lawrence Cardman, Jefferson National Laboratory (JLab)
Altaf Carim, White House Office of Science and Technology Policy
Leland Cogliani, Lewis-Burke
David Dean, Oak Ridge National Laboratory (ORNL)
Patricia Dehmer, DOE
James Dunlap, Brookhaven National Laboratory (BNL)
Rolf Ent, JLab
George Fai, DOE
Marc Garland, DOE
Jehanne Gillo, DOE
Thomas Glasmacher, Michigan State University
Ken Hicks, National Science Foundation
Barbara Jacak, LBNL and University of California-Berkeley
Ming Liu, LANL
Bob McKeown, JLab
Pete Misty, DOE
Adina Numi, Bracco
Allena Opper, NSF
Mike Osinski, DOE
Dennis Phillips, DOE
Gulshan Rai, DOE
Thomas Roser, BNL
Lee Schroeder, University of California-Berkeley / TechSource

Brad Sherrill, Michigan State University
Michelle Shinn, DOE
Jim Sowinski, DOE
Alan Stone, DOE
Ed Temple, Argonne National Laboratory
Jon Trump, Bracco

APRIL 3, 2015

OPENING REMARKS

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) was convened at 8:30 a.m. EST on Friday, April 3, 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.

U.S. DEPARTMENT OF ENERGY OVERVIEW

Dr. Patricia Dehmer, Acting Director of the DOE Office of Science (SC) gave an overview of the SC FY2016 budget. SC accounts for nearly half of the U.S. Federal funding support of physical science research in the U.S. This furthers U.S. and world leadership in high-performance computing and computational sciences, highlighted by the number of researchers and students, among others, who leverage SC-funded user facilities.

Most SC programs see increased funding in the FY16 request. Increases in Advanced Scientific Computing Research (ASCR) are due to investments in exascale computing. The only decrease is in Fusion Energy Sciences (FES). Additional funding allocated by Congress is not reflected in the budget. Nuclear Physics' (NP) request is \$624,600k, a 4.9 percent increase.

Research funding is about 40 percent of the total SC budget. The Computational Science Graduate Fellowship has been restored. NP research funding has been held flat for several years due to construction at the Facility for Rare Isotope Beams (FRIB) and upgrades at the Thomas Jefferson National Accelerator Facility (JLab). The NP research budget will increase by more than eight percent in FY 2016, an increase supported by the DOE Secretary and the Office of Management and Budget, among others.

Within SC facility operations, facilities will in general operate near optimal. In NP, the Relativistic Heavy Ion Collider (RHIC) will operate for 22 weeks, ATLAS will run for 37 weeks, and CEBAF is supported for continued machine development and commissioning of beam to Halls B and C.

The Linac Coherent Light Source-II (LCLS-II) will reach peak funding at \$200,300k. In NP, FRIB will reach its funding profile peak of \$100,000k. Accelerator commissioning and detector construction of the CEBAF 12 GeV upgrade will continue at \$12,000k. In SLI, top priorities were identified through a year-long project assessment of all laboratories and infrastructure support of \$31,000k has been received.

In Major Items of Equipment (MIE), there will be an upgrade at the Advanced Photon Source (APS). The National Synchrotron Light Source-II (NSLS-II) will see an upgrade in experimental tools of \$15,500k.

NSAC members are urged to support the Presidential Budget Request.

The NSAC 2007 Long Range Plan implementation strategy was presented on January 13, 2013. The recommendations from this strategy were brought up by the House Energy and Water Development Subcommittee on March 17, 2015, in the discussion of a flat budget scenario. Dehmer noted the connection between congressional questions and the subcommittee notation in January 2013. Recommendations can have a long lifetime and re-emerge later. The NSAC was urged to think about the long-term implications of long range plans, and the implications of words such as “shut down.”

Discussion

Donald Geesaman thanked **Dehmer** for her support of the Nuclear Chemistry Summer School, and congratulated her on the FY16 budget. He noted the potential lifetime of words used on reports, the need for sensitivity in planning documents, and the occasional need to punt on decisions.

Jamie Nagle noted that it was not correct that the 2013 implementation report was considering a flat budget scenario, it was considering a big cut followed by a flat budget scenario which reflected a significant further cut.

Karsten Heeger asked how many users at user facilities are from other countries. **Dehmer** shared that the percentage varies from one facility to another but is about 15 percent.

Geesaman noted that in the 2005 NSAC implementation report that if the budget were held flat, a different facility was suggested for possible closure. Fortunately, there was funding to continue with an upgrade. Over time, recommendations need to be reviewed as budgets change. **Dehmer** agreed that recommendations can be overcome by events.

U.S. DEPARTMENT OF ENERGY NUCLEAR PHYSICS OVERVIEW

Tim Hallman, Associate Director of SC, shared NP science and research activities and accomplishments. NP supports more than 90 percent of the nuclear physics research that occurs in the U.S. via individual investigator grants and user facilities.

The NP FY16 research budget has been increased by about eight percent and is uniformly spread across NP’s five research areas. The total budget is \$13,483k higher than FY15. Hallman highlighted high priority research in each of the five areas.

In facility operations, the overall increase for FY16 is about \$13,000k. One increase is the upgrade at JLab. In heavy ions, RHIC will operate for 22 weeks and will see funding for experimental equipment and spares, among other things.

The construction project budget is \$1,000k higher in FY16. The 12 GeV CEBAF Upgrade is it in final year. The FRIB construction funding will peak at \$100,000k. FY16 funding will allow FRIB construction to proceed as planned.

The FY16 budget is strong and positive. NSAC should articulate the value of what this support will bring in terms of knowledge, scientific advances, and junior scientists.

RHIC performance in 2014 set new records. Luminosity reached new peaks beyond the accumulation of all previous runs. There are continuing scientific questions for RHIC to include knowing more about the initial state of the new matter discovered. The approach of the QCD phase diagram is not yet known, and what jets and heavy flavors can show with regard to the structure of the strongly coupled QGP is still unknown. The other scientific thrust at RHIC is the spin program. Research suggests where the proton spin originates and the relationship to gluons.

Science at JLab impacts varied aspects of nuclear science to include understanding if nuclei have neutron skins. There are connections that go beyond knowing about nucleons. Hallman

noted new research results from Hall D, and results from the study of longitudinally polarized electron scattering from unpolarized deuterium. Hallman noted the new construction at Hall D and data that shows that the capability exists to do incredible science. The 12 GeV CEBAF Upgrade is more than 90 percent complete, enabling the search for exotic new quark anti-quark states.

The JLab urgent 21st century scientific questions were presented.

Both RHIC and the JLab work suggest the value of a high energy high luminosity polarized electron ion collider.

The new interest at ATLAS is radioactive isotopes that can be provided via CARIBU. New measurements of the mass of neutron-rich isotopes is being understood and is guided by theoretical understanding. CARIBU is expected to go much further with improved performance.

The future of nuclear structure and nuclear astrophysics is tied to the FRIB. Hallman described progress on FRIB construction showing the structural steel that will cover the tunnel that has been built, painted and into which cement has been poured. FRIB construction has taken place in the span of about 54 weeks and is continuing very rapidly.

FRIB will be unparalleled once operational. Hallman shared how outcomes will advance clarity of new isotopes, how protons and neutrons form the structure of a nucleus and what to expect for the nuclear structure, and how structure changes as protons and neutrons are added.

The Neutrino-Less Double Beta Decay (NLDBD) experiments are being stewarded by the NP within DOE. Demonstration efforts are taking place with data coming in several years.

Nuclear theory underpins everything and is the key to progress. NP started another round of an FOA for topical theory collaborations, based upon positive outcomes from the first FOA concerning the ability of theoretical groups to collaborate in this novel new way to tackle urgent scientific questions within a limited time horizon.

The DOE Isotope Program produces and distributes radioactive and stable isotopes that are in short supply, maintains the infrastructure for producing and supplying isotope products, and does R&D on new production and processing techniques to make new isotopes available. Hallman discussed the key isotopes and radioisotopes, and the companies and Federal government offices that use isotopes. IP has managed to get almost all Federal offices to estimate the amount needed in order to provide better scheduling and production output.

When the isotope program came to NP, it started a new research component which has proven to be very important. A hot topic stemming from isotope research is alpha emitting isotope production. Alpha emitting isotopes deposit radiation very locally in the tissue in which they are placed without damaging tissue that is further away from the site of the isotope. This makes them potentially of great interest for treating certain types of cancer.

The science being done in NP and SC touches on the understanding the nature of the universe and represents a diverse portfolio with opportunities for young scientists.

SC has been using NSAC to develop long range plans since 1979 and is undergoing that process again now. The 2015 long range plan will be finalized soon.

Hallman noted that part of the nuclear physics outlook is understanding how an electron-ion collider can be the path toward new opportunities in QCD research. 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

Robert McKweon noted that the DOE NP has no MIE projects in the budget at present, asked if this should be discussed in the long range plan, and if the NP could make room for such

projects. **Hallman** shared that this is an area of concern. There has been a push to build facilities; hence research and MIE implementation have been stressed. A lack of MIE projects is not sustainable. NP present and future facilities are concerned with the lack of MIEs and all have well-developed plans for instrumentation they will need. Communities should be patient with the progress as not everything can be accomplished at once. **Geesaman** added that there is time set aside for MIE discussion at the Long Range Plan meeting.

Ani Aprahamian asked about plans for the infrastructure item that **Dehmer** mentioned in her talk, the need to support facilities, and if there are concrete plans going forward. **Hallman** shared that these initiatives generally arise from the labs and do not necessarily come through the NP office, but the Scientific Lab Infrastructure (SLI) program. NP is currently benefitting from this support, most recently from investments made at JLab. Brookhaven management and SC are discussing ways to improve infrastructure and services for users. Most labs would like a bigger SLI budget, especially if it did not take money out of the NP program. **Hallman** shared with **Aprahamian** that university PIs and smaller grantees' leveraging of this has not been discussed. There was a one-time call made for PIs who needed a piece of infrastructure to keep their programs robust. There is no plan now. NP could explore ways to support university staff.

Filomena Nunes noted concern about the balance between research and operations, and asked how this plays out in the FY16 budget. **Hallman** shared that the trend in FY16 is positive. Despite what looks like a large increase, program managers suggest that it does not accomplish as much, due to the requirement of the full funding of grants. Work is needed to continue to build up the research investment. Recently, things have been tilted toward new construction; as these investments roll off, there could be more investment available for research. Historically, research has been at or below 38 percent of the total budget and is currently at about 31 or 32 percent., including SBIR.

Hallman clarified for **Geesaman** that NP is in year two of the full funding of grants with one year to go before the first full 3 year cycle is complete.

NATIONAL SCIENCE FOUNDATION NUCLEAR PHYSICS OVERVIEW

Allena Opper, Program Director of Experimental Nuclear Physics for NSF MPS/PHY shared that the NP scope has changed. At the end of 2014, a reorganization of the Particle Astrophysics Program moved the NLDBD research to the Experimental Nuclear Physics (ENP) Program. Of the 62 proposals considered by the Experimental Nuclear Physics Program this year, nine are for research in NLDBD. The ENP proposal review group met and found the NLDBD proposals to be interwoven with other proposals.

The FY15 operating budget for NSF totals \$7,344M, an increase of 2.9 percent over FY14. The Mathematical and Physical Sciences Division (MSP) in which PHY resides has an operating budget of \$1,337M, an increase of 5.4 percent over FY14. PHY is participating in three NSF-wide initiatives: Brain, Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21), Optics and Photonics.

The PHY FY15 budget is \$274M, an increase over the FY14 budget of \$267M. The increase allowed PHY to support the National Superconducting Cyclotron Laboratory (NSCL) at \$23M in FY15. The FY16 request is \$277M.

Major activities supported by PHY are the NSCL and JINA; Nuclear Physics research has also benefited from the MRI program and the PHY Mid-Scale Instrumentation funds. Support since 2009 has been around \$50M per year. There was an 11 percent cut in the program in 2013 but NP still totaled out at \$47M.

Major Research Instrumentation (MRI) funding is for instrumentation ranging between \$100k and \$4M. Major Research Equipment and Facilities Construction (MREFC) funding supports the acquisition, construction, and commissioning of major research facilities and equipment that provide unique capabilities at the frontiers of science and engineering. MREFC funds are for projects that have a total cost that is 1% or more than the associated NSF directorate's annual budget; for PHY that amount is about \$140M. The MPS Directorate uses Mid-Scale funds to bridge the gap between MRI and MREFC sized projects. NSF Physics Division treats Mid-Scale funds similarly to MRI construction funds. Mid-Scale projects take time to grow and need to be on the radar for a while. Opper encouraged project leads to approach NP. These projects need to be scheduled in due to their size. Proposers cannot necessarily count on MRI fund and midscale funds. There are no NP budget numbers available for 2015. It is anticipated that there will be some increase in funding over 2014. Additionally, funding for NLDBD will be added to the NP budget.

In FY14, proposals moved from the use of "Dear Colleague Letters" to a solicitation process. There is a new iteration of the solicitation for 2015 and all proposals coming into the Division must adhere to the new approach. These include conference, workshop and school proposals. Proposers should include a letter of collaboration as a supplemental document, with prescribed text offered by NP. Letters of support have never been allowed. One of the first funding deadlines is for Particle Astrophysics to occur on October 28. The Experimental Nuclear Physics and Theoretical Nuclear Physics deadline is November 13.

The MRI solicitation deadline was January 22. Twenty-four proposals were received with eight from nuclear physics. Proposals are under review. Many submitters did engage Opper about how the program works.

NSF has a Dear Colleague Letter to address its Career Life Balance Initiative. Awardees may request supplements that support life events such as child birth or illness. This supports those who have career awards, and PHY will consider this type of support for all awardees.

PHY is studying ways to increase diversity in the research community, and is collecting best practices from the community, PFCs and facilities. Opper asked NSAC to give comments through a website and to Dr. Kathy McCloud. The demographic data on awardees collected by NSF are provided voluntarily and hence response rates can be very low. In the past, awardees have received an email from NSF that appeared to be spam and is being revised. NSF proposal leads should ask their recipients and students to complete the email and survey, and either provide the demographic data or indicate that they do not want to offer this information.

Opper shared a report on MPS and PHY personnel and that the roster of employees has stayed consistent.

NSF is looking forward to the Long Range Plan, especially how university research groups can participate in nuclear physics and how they can have leadership roles. There is a gap of funding opportunities within NSF from \$4M to \$140M. If that is a problem for the community, it is an NSF problem and NSF might need to know that. Opper also reminded the NSAC that the charge is to prepare a Long Range Plan at constant level of effort. The plan could set priorities so that if something new is proposed, something else will have to be reduced.

Discussion

Geesaman noted that the constant level of effort is one of the charges.

Opper shared that the surveying of all who are participating in a research activity have evolved from just looking at PIs to all who participate. **Ken Hicks** shared that the response rate

is around 20 to 30 percent to the demographic information request, but more data about demographics is needed. But only about 10 percent of recipients respond to the survey overall.

Abhay Deshpande asked about the inclusion of NLDBD experimentation interwoven with the PHY proposals. **Opper** shared that the proposals for that were assessed along with the whole cohort of proposals. When ranked, they were interspersed with all of the proposals and reflected a range of quality.

Dehspande asked about the mid-scale projects and the attempt to fill the gap between \$4M and \$140M. **Opper** shared that the gap exists at the agency. The MPS has mid-scale funding. Different divisions treat the mid-scale funding allotments differently. Given how much funding can be spent, NP received \$1.2M and anticipates going up to \$2M in the next few years.

Nunes asked about computational physics program, and if it would be grown given NSF's priorities. **Opper** pointed out the CIF21 program, and that PHY is participating. **Bogdan Mihaila** of NSF is the program director to contact regarding.

Jorge Piekarewicz cited Nuclear Astrophysics, and asked if there is a relationship to advanced LIGO at NSF. **Opper** shared that there are few walls in PHY when proposals come in. Proposals are often co-reviewed by multiple programs as completely as possible and by the community. If the nuclear physics community connects broadly to physics, then putting that in the Long Range Plan makes sense.

Michael Weischer added that the programs such as JINA branch out to look at other areas of physics, to include nuclear physics signals in other physics work. The interdisciplinary nature of the field of astrophysics seeks to see effects in nuclear physics and other areas.

Aprahamian asked about the inclusion of NLDBD. The Nuclear Astrophysics idea was started with the hope of increasing the astrophysics budget, and budgets should grow accordingly. **Opper** shared that with this particular scope broadening, funds are moving over to NP and constitute a five-year average that will be put into NP. **Aprahamian** is concerned that when Nuclear Astrophysics previously moved it suffered a budget cut. **Opper** suggested that whenever the scope of the program has increased, additional funding has been provided and that current numbers are influenced due to the cuts that occurred in 2013.

Robert Atcher noted concern about the education budget going down by about five percent. **Opper** shared that within PHY, support goes to summer schools. NP supports nearly \$200k per year in support of schools and workshops. **Atcher** asked why the budget has gone down, knowing that the NSF is a Federal steward of education funding. **Opper** shared that NSF has a full directorate on education that studies education and pedagogy but not activities. PHY supports training for graduate students. **Geesaman** added that the training of graduate students in disciplines was under question relative to the NSF mission, and it is clear now that there is need for NSF or someone to respond to that need. If Congress is comfortable with only NSF making that charge then that is something that PHY should be responsible for. **Hicks** added that within the program, NP is supporting summer schools and REU supplements. The cut shown is division wide.

Wiescher asked if funding includes graduate student training by research grants. **Opper** shared that when an award is made, there is usually some support for graduate students.

RECOGNITION OF NSAC MEMBERS

Timothy Hallman shared appreciation from NSF and DOE for Ani Aprahamian, Allena Opper, and Paul Mantica for their service to the NSAC.

PRESENTATION OF NEW CHARGES: NEUTRINOLESS DOUBLE BETA DECAY

Timothy Hallman presented a charge to give guidance on NLDBD to include assessing the state of ongoing R&D candidate technology demonstrations for a possible ton-scale experiment. The charge calls for identifying remaining R&D tasks to demonstrate down select criteria including sensitivity goals, the time duration needed to accomplish activities, and resources required.

There is broad interest in NLDBD to determine whether lepton number is conserved and further illuminate the mechanisms resulting in such light neutrino masses. The scientific community, including high-energy physics, is interested in these questions. DOE NP and NSF want to be stewards of that scope of interest. Making a down select decision should ensure equal competitiveness for all possible R&D technology demonstrations, and to enable an informed decision by the agencies.

NSAC is asked to gather information about the demonstrations and the fundamental remaining questions to be answered by R&D. A full proposal process will then be conducted by DOE and NSF; hence NSAC will only need to do identification and not prioritization.

Discussion

Hallman confirmed for **Nunes** that the membership of the NLDBD subpanel will likely be the same although it could be modified if appropriate. The report on NLDBD is due to NSF and DOE by November 2015.

Hallman shared with **Heeger** that a definite timeline for conducting the NLDBD down-select process has not been determined but that DOE should move as quickly as possible within the next year or two to get out a solicitation for any crucial R&D that is still required. **Opper** agreed on behalf of NSF that that would be the goal. NSF is working to see how that fits with the budget.

Hallman confirmed for **McKeown** that the DOE Office of Nuclear Physics has discussed this topic with the Office of High Energy Physics.

Kate Scholberg asked if NLDBD would be restricted to just U.S. participation. **Hallman** shared that if the leading technology has a European component to it, then that should be up for discussion. The experiment itself would be difficult and take a lot of time and resources. The selection should be driven by the best technology available. **McKeown** added that relative to global competitiveness, the subpanel should hear about other international activities to drive a conclusion about what is best for the U.S. program.

PRESENTATION OF NEW CHARGES: MOLYBDENUM-99

Hallman described charges to conduct an assessment of the effectiveness of the National Nuclear Security Administration (NNSA) Office of Material Management and Minimization's (MMM) Domestic Molybdenum-99 (Mo-99) Program. It was previously known as the Global Threat Reduction Initiative. There is a sitting subpanel for this activity. It has presented one report. This charge asks for a reconvening of the subpanel to look at implementing the goals of the NNSA-MMM, how any risks identified would be managed, if concerns are adequately addressed, and steps to take to improve the production of a domestic supply of Mo-99.

Discussion

Geesaman added that **Steve Mattmuller** of Kettering Hospital would join the subpanel. This is a complicated issue and concerns that the topic be adequately addressed. The report from this subpanel is due in July 2015, and NSAC would have to meet in July to consider the report.

Suzanne Lapi asked about interaction between this committee and the National Academies of Sciences' study of this topic. **Geesaman** shared that the subpanel is trying to get someone from the Academies to meet with the subpanel in May 2015.

Jamie Nagle shared that the previous report indicated that the agency was handling this well but were uncomfortable saying that due to the complexity of the challenge. He asked if the report in July will say that. **Geesaman** clarified that the report expressed that there is still a constraint and that it is wise to continue to hold concern.

Atcher commented that **Mattmuller's** participation is an asset. He reiterated concern that most of the panel members are not experts in the production of Mo-99 and reactor production of isotopes, as well as quantities to serve a commercial market.

Hallman added that the MMM office is also responsible for reducing the use of highly-enriched uranium that has been the mainstay of Mo-99 production. This a very challenging issue.

Leland Cogliani shared that this topic will get a lot of Congressional scrutiny especially concerns about NNSA finding a U.S. supplier who can produce the quantity needed. Over the past four years, \$50M has been committed to finding a supplier. This is not an esoteric issue that will be ignored. The Appropriations, Armed Services, and Health committees will read this report very carefully as it is a critical issue. The market makes this even more critical as well as restrictions on supplying to countries that also produce Mo-99.

REPORT ON THE NSAC ISOTOPES SUBCOMMITTEE CHARGE

Lawrence Cardman shared the NSACI subcommittee report, highlighting the DOE Isotope Program (IDPRA) mission and history. It produces and distributes radioactive and stable isotopes but not in competition with industry. It maintains the infrastructure for producing and supplying isotope products and services. It is overseen by the SC Facilities and Project Management Division in the Office of Nuclear Physics. There is a network of production sites at national labs

NSACI looked at biological, medical and pharmaceutical isotope use. Isotopes are used for imaging and treating cancer, the evaluation of oil wells, in forensic analysis to examine interdiction samples, and as truck portal monitors at U.S. borders.

Within the DOE NP budget, IDPRA is a small piece at \$19,850k in FY15 of appropriated dollars; additional funds are collected from customers to support isotope production costs. Two-thirds of the total budget includes revenue due to isotope sales.

The 2009 NSAC report showed the isotope lifecycle and potential use. Modest amounts of material are used at the start of an experiment, and once deemed useful via clinical trials, are expanded. ^{82}Sr is one such useful isotope. It is a large fraction of current isotope sales at around 40 percent. Once commercial ventures can fill this need, this source of revenue for DOE will decrease as DOE is not permitted to compete with industry.

When the Isotope Program moved to the Office of Nuclear Physics in 2009, it was in need of much improvement, as described in two NSAC reports published in 2009. The subcommittee was charged with updating these reports via a long-range strategic plan, and to evaluate progress since 2009.

Three NSACI meetings included outside presenters who provided background details. Cardman is awaiting final feedback from the NSACI and the NSAC on the subcommittee report.

One recommendation is to increase R&D funding. Moving the program to the SC is positive as there is a path for R&D funding support. NSACI would like current funding of around 15 percent to be devoted to research to a higher level. It also recommended R&D support for the production of high specific activity theranostic radioisotopes, and the production of alpha-emitting radioisotopes. R&D would fine-tune production techniques to give the quantity of theranostic radioisotopes needed. R&D recommendations include continuing research into the use of electron accelerators for production and the development of irradiation materials for targets that will be exposed to extreme environments.

It is recommended that the stable isotope operational capability at Oak Ridge National Laboratory (ORNL) be developed. Initial demonstration capabilities need to be expanded and set up as an operating facility rather than a demonstration effort.

Isotope harvesting at FRIB, and the re-establishment of radioactive isotope separation are high-impact infrastructure investments that should be pursued. Infrastructure opportunities include enhancing facilities at the Brookhaven Linac Isotope Producer (BLIP) and Los Alamos National Laboratory's Isotope Production Facility (LANL IPF).

The committee recommended continuing to integrate university facilities into the isotope program. Universities can offer supplemental or complementary activities. Coordination of effort can enable the production of key isotopes, and also provide workforce training opportunities.

The IDPRA is funded at around \$19.8k in FY15. The American Recovery and Reinvestment Act (ARRA) boosted funding in FY09. NSACI is recommending \$4M more to move R&D to about 15 percent of the programs' overall budget, \$2M to operate a stable isotope production program, \$14M for infrastructure investments, and \$1M for university production facility improvements. This supports the long-range plan and gives a way to realize its aims.

Accomplishments since the 2009 NSACI report include substantial progress in the development of new production capabilities for alpha emitters.

IDPRA has excelled at improving activities since 2009 through reorganization and communication. New structures and processes are improving IDPRA's effectiveness. Operations in IDPRA should continue to be improved. NSACI suggested ways to guide improvements. The committee concluded that there are many opportunities to enhance production capabilities.

Discussion

Wiescher asked what defines the success or failure of certain isotopes. **Cardman** noted that early testing can give insights into success. For example, an isotope may reduce the rate of cancer but produce negative side effects. That would be a failure. A positive result could stimulate a commercial producer to take over production from DOE. As far as the IDPRA, they might see that example as a success in that it derived some revenue, that production moved into the commercial sector, and it is being used effectively.

Patrizia Rossi pointed out that an isotope may sometimes be purchased more cheaply overseas. **Cardman** shared that the Isotope Program takes into consideration reliable foreign supplies of isotopes into its decision making. If someone has an idea for an isotope that is not available commercially, IDPRA may be the place where that isotope can be acquired. The stability of a source is one concern.

DISCUSSION OF THE NSAC ISOTOPE SUBCOMMITTEE REPORT

Aprahamian asked **Cardman** about the 2009 recommendation to build a reliable facility for isotope production. He shared that one might argue that enough has changed since 2009 that these types of facilities are publicly-available and that isotopes can be available through a DOE-commercial partnership. This presented a best approach over building a facility.

Aprahamian noted that recommendations impact universities' investments, and asked if the integration of universities is just in production or also R&D. **Cardman** shared that they already support R&D through proposal submissions. This could expand with more R&D funding. The NSACI has recommended an additional \$1M that would support university research.

Cardman pointed out that a difficult aspect of the university system is formally adding pieces of university capabilities to the program, making isotopes, and selling isotopes through the program. This neglects the fact that some universities have a thriving relationship with buyers of isotopes. The NSACI report encourages continuing the effort to find mutually agreeable paths. This could potentially address the need for a broad variety of isotopes.

Geesaman added that the recommendation in 2009 for a dedicated facility was based on the list of available and desired isotopes at that time. That subcommittee found that many could be made via low energy machines. Now, those isotopes are sufficiently supplied such that a machine is no longer needed. There seems to be a reasonable response to this former recommendation even though the recommendation was not followed.

Nagle commented that the base budget recommendation of \$20M is broken out and shows dissemination over several years. **Cardman** did not want to get too detailed as these proposed costs are estimates. Nagle suggested that the costs may differ by a factor of two or three and that should be made clear in the report.

Nagle asked about cost recovery. **Cardman** shared that **Jehanne Gillo's** office has given details on what is included in the price. Documents show what the costs ought to be and how to apply them. That defines DOE's actions. This is now done in a systematic way. **Cardman** shared that this was not examined by the NSACI but it believes that this is done in a trusted way.

Nagle noted that the program provides isotopes to industry and others, and wondered about the cost breakdown for different buyers. **Cardman** shared that the program operates via full-cost recovery. **Gillo** confirmed that the appropriation supports mission readiness, key individuals, and competitive R&D. The revenue supports production costs such as transportation, reactor time, facility maintenance, the business office, and other needs. Prices are set at full cost recovery with some contingency or at market price. DOE does not often sell at market price as it typically is the only source in the market. There is rarely opportunity to raise prices. Buyers come to the government as a last resort when they need expertise or lack facilities.

Geesaman added that producing the isotope upfront is designed for full cost recovery and it does not include the initial infrastructure costs. **Gillo** shared that industry has partnered with DOE and made investments in facilities and operations that DOE would manage.

Geesaman shared a question from **John Wilkerson** via email. He asked if the cost of enrichment for NLDBD might be more if the U.S. invests in the infrastructure to do this in the U.S. It might be comparable to investing in non-U.S. facilities. **Cardman** shared that once the NLDBD community decides what it wants and how to proceed, then this question should be asked. The specific outcome is unknown at present.

Rossi asked about describing funding recommendations as significant yet pointed out that the estimates are not too significant. NSACI should recommend doubling funds. **Cardman** shared that the estimates seem like reasonable increases. **Geesaman** shared that the recommendations are in priority order for more funding.

Erich Ormand asked if the isotope program would succeed if it no longer offered specific isotopes when industry takes over. **Cardman** pointed out that this is a constant stress to the viability of the program and is challenging. It is explicitly addressed in the strategic plan and offers increasing the funding for the program so that revenue fluctuations have less impact.

Ormand showed that increasing the budget by \$20M would increase it to where it was in 2009 through ARRA funding. **Cardman** noted the benefits of the ARRA funding. **Ormand** suggested that the request be direct without highlighting ARRA funding.

Cardman shared with **David Hobart** that the report that addresses things at ORNL and other places that could be recovered and used. **Cardman** is impressed with IDPRA processes for gathering isotope demand information from agencies, the physics and research community, and industry to identify needs and desires, and then using the information to develop a strategy.

Piekarewicz shared that the report is well-written but too technical. He recommended including francium as an example.

Arahamian voiced concern about the age of some isotope facilities and if the recommendation for \$14M in infrastructure improvement will be sufficient. **Cardman** shared that this amount is based on information from the facilities. It will address a reasonable fraction of their plans for scaling in the next three to five years.

Wiescher noted that the formulation of the infrastructure investment includes a distribution. **Cardman** responded that the report contains estimates without too much detail, especially as facility costs required details and a plan. The NSACI can suggest things that need to be done and proposed costs. FRIB as an example has the potential to generate isotopes but there is not enough information to identify all of the costs. NSACI has asked experts for estimates to inform these costs. **Geesaman** added that there are specific dollar amounts in the report. The \$14M takes a sum and divides it over several years. They may find in the coming years that costs of specific facilities are more. **Cardman** shared that the NSACI provides a reasonable estimate based on understanding some of the activities.

Nagle noted that other sections of the report propose projects and costs, and asked if this is a future number or part of an overall \$42M proposed cost. **Cardman** shared that the estimates are shown as increments and future costs will vary. At the right time, one must investigate the details and look at detailed costs. **Cardman** clarified that the funding needs to be an increase over the base appropriated budget. A discussion of how best to present the funding being requested followed. **Nagle** urged including a clear investment timeline to avoid losing the opportunity to capture investments that are needed now.

Heeger wondered about the timeline for NLDBD next generation experiments. **Cardman** shared that this is not used as a framework for NSACI's estimates. After choosing a timeframe, the community should consider developing capabilities to produce an isotope or buy it. All costs and future implications need to be addressed. **Heeger** asked if it is feasible to suggest a time in which community consideration should occur. **Cardman** shared that ORNL is the place to think about this, discussions are occurring, and that could be worked into proposals for the experiment. **Geesaman** commented that researching this would go beyond NSACI's charge. It would not be appropriate to incorporate the cost of that very large need into this program at this time.

Geesaman urged the NSAC to think about accepting the report. Several members were recused as they are associated with the facilities mentioned in the recommendations.

Ormand shared concern about the extent to which the program relies on production from facilities that they do not control, and if there is a back-up plan if one of the facilities closes.

Cardman shared that the IDPRA has been active in this planning and is encouraged to continue.

Piekarewicz urged that the document be changed for non-community readers. **Rossi** added that the report contains too many technical details that do not aid comprehension of the problem, and many concepts are repeated. Budget and timeline recommendations should be clearer.

Scholberg added that the document was voluminous and agreed with the endorsement.

Shepherd suggested that sidebars might be useful, can be written for a diverse range of audiences, and could be more uniform to support a common audience. Sidebars can describe a connection between the value of physics in society, such as describing specific individuals who have benefitted from treatment possible through isotope production.

Nagle urged that NSAC take a vote after it sees a timeline. The document argues to double the funding but is vague about when it would be dispersed and how it would be sustained. The intended audience is unclear and the length may not be a match for that audience or depth of the charge. **Hallman** explained that appropriators may be the first audience and that the document should be written with that audience in mind.

Lapi thanked the NSACI for their efforts.

Hobart recommended refocusing the executive summary to address the specific audience for whom it is intended, and will share some minor corrections with **Cardman** by email.

Heeger endorsed the recommendations, and that the improvements made over time and value outside of the field is a story that should be told clearly.

Deshpande suggested shortening the report. The executive summary should highlight the basic need and the last portion should highlight what will be missed if the recommendations are not followed. Personal stories can describe the impact of this work. The writing is meant for elected officials and government leaders, and the content should be focused for them.

Aprahamian congratulated the NP on their running of this program. She suggested a concise executive summary for distribution to staffers and others, and an emphasis on future facilities. The prior report suggested building a facility and it is not mentioned this time, but the public-private partnership that removes this need is an appealing story. Removing old infrastructure versus investing in new makes a good case. Highlight the number of universities engaged in isotope production. **Lapi** shared that universities did offer input and helped the NSACI form its recommendations. **Cardman** pointed out that universities gave presentations to the NSACI.

Aprahamian noted that isotopes give additional benefit beyond health and that those stories might also be called out in the sidebars.

Gillo thanked the NSACI for their hard work, and efforts to engage the broad and diverse community. **Gillo** has passed along comments to **Geesaman** and **Cardman**, and expressed a need for the report to be more concise and to the point.

Nagle added that the timeline needs to indicate if it is two to three years or longer.

Geesaman suggested that the NSACI revise the report based on feedback heard and present it to the NSAC for review by email or as a committee in July.

Cardman confirmed that comments about infrastructure and timescale should highlight starting on near term activities like investments in FRIB. He indicated that talking about infrastructure improvements at other institutions represent many little projects that can be

juggled from year to year, and are not convenient for placing in a specific timeline and sequence. A Gantt chart may not be that helpful. **Geesaman** shared that things that seem constant are well spelled out. A related issue is that there are things that could be ramped up in addition to things that need to happen right away. **Cardman** expressed that he is comfortable positing with the Program where small details need to be decided. **Geesaman** urged finding a way to make information about investments and timeline to be clear and compelling.

Hobart urged that the report is not asking for enough as it piggy-backs on current facilities.

Nagle pointed out that the budget slides show a \$20M increase continuing out over many years which contradict showing the increase for two to three years. **Cardman** clarified that the NSACI is recommending \$20M and that the base for the isotope program double and be devoted to a known list of things. The budget contains a mix of things such as an operating budget that continues on across many years, and some funded items that will conclude after several years. It notes that funding will be renewed by the next report to pay for some new needs.

REPORT ON THE EIC COSTING SUBCOMMITTEE

Ed Temple reported on an NSAC subcommittee review of the Electron Ion Collider (EIC) cost estimates. The subcommittee was asked to provide the best current estimate of costs of projects to address physics opportunities identified in the EIC white paper. These opportunities include R&D, construction, pre-operating and operating costs, and initial experimental equipment. The report draws upon a report by Thomas Roser.

The eRHIC design provides a new electron source and includes electron recirculator rings so that the ions are brought into collision with the electrons in one of two detector hulls. The recirculating rings are positioned next to the RHIC rings. Temple reviewed peak luminosity at eRHIC versus a wide Center-of-Mass energy range.

In the Linac-ring collider, having only a single pass collision removes the limitation of the beam effect of the high energy hadron beam on the lower energy electron beam. High luminosity can be reached with a high intensity, low emittance hadron beam and lower intensity electron beam. Strong hadron beam cooling is required. The performance needed has been demonstrated in simulations and proof of principle test results are expected in 2016.

The performance risk identified in Roser's paper is if fast hadron cooling is achievable. Luminosity does not depend strongly on cooling time. Temple reviewed the cooling time in minutes versus varying luminosities.

Some innovations and challenges of eRHIC accelerator design include the use of a high intensity polarized electron source multi-cathode gun. An energy recovery Linac with high recovery efficiency is needed, with up to 16 re-circulations of the electron beam through the same 1.32 GeV Linac. The novel fixed-field (FFAG) lattice allows for the 16 re-circulations with only two beam transport loops. Strong hadron beam cooling is required at high luminosity while minimizing electron beam current and synchrotron radiation loss.

The cost elements inherent in the eRHIC total \$755,900k including a 31 percent contingency with the Linac at \$129,800k of the total cost. Estimates were generated based on the full bottom-up cost and contingency estimate of the eRHIC conceptual design. Along with the Linacs, the main cost drivers are the FFAG arcs and the spreader / combiner beamlines on either side of the main Linac. Pre-project R&D would continue into project approval at a cost of \$20,000k per year when on-project R&D would begin.

The subcommittee concluded that the work will be successful if technical components can be shown to meet specifications.

The design strategy of the medium energy Electron Ion Collider (MEIC) at JLab is built on high luminosity and high bunch repetition rate CW colliding beams. The baseline layout draws upon the CEBAF full energy injector. The ion collector ring and electron ring are in the same tunnel in a figure-eight layout measuring 2.2 km in circumference and uses recycled components from the discontinued PEP-II activity.

MEIC follows a unique multi-phase cooling process. Baseline cooling requirements include a novel bunched beam cooling approach performed by bunched electron beam.

Mitigating strategies have been developed to address needed R&D for the MEIC baseline.

Cost estimates for MEIC total \$1,291,255k inclusive of new tunnels for the facility and the accelerator and without a detector, and \$1,479,311k with a detector.

The subcommittee comments on the ring-ring design are largely based on conventional technologies and there are some higher risk components that R&D should address. Estimates are given credence by the cavity and cryomodule work at JLab, and the recent 12 GeV Upgrade.

The committee concluded that eRHIC technical advances are beyond state of the art. MEIC is based on conventional technology with fewer technical risks. An EIC could be built for about \$1.5B in FY15 dollars. As technical risk is retired, on-project costs could be reduced, especially by off-project funds from detectors from non-U.S. sources, redirecting operating funds at the host laboratory, or reducing design requirements.

Discussion

Heeger asked about the appropriateness of contingency levels at this stage of the project. **Temple** explained that the committee did not produce a separate contingency estimate. There are more considerations that need to be made in the projects but it is hard to predict what types of circumstances may arise. “What if?” A technical risk management exercises may aid understanding and the calculation of contingency needs. It is unknown if each concept will work.

Temple shared with **Heeger** that the time-phasing of the projects is the same.

Nagle commented that the report highlights areas where the contingency is described as low but does not elaborate. What is really being said is that 2016 needs to happen and for tests to run to determine if any of the designs are viable and would be viable at additional costs.

Nagle noted that the eRHIC design exceeds the design requirements. Numbers above it and lowering the luminosity does not meet the design requirements and should be reflected in the language. **Temple** pointed out that prior reports as models did not demonstrate the need for defined quantitative numbers in this report.

Deshpande pointed out that need for how NSAC should proceed based on the report’s conclusions, and asked if the committee had some recommendations on the cost contingency. That part does not come through in the document. **Temple** clarified that the committee did not express the levels of contingency required. **Geesaman** added that the attitude of the subcommittee was that if alternatives had been presented with costs for those, then they could estimate contingencies. This committee could not do that based on the way that things like the Linac were coupled and they lacked the information to make a reliable statement.

Thomas Roser commented that the only feasibility risk in the design of eRHIC is CC cooling and the others are cost-related. There is a backup for the cooling, hence a conclusion that this design is not feasible is not appropriate. Feasibility has been confirmed by various committees in the past. In terms of contingency, the subcommittee agreed that the R&D estimate is under-estimated. He was pleased to see that the eRHIC hardware estimates were thought to be

reasonable and that contingency for those items was reasonable. He believes that the \$1B estimate is still an achievable amount for eRHIC.

Piekarewicz expressed the need to better understand the discrepancies between eRHIC, described as beyond the state of the art but with costs less than the MEIC that is based on largely conventional technology. **Geesaman** clarified that beyond state of the art defines eRHIC as being below advanced cost estimates.

Nagle urged that the report stated that the subcommittee did not do its own contingency analysis. A step further would be that the subcommittee did not find that the \$1B cost estimate was reasonable if the concept is proven to be feasible and that risks can be mitigated, to enable long-term planning. **Temple** added that eRHIC can be built for \$1B at the performance levels proposed if the technical and cost risks are mitigated and R&D is reliable and cost effective. **Geesaman** proposed adding a statement that the committee was unable to consider the \$1B estimate due to the risks, and did not independently evaluate the contingency estimate at this time. **Temple** agreed to go back to the subcommittee to ask about adding that statement.

Deshpande suggested explaining that if the R&D work is successful, the costs would range between \$1B and \$1.5B. That would address all of the concerns raised.

NSAC DISCUSSION OF THE EIC COSTING SUBCOMMITTEE REPORT

Geesaman commented that he sees that R&D work is needed and that a range of \$1B to \$1.5B is on the table, and that R&D could not likely start in 2016. The schedule would likely be delayed. The committee at present will give the NSAC the most rapid schedule that could be taken with a profile that is at \$1.5B. Putting this into scenarios such as cost-of-living scenarios, the immediate funding is still not possible. With modest growth scenarios, construction is pushed out toward 2025. The NSAC will see these scenarios. It is the hope that with both proposals the R&D can reduce the costs. The Long Range Plan Working Group will work with these numbers. The scenarios will be available before the Long Range Plan Working Group meeting.

Geesaman clarified for **Nagle** that the report will be changed and the members of the committee can access these slides via the DOE NSAC website and videocast.

PROGRESS ON THE LONG RANGE PLAN

Geesaman reminded the NSAC that details about NSAC activities can be found at <http://www.phy.anl.gov/nsac-lrp>.

Most of the text for the Long Range Plan (LRP) is to be developed by April 10 by the LRP Working Group. A resolution meeting will be held on April 16 – 20, with a completed second draft to be done in June for distribution to community members for review. The final LRP report is due in October 2015.

Geesaman reviewed the agenda for April 16 – 20. Topics to be addressed are cold QCD, hot QCD, fundamental symmetries and neutrinos, nuclei, astrophysics, theory, work, education and outreach, and double-beta decay.

Each of the national user facilities will make presentations with emphasis on their progress on delivering on the discoveries that they have proposed. International facilities will be discussed. The working group will seek to hear if there is underground space at the facilities to conduct the physics that NSAC would like to see happen.

Discussion will be held on the levels of research that are needed driving toward specific estimates of needed levels of research.

Closed sessions will discuss priorities and recommendations, and identify new issues that have emerged and that need to be addressed. The end goal is to emerge with final language for recommendations, and the schedule and homework assignments for moving forward.

Discussion

Geesaman confirmed for **Raju Venugopalan** that the open sessions will be inclusive of attendees but should not be overcome by lobbying efforts and possible over-attendance by individual institutions and organizations.

Geesaman shared with **Deshpande** that the meeting will not be accessible via Internet to optimize the value of being in the room in-person with other attendees.

Atcher shared his observation that the title of the NSAC is nuclear science but there tends to be emphasis on nuclear physics. He has sought to hold a session on nuclear chemistry and technology to contribute to efforts. **Geesaman** shared that a white paper would have been welcomed.

PUBLIC COMMENTS

None.

CLOSING REMARKS AND ADJOURNMENT

Geesaman adjourned the meeting at 4:20 p.m. EST.

The minutes of the U.S. Department of Energy and the National Science Foundation Nuclear Science Advisory Committee meeting, held at the Marriott Hotel in Gaithersburg, Maryland on April 3, 2015, are certified to be an accurate representation of what occurred.



Donald Geesaman
Chair, Nuclear Science Advisory Committee