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

PUBLIC MEETING MINUTES

Crystal City Marriott
1999 Richmond Hwy, Arlington, VA 22202

March 2, 2020

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 Monday, March 2, 2020, at the Crystal City Marriott in Arlington, VA, by **Committee Chair David Hertzog**. 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.

Committee Members Present

David Hertzog (Chair)
Mei Bai
Joseph Carlson
Jozef Dudek
Olga Evdokimov
Bonnie Fleming
Tori Forbes
Geoffrey Greene
Tanja Horn
Robert Janssens
Yury Kolomensky
Suzanne Lapi
Zein-Eddine Meziani
Thomas Schaefer
Artemis Spyrou
Rebecca Surman
Boleslaw Wyslouch
Sherry Yennello

Committee Members Unable to Attend

Renee Fatemi
Silvia Jurisson
Sofia Quaglioni

NSAC Designated Federal Officer

Timothy Hallman, U.S. Department of Energy, Office of Science (SC), Office of Nuclear Physics (NP), Associate Director

Others Present for All or Part of the Meeting

David Asner, Brookhaven National Laboratory (BNL)
Ethan Balkin, DOE
Kate Bannan, DOE
David Bossie, DOE
Steve Binkley, DOE
Maria Chamizo Llatas, BNL
Leland Cogliani, Lewis-Burke
James Dunlop, BNL
Rolf Ent, JLab
George Fai, DOE
Jehanne Gillo, DOE
Thomas Glasmacher, Michigan State University (MSU)
Vincente Guiseppe, Oak Ridge National Laboratory (ORNL)
Michael Heffner, Lawrence Livermore National Laboratory (LLNL)
Stuart Henderson, Thomas Jefferson National Laboratory (JLab)
Sean Jones, National Science Foundation (NSF)
Pete Karcz, National Nuclear Security Administration (NNSA)
Brian Knesel, DOE
Filomena Nunes, MSU
Allena Opper, NSF
Alan Poon, Lawrence Berkeley National Laboratory (LBNL)
Jianwei Qiu, JLab
Robert Redwine, Massachusetts Institute of Technology (MIT)
Ed Sadowski, Savannah River National Laboratory
Ron Soltz, LLNL

Paul Sorensen, DOE
Andreas Stolz, National Superconducting Cyclotron Laboratory/ MSU
Jim Thomas, NSF
Fredrik Tovesson, Argonne National Laboratory (ANL)
Robert Tribble, BNL

Monday, March 2, 2020
Morning Session

WELCOME AND INTRODUCTIONS

The Nuclear Science Advisory Committee (NSAC) Committee Chair **David Hertzog** welcomed everyone and asked the NSAC members to introduce themselves. Hertzog reviewed the agenda and reminded everyone that the meeting is being webcast and encouraged people to participate in the discussions. Hertzog noted Physics Update Talks across the Nuclear Physics (NP) program.

PERSPECTIVES FROM THE DEPARTMENT OF ENERGY, Stephen Binkley, Deputy Director for Science Programs, Office of Science

Dr. Binkley discussed the Fiscal Year (FY)20 Appropriations enacted and the FY21 President's Budget Request (released in February 2020), and the Office of Science (SC) reorganization. FY21 budget request is $5.8B for SC (38% of the proposed budget is for research to universities, 40% to facilities, and 22% projects). A continuing resolution is possible given the active political year. SC high priority research investments include: exascale, artificial intelligence/machine learning (AI/ML), quantum information science (QIS), microelectronics, DOE Isotope Initiative, Biosecurity, and U.S. Fusion Program Acceleration).

The FY21 NP budget is $653M (down 8% relative to enacted) in the President's Budget request. Six new FY21 research initiatives are Integrated Computational and Data Infrastructure for Scientific Discovery, Next Generation Biology Initiative, Rare Earth/Separation Science Initiative, Revolutionizing Polymer Upcycling, Strategic Accelerator Technology Initiative, and Data and Computational Collaboration with National Institutes of Health (NIH).

The SC reorganization changes mostly affects top level positions in SC. Dr. Chris Fall established the Principal Deputy Director position (occupied by Binkley), eliminated the Deputy Director for Resource Management position, appointed Harriet Kung to the Deputy Director for Science Programs, and Juston Fontaine will become the Deputy Director for Field Operations. The Office of Public Affairs and the Office of Scientific and Technical Information (OSTI) will move under Harriet Kung.

Discussion

Hertzog inquired about Binkley's responsibilities given the SC reorganization. **Binkley** will focus on strategic planning, budgeting, scientific integrity, and diversity-equity-inclusion. The DOE Isotope Program, and other specialized functions.

Hertzog asked about the new initiative for accelerators and its relationship to the Electron Ion Collider (EIC). **Binkley** responded that NP, Basic Energy Sciences (BES), High Energy Physics (HEP), and Fusion Energy Sciences (FES) programs depend on advancements in accelerator technology and related technologies. With increased competition on the global stage, the DOE leadership decided to focus more concentrated effort on that area. Planning to increase funding in the accelerator technology and related technologies and will have a defined place in

the organization. SC is in the process of bringing an individual in to lead that part of the organization. **Hallman** explained the EIC may benefit, but is not directly coupled to the initiative.

Spyrou requested more information on encouraging interdisciplinarity in the labs. **Binkley** responded several labs are essentially single discipline labs, Fermi National Accelerator Laboratory (Fermilab), Thomas Jefferson Laboratory (JLab), Princeton Plaza Physics Laboratory (PPPL). To remain viable in the future, Director Fall expressed the importance of greater dimensionality. For example, SLAC now incorporates capabilities for BES and FES, as well as HEP work and computing capabilities; the transition took 10 years. In the near term SC will focus on JLab and some activity has been discussed with PPPL. The overall strategy is to ensure the health and vitality of the smaller labs going into the future.

Yennello asked about the separations initiative and any connection to the isotope program. **Binkley** said separations is aimed at critical rare earth elements, but there are opportunities for isotope work as well.

Bai asked if the strategic accelerator technology program was a joint effort between BES, NP, and HEP or independent of the three offices. **Binkley** explained it will be closely integrated with these three sciences as well as FES who are interested in high field magnet development.

Yennello questioned the anticipated time frame of the SC reorganization. **Binkley** shared most of the approval steps are completed and is hoping for final approvals in the next few weeks.

PERSPECTIVES FROM THE NATIONAL SCIENCE FOUNDATION, Sean L. Jones, Deputy Assistant Director, Mathematical & Physical Sciences (MPS)

Shared organizational changes within NSF, some facts about NSF and MPS, the FY20 budget and FY21 request, and budget drivers. NSF celebrated its 70th anniversary. Director Frances Cordova is leaving in March 2020 and is eagerly awaiting Dr. Panchanathan's Senate confirmation as the new Director, and NSF welcomes Dr. Martonosi as the new Assistant Director for the Computer and Information Science and Engineering (CISE) Directorate. Organizational changes within MPS include Dr. Jones, Deputy Assistant Director, and three new Deputy Division Directors, Dr. Pesce (Acting), Dr. Schmoltner (Acting), and Dr. Cottam Allen.

The MPS Directorate FY21 budget is ~ $1.5B with ~30% funding rate. There are notable differences within each Division because MPS is honoring the Industries of the Future and Big Ideas. Industries of the Future include QIS, AI, Advanced Wireless 5G (including the Spectrum Innovation Initiative), Biotechnology, and Advanced Manufacturing. MPS will steward QIS (quantum sensors, quantum simulators, quantum interconnects, quantum computing). CISE will steward AI (machine learning, deep learning, molecular synthesis, manufacturing). Astronomy will steward the Spectrum Innovation Initiative in Advanced Wireless/5G. Biology will steward Biotechnology, but MPS will play heavily here. And Engineering will steward Advanced Manufacturing. Physics is a leader in the Quantum Leap Big Idea, MPS leads Windows of the Universe and shares in Harnessing the Data Revolution and Understanding the Rules of Life.

The National Science Board approved the award for the High Luminosity – Large Hadron Collider (HL-LHC) upgrades for CMS (Compact Muon Solenoid) and ATLAS (NP Argonne Tandem Linac Accelerator System).

Discussion

Hertzog asked why NSF has a 5G initiative. **Jones** explained the initiative seeks to get pure fully operational 5G wireless with more bandwidth and interconnectivity and to reduce interoperability issues currently observed. NSF will focus on the fundamental science that allows the Industries of the Future to be successful for other agencies and researchers who are doing applied work.

Horn requested more information on the pure AI, AI enabled or cross-cutting other disciplines activities in the NSF and asked about supporting facility utilities for AI development. **Jones** said AI is a stewardship activity managed out of the CISE Directorate. Every Directorate within NSF will participate and must determine how to advance AI from their community's perspective. This will involve pure AI and AI tools; NSF is looking broadly at AI. At the facility level there will be many opportunities to address AI. One current example is the AI Institute grant which would be excellent for a planning grant or institute concept to leverage AI for a facility. Another example is opportunities from CISE for harnessing data, data networks, and AI.

DOE OFFICE OF NUCLEAR PHYSICS OVERVIEW, Timothy J. Hallman, Associate Director, Office of Science

One of the priorities of the FY20 Appropriation is to increase utilization of the facilities and make sure they have robust operations funding. The overall NP funding level for FY20 is $713M, an increase of ~$23M over FY19. The Appropriation directs $28.5M toward FRIB (Facility for Rare Isotope Beams) operations and $40M for FRIB construction, $1M for the first year of construction funding for the EIC, and $12M for the first year of construction of SIPRC (Stable Isotope Production and Research Facility).

Nuclear Physics (NP) imagines funding opportunity announcements (FOA) for the FY20 budget for QIS, nuclear data, isotope production, and accelerator research and development (R&D). Within QIS funding, there is funding for basic research and for the isotope program. RHIC (Relativistic Heavy Ion Collider), CEBAF (Continuous Electron Beam Accelerator Facility) and ATLAS facilities operate at greater than 90%, on average, in FY20. TEC (total estimated cost) starts are available for the High Rigidity Spectrometer at FRIB and MOLLER (Measurement of a Lepton-Lepton Electroweak Reaction). GRETA (Gamma-Ray Energy Tracking Array) and sPHENIX (upgrade to the Pioneering High Energy Nuclear Interaction eXperiment) continue to be supported. The FRIB isotope harvesting accelerator effort is initiated to add isotope separation and harvesting capabilities at FRIB. Direction given regarding the FY20 Appropriation's results in a 5.5% decrease in research, the biggest impact being the loss of flexibility for new proposals. The FY21 budget request continues the research funding reduction in all areas. Hallman shared FY21 information on FRIB (currently > 93% complete), ATLAS, CEBAF, RHIC, GRETA, sPHENIX, and MOLLER.

EIC received critical decision-0 (CD-0) in December 2019. The EIC project will be carried out as a full intellectual partnership between Brookhaven National Laboratory (BNL) and JLab collaborators with major participation by all. The TPC (Total Project Cost) range is currently $1.6B - $2.6B.

Initiatives in the FY21 budget request include $1M in strategic accelerator technology, $4M in AI, $16.5M in the isotope program, and $13M in QIS. A FOA in QIS is anticipated in FY20 with reviews to be held in FY21. There will be a lab call for AI/ML, a new interagency FOA on nuclear data, and a new FOA on accelerator R&D.

Stacyann Stephanie Nelson from Florida A&M University was the latest recipient of the Office of Science Graduate Student research program award. SC continues to focus on diversity and inclusion.

Discussion

Greene inquired about the process for a down-select of potential sites for the ton-scale neutinoless double beta decay experiment. **Hallman** noted SC is currently considering the best method for the down-select decision. NSF must be consulted as well. The current NP concept is an expert panel. Significant progress must be made this year.

Yennello asked about the impact of the isotope program moving out of NP. **Hallman** said if the isotope program moves out, NP imagines maintaining the current symbiosis. NP facilities will continue to leverage isotope production thus necessitating a close relationship. Given the scale of future progress in the Isotope program, such a move may be necessary. **Gillo** added that moving the Isotope program out of NP will increase its visibility in the DOE. In addition to NP facilities, the Isotope program uses NNSA (National Nuclear Security Administration), Nuclear Energy, and BES facilities; the synergies go far outside of NP and are dominated by other programs.

Evdokimov inquired about the management of the EIC ramp-up between medium energy and heavy ions. **Hallman** explained that is a future discussion; currently the focus is on ensuring that the two teams constructing the machine and the detector become fully integrated. The ground rules are just now being determined.

Kolomensky asked about the funding overlap between double beta decay and the EIC. **Hallman** said the EIC opportunity opened up and was seized, especially since there was appropriated funding for it. Double beta decay has not moved down in priority. There will be some competition, but NP will not lose sight of the fact that the double beta decay experiment is extremely important.

Hertzog called a break at 10:15 a.m.; the meeting reconvened at 10:32 a.m.

NSF NUCLEAR PHYSICS OVERVIEW, Allena K. Opper, Program Director, Nuclear Physics, NSF

The transition from NSCL (National Superconducting Cyclotron Laboratory) to FRIB is going smoothly. FRIB is planned to come online in FY22. To accomplish this the A1900 isotope separator that links the cyclotrons to the experimental beam lines has to be taken apart and reconfigured to couple the FRIB linac to the beam lines. This will require NSCL cyclotrons to be offline. About one year ago NSCL presented NSF with a plan on the physics that could be accomplished using stable beams or beams from long-lived isotopes and the ReA 3 and ReA 6 facilities during the period in which the NSCL cyclotrons will be off. NSF reviewed the intellectual merit and the feasibility of that plan and found both to be strong. A call for PAC (Program Advisory Committee) proposals using ReA3 and ReA6 beams has been released.

CAREER proposals are anticipated in July 2020. Proposals to the PHY (Physics Division) solicitation were due December 3, 2019 and those proposals are out for review. The MRI (Major Research Instrumentation) program is for projects between $100K and $4M. Those proposals have come in and have been checked for compliance; review requests will be sent out soon.

Mid-scale is one of the 10 Big Ideas for NSF; there are two levels Mid-scale 1 ($6M-$20M) and Mid-scale 2 ($20M-$70M). Solicitations were issued in FY19; Mid-scale 1 has made its awards for a total of $120M, funded in FY19 and FY20. Mid-scale 2 is finalizing its packages for the National Science Board to consider; awards are anticipated in August 2020.

The base funding for the experimental nuclear physics program has remained flat since FY16. In FY19, the nuclear physics experimental program made awards of $20.5M. In FY19 planned support for NSCL was $24M but received $28.5M; the $4.5M increase was a result of last year's Appropriations lapse (35 days). NSF used FY19 appropriations to forward fund one-quarter of the operations and maintenance (O&M) costs of all facilities. In FY20, NSF has its Appropriation but is awaiting Congressional approval of the operating budget. In the FY21 budget request, PHY research support will go down by 9.6% compared to FY19. Due to the forward funding for LIGO (Laser Interferometer Gravitational-Wave Observatory) its FY19 budget went up to $45.5M and will go back down to $45M in FY21.

Opper closed with three highlights Betelgeuse and ^{12}C burning, the third GRETINA (Gamma-Ray Energy Tracking Array In-beam Nuclear Array), campaign at NSCL, results on 50Ti(d,p)^{51} Ti using the "Super-Enge" split-pole spectrograph, at Florida State University, and longitudinal wobbling in ^{187}Au.

Discussion

None.

PRESENTATION OF THE DOE COMMITTEE OF VISITORS (COV) SUBCOMMITTEE REPORT, Filomena Nunes, COV Subcommittee Chair, Michigan State University

NSAC was charged with assessing the operations of the Office of Nuclear Physics and providing evaluation on two major elements: the efficacy and quality of the processes used to solicit, review, recommend, monitor and document application proposals and award actions; and the quality of the resulting portfolio including its breadth and depth, and national and international standing.

The COV concluded that the NP portfolio is world leading in many areas, and this is consistent with previous COV findings. The program supports a broad range of research programs and is vital and important domestically. The COV was impressed with the growth and capabilities of the DOE isotope program, exciting nuclear science being produced at major facilities concurrent with two major construction projects, the recent creation of the fundamental symmetries program and the recent hires of the program managers for those two programs, nuclear structure, nuclear astrophysics and the fundamental symmetries, the superb performance of the SBIR program, the reestablishment of the domestic stable isotope enrichment and the alpha emitting isotope ^{227}Ac, and the additional Topical Collaborations in nuclear theory and the establishment of the FRIB Theory Alliance. NP funding decisions are consistent with reviews and PAMS (Portfolio Analysis and Management System) has become a useful tool for the program managers. NP has implemented fair reviews in its selection processes and the committee commends their efforts in formulating and executing budgets in unique, challenging times. NP has been executing the priorities of the 2015 long-range plan and has made significant progress towards all four top recommendations.

The COV 2016 made five recommendations. Recommendation one – it is urgent that the Research Division Director position be filled within a year. Recommendation two – the COV

recommends that NP leadership develop a succession plan for the office to mitigate the risk involved in the potential loss of critical staff. Recommendation three – in addition to filling the current vacancies, NP should bring on board an additional scientist to support the nuclear theory program. Recommendation four – NP should continue efforts to increase diversity and inclusion in the community of Principal Investigators (PI) and those supported by their grants. And Recommendation five – SC should maintain the strong relationship between the NP and the U.S. research community through the Nuclear Science Advisory Committee.

DISCUSSION OF THE DOE COMMITTEE OF VISITORS SUBCOMMITTEE REPORT, NSAC

Fleming inquired about COV thinking concerning funding for junior researchers. **Nunes** said the COV did note there were many Early Career Award (ECA) proposals that were excellent quality and could have been funded had there been enough funds for it. In the past, the parts of the NP budget for ECA has been mandated which limits the number of awards that can be made. The comparative review usually serves as a tool to provide flexibility funding. **Schaefer** added the COV noted that the difficulty in getting an ECA, but it is even harder to get into the regular program. **Fleming** expressed it feels as if there is a wall for young people to obtain funding, that there is a low funding rate for ECA as well as a large fraction of comparative review funding is spent on renewal grants. **Hallman** explained that the funding levels for the ECA have been historically prescribed but NP is sensitive to the issue. There are two methods we are using in the core program. One is to review all the proposals at once, rather than as they come in (this is for new and renewal proposals). Additionally, NP is considering holding a separate process for at least one renewal, but after that the proposal should be competed with all other proposals. This would be followed by a periodic comparative review in the subprograms to look at everything all at once.

Greene asked if the COV provided any suggestions to NP for filling the Research Division Director. **Nunes** explained the COV had discussions with the leadership on this topic. There is a cap on SES (Senior Executive Service) positions such as this one. However, the committee identified that the lack of this position presents such risk that one should consider options out of the box. We are also entertaining visiting Dr. Binkley's office to discuss this as a subgroup of the COV. The COV is hoping the report can be helpful; it is meant to point out the risks involved in keeping this position unfilled. **Kolomensky** asked if the COV provided any suggestions on how the NP office can be more nimble in responding to new initiatives and opportunities. **Hallman** said NP has been trying to follow a traditional approach to fill the Research Division Director position at the SES level. NP's takeaway from this COV is the position cannot continue to be open and alternative approaches, such as a non-SES level should be considered.

Dudek asked, in the context of the recent issues with foreign talent programs, if the COV inquired about application and approval rates for citizens versus non-citizens. **Nunes** said the COV looked at rates of success in the various subfields, but not specifically for citizens and non-citizens. **Hallman** explained there was a recent government response to a program in another country specifically designed to accomplish goals other than basic research. The specific policy is in place to deal with that particular program from that country only. **Dudek** added this issue is a worry that the philosophy leaks out beyond that specific intention and reviewers may be interpreting the policy differently. **Hallman** expressed he had not encountered that. He acknowledged the comment and stated he would certainly be sensitive to it.

Carlson resonated with your first recommendation but questioned if it was sufficient. He asked if more coverage at the program manager level is necessary for such things as QIS, quantum computing, and AI/ML. **Nunes** shared that NP decided to split nuclear data and computing into two different programs understanding that there are separate needs in the two areas. **Carlson** asked where AI/ML will fall. **Hallman** reminded NSAC that the COV takes a snapshot at a particular point in time. On AI/ML, this is still early in the game and the level of activity there is still nascent. For example, in QIS the burden of stewarding that program has increased dramatically, both in the interest level in the community and a number of proposals. He speculated that a dedicated person may be needed to address QIS itself; a similar situation may be warranted if AI/ML increases in the same fashion as QIS.

Meziani inquired as to the intent of the comment on medium energy physics and the fact that the other program areas had significantly lower award rates. **Nunes** said the program manager for the medium energy was not able to participate in the COV and some things were not clarified. There is no evidence of an unfair process; the COV believed there to be proper oversight but simply noted the success rate is higher in this program. The comment is simply meant as a comment, without judgement.

Spyrou asked about the representation of underrepresented groups in terms of diversity. **Nunes** responded that NP has made a lot of progress in addressing gender representation. The COV has encouraged the office to expand that to all fields. NP is quite diverse in terms of staffing, but there is still a long way to go in terms of working with the community and improving diversity at other levels. **Hallman** added that the main vehicle NP has for contributing to diversity is through the review and comments given to the annual lab diversity and inclusion plans. He welcomed additional suggestions from the community for ways to improve diversity in the community. **Yennello** pointed out the COV noted that there is an extension to the ECA time period for all sorts of life issues. The code of conduct is not just for sexual harassment against women, it is a broader code of conduct. **Nunes** stated that COV did note that the response rates in PAMS are very high; most PIs report their gender but less so on the other classes.

Kolomensky inquired about COV discussions with NP concerning "blue sky" nuclear physics research for both detectors and accelerators. **Hallman** explained the COV is a retrospective look over a particular period of time rather than forward looking. HEP has traditionally been responsible for "blue sky" R&D of accelerators. The new Strategic Accelerator Initiative may change that. NP's accelerator R&D is more programmatic and focused on improving the efficiency and operation of existing facilities. That portfolio and much of the funding is in the operations of the facilities. The detector R&D portfolio fell victim to previous austere budgets and NP has not re-established or considered it, however it is something NP will look at along with the new detectors needed for the EIC.

Janssens asked if the COV considered recommending a process for ECA reviews. **Nunes** said the process depends on the activities within NP at the time of review. **Hallman** explained that each year NP asks one of the program managers to take responsibility for the exercise. Some years there has been a panel review, some years a mail review, and some years both types of review. Because of new vetting processes for FOAs the time available for carrying out this process has been contracted quite a bit. In the past two years NP has conducted an internal panel review. NP takes the point that a consistent process would be nice, but it depends on the time allotted to carry it out – ECA is across the entire SC.

Hertzog explained why filling the Research Division Director is paramount and continually noted. Since the landscape and breadth of the program managed by NP has expanded significantly (fundamental symmetries, isotope program growth, EIC - a more than a billion-dollar project, detector R&D, accelerator R&D and the international aspects of that, and counter parts on ton-scale beta decay) this is no longer a singularity within just NP but a position which must be filled as the oversight role it encompasses involves complex conversations with other agencies. Tossed on top of the aforementioned additions, without much warning, was the NQI. And on top of that was added AI/ML. The COV spent a lot of time exploring ideas of how one could get a senior person in the position to at least take on part of the increased workload.

Hallman thanked Nunes in particular and the committee in general. He explained the COV did an excellent job, were insightful, understood the nuances, and were very committed to making good, hard recommendations. NP takes what is recommended, along with the questions expressed by NSAC, very seriously.

Hertzog called for a roll-call vote. **NSAC** unanimously approved the report.

Hertzog called Hallman back up for questions. **Hallman** stated NP has agreed to partner in a National Academy of Sciences, Engineering, and Medicine study concerning progress on isomers. This intent is to explore the possibility of using isomeric states as nuclear batteries or nuclear clocks. NP will be partnering in a workshop to examine whether there has been enough progress to warrant a full-out National Academies study.

Wyslouch expressed concern about the long-term excitement of the physics in relation to the EIC and noted that while there is good support for the labs, universities cannot be left behind in terms of funding. **Hallman** said momentum in the university research community is indeed something to be kept in mind. RHIC and JLab are examples of maintaining the momentum and level of interest so that when the machine is finally ready everybody will be able to engage.

Fleming asked about the mechanism for QIS funding and ways it is funded within NP. **Hallman** within NP the proposals received have been in response to a targeted FOA and "Quantum Horizons," that is most likely the model that will be followed. Once proposals come in, experts in the field will review them using the mail review method. Targeted FOAs will continue to be utilized. **Fleming** said QIS topics could span a number of the different research lines, theory, and experiment; how will that funding be distributed? **Hallman** explained the amount allocated to NP for QIS has been segregated and will be processed by one program manager, with the exception of nuclear theory. The funds will be in a single account and adjudicated by one program manager.

Kolomensky asked about international negotiations and discussions concerning the EIC and double beta decay scope and cost. **Hallman** said in the case of the EIC, the milestones you have seen have been very significant and have generated a lot of interest in other countries. On the EIC side, team level interactions have started in earnest and actively being pursued; on the double beta decay side, it is not quite at the same state of advancement. For double beta decay we are talking at the agency representative level to determine what the level of interest is. There is an IUPAP (International Union of Pure and Applied Physics) meeting in late spring/early summer and that will be an opportunity to meet again with our counterparts and establish further connections. Part of our goal in IUPAP will be to discuss the question of site selection. **Kolomensky** mentioned the EPAC (European Particle Accelerator Conference) committee discussing European interests in double beta decay and asked if NSAC could play a role in international discussions. **Hallman** said NP was aware of EPAC and of their report, but it seems very Eurocentric in that there are major candidate technologies in the U.S. which are not

mentioned in that report. While it is unclear exactly how we connect to it, it is very clear that double beta decay has to be a global activity. There has to be more than one big detector because if anyone sees a signal a second detector will be required to confirm it. Cooperation across continents is essential. NP is trying to make the connection to discuss potential achievements in terms of a grand plan.

Bai expressed confusion about the FY21 budget and accelerator R&D appearing in the minus column while the new initiative is plus $1M. **Hallman** said in the FY21 scenario many things are in a minus category. The initiative is +$1M because it is an SC initiative. **Bai** reiterated that the next generation workforce is needed for accelerator R&D. **Hallman** explained up to this point much of the accelerator R&D has been managed centrally within NP. The EIC R&D funds will likely get separated out and be part of the EIC project. The remainder is the competitive pot...

Kolomensky asked if NP's suggestion is to retrain the existing workforce for the new programs given the impact on the research budget of new programs such as QIS, AI/ML, and the EIC. **Hallman** said for these national imperatives, such as QIS, NP is responding as Leadership in QIS is seen as very important for national security and competitiveness. NP's response to the NQI does not have to have a negative impact on the level of effort devoted to more traditional nuclear physics research. The challenge has been articulating that there needs to be a balance between operations and research. That balance is not being maintained at the moment because the research is being cut while other things are being optimized.

Hertzog expressed concern that there have been continual non-starter versions of the President's budget requests and Congressional markups and Congressional mandates to the point that advice from the Nuclear Physics community is lost. **Hallman** stated NP has opportunities to brief staffers on the Hill. The staffers have heard there are issues with research and they want to understand that more. **Gillo** added that the budget formulation has changed over time and NP has tried to work within the constraints and minimize the impacts. While it is a challenge, it is not because the importance of research is not recognized by NP, or because NP does not realize the balance of funding is not optimal. **Hertzog** asked how the community relays their faith in NP to make the difficult budget choices. **Gillo** suggested being extraordinarily sensitive to the messages put out.

Carlson strongly agreed with the sentiments expressed by Hertzog considering the cuts to research and requested the past few years' data to see how things are going. He asked if there is there something NSAC can do to improve the situation. **Hallman** commented that NSAC is a body that only responds to charges; there is not the possibility for NSAC to create a charge. Every individual in the community needs to articulate the value of the science, the stress points that damages the value, and efforts to advance everyone. It is a mistake to go in and be negative about anyone else's science or program, this will be defeated from the start. Congressional staffers want to know why what the community is doing helps the nation, what America gets out of it, and why it merits the support.

Hertzog dismissed NSAC for lunch 12:18 p.m. and reconvened the meeting at 1:30 p.m.

Afternoon Session

PRESENTATION OF THE NSAC Mo-99 SUBCOMMITTEE REPORT, Suzanne Lapi, Mo-99 Subcommittee Chair, University of Alabama

Lapi explained the Mo-99 program, rationale, and the subcommittee findings and recommendations. In response to recent shortages of Mo-99 in some markets, the Mo-99 program seeks to develop two producers of Mo-99 to produce at least one-half, each, of the U.S. domestic supply for medical imaging (using Tec-99). Mo-99 can be created without the use of highly enriched uranium (HEU) by low enriched uranium (LEU) fission-based, neutron capture, and accelerator-based. Four cooperative agreement partners are involved: NorthStar Medical Isotopes, SHINE Medical Technologies, Northwest Medical Isotopes, and Niowave. NorthStar has completed its work and has Mo-99 in the U.S. market (30%-35%). NorthStar is also working on an accelerator technology and their period of performance has been extended to 2021. Shine Medical Isotopes now has an active cooperative agreement and they aim to be in the marketplace in 2022. Northwest Medical Isotopes is a new company that aims to do LEU fission and enter the market in 2023. Niowave is another new cooperative agreement partner that aims to make Mo-99 and other isotopes by photo nuclear LEU fission and they aim to enter the marketplace by 2024 or 2025.

Findings. The Mo-99 program is continuing to make progress and the reliability of domestic Mo-99 supply is improving. The uranium release and take-back (ULTB) program is underdeveloped, however, some of the cooperative agreement partners have found alternative methods to continue moving forward: outright purchasing of material or putting off the waste deposition path. Both of the NNSA goals, to reduce the HEU for making Mo-99 and to have a domestic Mo-99 supply, are moving forward. The committee felt that the national laboratory program has been effective and should be continued with a focus on R&D specific to advancing Mo-99 production. NNSA continues to highlight the need for potential ULTB customers to engage with DOE and NNSA at least two years prior to the first delivery needs. However, the committee felt that NNSA and DOE-Environmental Management (EM) did not provide the committee with a waste take-back model and contract template as requested in the last report.

Recommendations. The committee felt that limitations of the ULTB program is one of the biggest risks of the program's success. The ULTB contract templates should be reviewed and revised as necessary, in particular with respect to reducing the continuing significant uncertainties in the take-back aspects of the DOE-EM program. The second recommendation was that the NNSA should focus their strategy on prioritizing future awards such that time-to-market consistent with the stated objective is considered the most important review criteria.

DISCUSSION OF THE NSAC Mo-99 SUBCOMMITTEE REPORT, NSAC

Greene questioned the use of an HEU reactor in the neutron capture process. **Lapi** said the fact that NorthStar is using a reactor that runs on HEU was not missed by the committee. NorthStar's motivation there was to achieve the goal of making low specific activity Mo-99, get it in their generators, and move that technology into the accelerator driven Mo-99 process to do gamma N on Mo-100 using the same generator. Their strategy is the use neutrons available at University of Missouri Research Reactor (MURR) to make a product similar to the end product and then to get the generator FDA approved. Getting the generator FDA approved took several years.

Kolomensky asked about the changes in the landscape and new facilities coming online. **Lapi** said NNSA has supported the conversion of other facilities from HEU to LEU targets. There are a significant number of processors and irradiators coming online using LEU targets,

but they are all outside the U.S. The goal of having a stable supply domestically means having a domestic source.

Hertzog requested the U.S. demand per week and asked if the goal of the program is 100%. **Peter Karcz** (Mo-99 Program Director at NNSA) explained the actual U.S. supply nominally is ~ 4,500 six-day curies. The 6,000 total would yield the 4,500 plus a 35% outage reserve capacity recommended by the Organisation for Economic Co-operation and Development (OECD) report. In terms of MURR and the HEU, there is a requirement in the AMIPA (American Medical Isotopes Production Act) that allows the use of HEU fueled research reactors, and specifically states they should not exclude the use of those reactors as long as there is a plan in place to convert from HEU to LEU fuel. There is a Secretarial Determination that allows MURR to be used for production of Mo-99. **Lapi** added that the supply of Mo-99 for the Tc-99 medical imaging is not distributed equally to all. The overage reserve capacity is necessary because of the uncertainty that all markets and all hospitals are able to obtain it.

Lapi explained the NorthStar generators use a unique a generator system with a much larger footprint than the old generator systems. There is some discussion about market penetration, because a switch is required to use the new technique. Which facilities will use these is undetermined but it is important to be aware that the NorthStar generators, although they are the first to market, are more complicated to operate.

Forbes asked about the major bottleneck with the ULTB. **Lapi** said the bottleneck is a lack of a disposal path for waste greater than class C. It is difficult to define what will be in the waste and how much it will cost. Contract templates and ballpark numbers exist, but determining what it will cost on the take-back side remains elusive.

Kolomensky asked about the time scale for NorthStar to ramp up production and use the technology consistent with the stabilized isotope production capabilities in the U.S. **Lapi** said her understanding is NorthStar has enough Mo-99 to get to about a third of the U.S. market needs for the next N years. The limiting step for NorthStar is their FDA approval.

Yennello asked what NorthStar's capacity will be given the additional $15M for their accelerator based production (gamma N). **Lapi** said with the gamma N reaction, NorthStar could be capable of producing 100% of the U.S. market. **Karcz** added the capacity for the accelerator project is limited to the number of pairs of accelerators. Each pair will produce ~850 six-day curies per week. The plan is to start up with one pair and observe market reaction and then add accelerators as the demand increases for the accelerator-produced Mo-99. **Yennello** inquired if NorthStar will be able to be self-sustaining as they expand or will they require another infusion of funds for each pair of accelerators. **Lapi** said NorthStar stated if there is more money and a new FOA, they will apply. A lot of these cooperative partners have substantial private investment enabling them to move forward on their own too. **Karcz** explained that NNSA is not getting involved in the commercial operations. For NorthStar to increase capacity for the accelerator facility they have to purchase another pair of accelerators (~$2M). NorthStar would also have to build another building connected to the current one. The current location of their accelerator facility can fit one pair, and they would just add on modularly.

Yennello inquired if the committee saw a need for continued investment. **Lapi** said the 2019 committee members were surprised there was an FOA and a new infusion of funds (a decision by Congress). **Karcz** added that NNSA has another FOA for $35M; NNSA did request an additional $50M in 2021 to be added to the cooperative agreements. **Yennello** asked about the long-term plan and continued investment from NNSA. **Karcz** said most of the cooperative agreement partners do not have all of the investors lined up to meet all of their requirements for

the projected costs. With the additional funding NNSA will assist them in their equipment and construction costs and intend to continue lab support for R&D, licensing, and seed money.

Hertzog called for a roll-call vote. **NSAC** unanimously accepted the report.

THE FIRE (Fission in R-process Elements) TOPICAL COLLABORATION, Nicholas Schunck, Lawrence Livermore National Laboratory

The collaboration's goal is to understand the formation of heavy elements in the universe covering three main topical areas: astrophysics, nuclear structure, and nuclear reactions and data. Five institutions are involved in the collaboration. The budget is $500k per year. The FIRE project is about nuclear synthesis. For light nuclei most of the nuclear reaction processes are stellar processes, the reaction rates can be measured accurately in the lab, and most of the uncertainties in the simulation come from the astrophysical conditions. In heavier nuclei, the preferred mechanism is the rapid neutron capture process with a sequence of several neutron captures followed by beta decay. Those reactions take place in neutron-rich environments meaning we have to deal with the uncertainties from the astrophysical conditions as well as with nuclei without experimental information. With the multi-messenger observation of a neutron star merger these became a prime candidate for the site of the R-process responsible for nucelo-synthesis.

To carry out process simulations one calculates the relative abundance of a given element as a function of time in the universe; this requires nucleosynthesis codes. FIRE uses the PRISM code which clearly separates the reaction network from the nuclear physics input. This is a very important capability unique to the project and unique to the U.S.

Nuclear inputs are complete information about the structure, decay, and reactions of all atomic nuclei. FIRE works to improve the description of beta and gamma decay to do the framework, to do a direct calculation of fission yields rather than relying on systematics and hand-weighted arguments.

From a theory point of view, there are three classes of theoretical inputs to calculate. One is the probability that fission takes place, fission fragment yields, and fission spectrums. The FIRE collaboration has developed a table of initial fission fragment distributions for all Z> mercury. R-process simulations include physics-based fission fragment distributions, the impact of neutron emission from all fission fragments on R-process simulations, discovery of the role of beta-delayed fission in the R-process, and special nuclei – the crucial role of spontaneous fission in ^{254}Cf.

The FIRE collaboration has built a unique U.S.-based capability to tackle the problem of nucleosynthesis, has made great progress in incorporating realistic models of fission in R-process simulations, describing the fission spectrum, following decay and using it in the network, describing beta and gamma decay in a single framework, and connecting network calculations with astronomical observations. Two former FIRE collaboration postdocs have been hired as staff at national laboratories which is an important aspect of this topical collaboration.

One conclusions of the FIRE collaboration was if nuclear physics uncertainties dominate over astrophysical uncertainties, to reduce those uncertainties it will be important to develop a consistent description of the nuclear data. That is it is important to have a single theoretical framework that provides all the ground state properties, all the decay properties, and all the fission properties, rather than a patchwork of models stitched together, which is the current method. One of the next frontiers is using nuclear density functional theory that has the potential to describe many of these nuclear data in a consistent framework, but this is a computationally

demanding problem. That is where high performance computing could help. And ML techniques could be used to build emulators of some of the expensive theoretical models thus enabling simulations to be run in a more consistent way.

Discussion

Spyrou mentioned ^{254}Cf stating other groups, especially in Europe, do not see this signature, and asked what is being missed experimentally to decide if it is important or not important. **Surman** explained the difference between the European groups and the FIRE collaboration is the set of fission barriers being used for the calculations. If the fission barriers in the decay pathways that feed the ^{254}Cf are high then there is plenty of ^{254}Cf produced and the signature is seen. If the barriers are low fission will depopulate that region before any ^{254}Cf is made. The experimental signature necessary to understand is the fission barrier height in that region. There is no information about any of the barrier heights on the neutron-rich side. **Schunck** added this points to the need for developing a better theory for spontaneous fission. Many of these spontaneous fission calculations rely on barrier heights through simple models. There is technology to do more advanced calculations looking at the tunneling probability in the multidimensional space; it is doable but computationally expensive.

Horn asked how the collaboration is considering doing the calculations: using surrogate models in ML or combining experimental data with simulations. **Schunck** noted both were being considered. A pragmatic approach is to build an emulator that can learn the discrepancy between the model and experiments. That can be expanded to other kinds of observables like fission lifetimes, beta decay rate, etc. Another option is to use ML to build emulators to make the calculations faster. For example the fission fragments distributions requires calculating the potential energy surface. There are many points to calculate. Instead of coming up with millions of points to calculate, use a thousand or two then build an emulator that will learn how to fill in the gaps faster. The surrogate model would be an emulator of the full theory that learns. **Horn** asked if additional computing resources would be needed to achieve this task. **Schunck** explained the need for additional computing is to create the microscopic theory to yield a consistent set of theoretical inputs. It is more computationally expensive, therefore ML could help.

Hallman recognized NSAC members who are rolling off the committee with Certificates of Appreciation. The members recognized were Bai, Greene, Jurrisson, Kolomensky, Quaglioni, Meziani, Janssens and Schafer. Dr. Hertzog was presented with a plaque recognizing his years of service as the chair of NSAC. Hallman also presented a Certification of Service for 20 years to Gillo.

THE TMD (Transverse Momentum Dependent) TOPICAL COLLABORATION, Jianwei Qiu, JLab

The need for the TMD Topical Collaboration is to understand the QCD at the Fermi scale, which responding to the range from 0.1-10 fm. All emerging phenomena depends on the probes and the scale at which we probe them. They represent not the single quark or single gluon, they emerge from another theory. There's unprecedented complication of the difficulty of the theory to study as we do not see any quarks and gluons in isolation. So you want to understand the structure of these hadronic phenomena or structure but without being able to see any of the quarks or gluons.

The mission of the TMD collaboration is to 1) develop reliable and controllable tools to match the quarks and gluons to observed hadrons, 2) to quantify the structure of hadrons in terms of particle nature of the quarks and gluons, and 3) to provide education and a training of the young generation of QCD physicists.

To define the partonic structure of QCD requires a hard probe. The hard probe needs to be observable with two scales – a large scale to pin down the particle nature of quarks and gluons, and a small scale to probe the detailed structure of the hadrons. We need to identify naturally measurable two-scale observables, and prove or improve the QCD factorization for the new types of observables. The TMD collaboration focuses on the observables that are sensitive to the transverse motion of the quarks and gluons inside the bound state known as the confined motion.

TMD uses a three-pronged approach including theory, phenomenology, and Lattice QCD. Theory is needed to strengthen the theoretical foundation of TMD physics. Phenomenology extracts TMD knowledge from experimental data. And Lattice QCD allows them to pursue non-perturbative calculations of TMDs. Newly identified two-scale observables noted are TMDs with measured jets – light hadrons, TMDs with groomed jets, TMDs with measured jets – heavy hadrons, TMDs with nuclei and at small x, and TMDs with quarkonia.

Qiu shared highlights including TMD factorization and TMD definitions (theory), extraction of TMDs (phenomenology), Lattice QCD and phenomenology, and Lattice QCD and theory. TMD has provided service to the community as well. Such service includes TMD Summer School in 2017 and 2020, a Handbook of TMDs. The TMD collaboration has developed two bridged faculty positions and trained 8 postdocs, 4 graduate students, and several undergraduate students. The collaboration is on track to achieve all its proposed milestones.

Discussion

Horn asked about plans to consider AI/ML going forward. **Qui** said future plans depends on approximation which needs data, but at the same time TMD cannot wait for data. Using the QCD we can compare what is learned from the ML to understand the approximations. For example, TMD used JLab12 data to train software. When the EIC turns on, TMD will be part of the method for analyzing the data.

Kolomensky asked if the SoLID (Solenoidal Large Intensity Device) facility be useful. **Qiu** indicated it would be. TMD predicts the non-perturbative factor can be neglected, however JLab12 is exactly the machine that gave structure information. SoLID is a much better 4 pi detector.

Schaefer asked for information on condensing the QCD information down to a format that is approachable and understandable by those outside, yet interested in, QCD. **Qiu** said at this stage TMD is trying to extract the most reliable information from the experiment to develop a tool to connect the quarks to the gluon. At the same time, within the collaboration is a different working group who have been talking and arguing and debating how to connect to the two fundamental issues.

PUBLIC COMMENT

None.

Hertzog adjourned the March 2, 2020 NSAC meeting at 3:29 p.m.

The minutes of the U.S. Department of Energy and the National Science Foundation/Nuclear Science Advisory Committee meeting, held on March 2, 2020, at the Crystal City Marriott, Arlington, Virginia, are certified to be an accurate representation of what occurred.

David Hertzog, Chair of the Nuclear Science Advisory Committee on April 28, 2020.