FUSION ENERGY SCIENCES ADVISORY COMMITTEE
U.S. DEPARTMENT OF ENERGY

PUBLIC MEETING MINUTES

Hilton Washington DC/Rockville Hotel & Executive Meeting Center
1750 Rockville Pike, Rockville, MD 20852

October 2, 2019

MINUTES OF FUSION ENERGY SCIENCES ADVISORY COMMITTEE MEETING

The U.S. Department of Energy's (DOE) Fusion Energy Science Advisory Committee (FESAC) was convened at 8:30 a.m. on Wednesday, October 2, 2019, at the Hilton Washington DC/Rockville Hotel & Executive Meeting Center in Rockville, MD by **Committee Chair Dr. Don Rej**. 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/fes/fesac for more information about FESAC.

Committee Members Present:

Dr. Don Rej (Chair), Los Alamos National Laboratory (LANL)
Dr. Troy Carter, University of California, Los Angeles
Dr. Robert Cauble, Lawrence Livermore National Laboratory (LLNL)
Dr. Diane Demers, Xantho Technologies, LLC
Dr. Ralph Izzo, Public Service Enterprise Group (PSEG)
Dr. Charles Kessel, Oak Ridge National Laboratory (ORNL)
Dr. Stephen Knowlton (Vice-Chair), Auburn University (retired)
Dr. Tammy Ma, LLNL
Dr. Rajesh Maingi, Princeton Plasma Physics Laboratory (PPPL)
Dr. Lorin Matthews, Baylor University
Dr. Gertrude Patello, Pacific Northwest National Laboratory (PNNL)
Dr. Susana Reyes, SLAC National Accelerator Laboratory
Dr. Scott Parker, University of Colorado
Dr. Fred Skiff, University of Iowa
Dr. Philip Snyder, General Atomics
Dr. Thomas Sunn Pedersen, Max-Planck Institute of Plasma Physics
Dr. Paul Terry, University of Wisconsin
Dr. Erik Trask, TAE Technologies, Inc.
Dr. Anne White, Massachusetts Institute of Technology (MIT)
Dr. Brian Wirth, University of Tennessee

Committee Members Absent:

Dr. Mitchell Walker, Georgia Institute of Technology

Ex-Officio Members Present:

Dr. John Verboncoeur, IEEE, Michigan State University
Dr. David Newman, American Physical Society (APS), University of Alaska, Fairbanks
Dr. Paul Wilson, American Nuclear Society (ANS), Oak Ridge National Laboratory

DOE Personnel:

Dr. Jim Van Dam, Associate Director, Fusion Energy Sciences (FES), DOE Office of Science
Ms. Sandy Newton, FES
Dr. Samuel Barish, Acting Designated Federal Officer, FESAC

Other Attendees:

Arielle Baker, National Academies of Sciences, Engineering, and Medicine
Curt Bolton, DOE
Ben Brown, DOE
Floyd DesChamps, CFS
Mark Haynes, Concordia Power

Scott Hsu, DOE (ARPA-E)
Chris Jones, NAS
Josh King, DOE
Carolyn Kuranz, University of Michigan
Matt Millon, Stellar Energy Foundation
Karl Mueller, PNNL
Gerald Navratil, Columbia University
Erol Oktay, FES (Retired)
Nirmal Podder, DOE
Wayne Solomon, General Atomics
Steve Xiao, Savannah River National Laboratory (SRNL)

Others attending online (43, including):
David Anderson, University of Wisconsin
Scott Baalrud, University of Iowa
Kate Bannan, DOE
Richard Buttery, General Atomics
Tricia Crumley, DOE
JF Decker, DOE
Lynne Degitz, DOE
Alex Friedman, LLNL
Mark Foster, DOE
Lauren Garrison, ORNL
Charles Greenfield, General Atomics
Brian Grierson, PPPL
Walter Guttenfelder, PPPL
David Hill, General Atomics
Matt Hourihan, DOE
Nathan Howard, MIT
Jerry Hughes, MIT
Hantao Ji, PPPL
Stan Kaye, PPPL
Matthew Lanctot, DOE
Michael Mauel, Columbia University
Dale Meade, PPPL (Retired)
Matthew Reinke, ORNL
Hans Rinderknecht, University of Rochester, Laboratory for Laser Energetics
John Sarff, University of Wisconsin
Thomas Schenkel, Lawrence Berkeley National Laboratory (LBNL)
Derek Sutherland, CTFusion
Tom Vanek, DOE
Mickey Wade, General Atomics

Wednesday, October 2, 2019
Morning Session

WELCOME AND INTRODUCTIONS

FESAC Committee Chair Dr. Don Rej welcomed everyone to the FESAC meeting. Dr. Rej recognized and thanked FESAC members rolling off (Dr. Wendt, Dr. Greenfield, Dr. Rapp, Dr. Groebner, and Dr. Neilson), and announced the six new members (Dr. Izzo, Dr. Kessel, Dr. Matthews, Dr. Parker, Dr. Skiff, and Dr. Snyder). Dr. Rej reviewed the agenda and requested members of the public who wish to make a comment to inform Sandy Newton.

NEWS FROM THE OFFICE OF SCIENCE, Dr. Chris Fall, Director, Office of Science (presented remotely)

Dr. Van Dam introduced Dr. Chris Fall who was confirmed as Director of the Office of Science in May 2019. Dr. Fall shared his background in neuroscience, Advanced Research Projects Agency-Energy (ARPA-E), the White House Office of Science and Technology (OSTP), and the Office of Naval Research. Dr. Fall assured FESAC that SC takes its advice extremely seriously, thanked the members for their participation, and requested their thoughts on two new programs.

The Innovation Network for Fusion Energy (INFUSE) program is a public/private partnership (PPP) idea focused on making resources at the labs accessible to the private sector. The second program will utilize Other Transaction Authority (OTA) which takes a step beyond the cooperative agreement to enable the exchange of money for services; it uses milestone-based payments. DOE is asking for money to start this OTA for development and support of a robust private sector fusion capability.

FES is reviewing its overlap with quantum information science (QIS) and machine learning. SC is determining where artificial intelligence and machine learning can move progress forward in discovery science.

ITER discussions focus on the level and forms of support the U.S. can offer. Dr. Fall expressed concern with the level of Federal engagement from the ITER organization. However, he noted there is a lot of good news coming out of ITER; given what they are being asked to accomplish, the project is in a better place due to the ITER leadership.

ARPA-E's project model is being considered for FES. Dr. Fall has spoken with the Nuclear Regulatory Commission (NRC) on lessons learned from the traditional nuclear power industry in terms of regulation and certification and a timely and cost-effective process.

All the SC program offices are paying attention to diversity, equity, and inclusion (DEI). The national labs will be held accountable for reaching milestones on this topic. Dr. Fall mentioned PPPL and expressed confidence with the leadership of Steve Cowley to revitalize the lab and with the organization that runs PPPL. SC is applying resources to PPPL, remediating the tritium, refreshing utilities, and improving lab facilities.

The FES long-range plan is critical. Congress is asking for the FES plan. Dr. Fall requested FESAC consider if the planning process can be moved along more quickly stating a plan, that can be adjusted if necessary, needs to be in place for forward momentum. He reminded FESAC of developments, such as the NAS Burning Plasma report and private sector innovation, since the initial charge was issued and suggested that the subcommittee include these changes in their considerations.

Discussion

Dr. Rej thanked Dr. Fall for his guidance and comments.

Dr. Sunn Pederson asked about FES's strategy for the issue of intellectual property (IP). **Dr. Fall** said there are two parts to IP. Under the traditional mechanisms (grants, cooperative agreements, contracts) there are clear rules and a well-established framework for IP. Exceptions such as exclusions and waivers can be made in that framework. The issue of IP bears on the second new program I mentioned. OTA allows SC to renegotiate all elements of IP and to decide what is in the best interest of the government and the private sector. The DOE leadership team is oriented to making SC labs, expertise, and programs about more than basic science, but also for economic and technical development on behalf of this country. The DOE leadership team is willing to listen and adjust.

Dr. Cauble inquired about the timeframe for the strategic plan. **Dr. Fall** explained that calls are coming in asking when SC will have a plan. This amount of attention from the Hill and from the commercial sector is unique; it behooves FES to articulate and share recommendations.

PROGRESS AND PLANS FOR THE APS/DPP COMMUNITY PLANNING PROCESS, Drs. Nate Ferraro (PPPL), Carolyn Kuranz (University of Michigan), Nathan Howard (MIT), and Wayne Solomon (General Atomics)

The goals for the community planning process (CPP) are to produce strategic recommendations for four topical areas and four cross-cutting areas, provide a near- and long-term strategic outlook, prioritize the recommendations, and deliver the recommendations to FESAC by March 2020.

The program committee is organized into subgroups to produce recommendations in Magnetic Fusion Energy (MFE), Fusion Materials & Technology (FM&T), High Energy Density Physics (HEDP), and Discovery Plasma Science (DPS). Weekly meetings of committees and co-chairs, frequent expert group and cross-cutting group meetings, and periodic check-ins have been occurring. Community outreach includes announcements to the Google group website and society mailing lists, advocacy groups and expert groups.

The four cross-cutting groups are beginning to meet. The first stage of the CPP was community input on research opportunities and scientific gaps. The next stage is to assemble the plan and get feedback and buy-in.

The first HEDP workshop in College Park, MD, generated five "tent-pole" initiatives. Webinars are planned prior to the November meeting in Palo Alto, CA. The goal of the second workshop is to reach consensus on key scientific opportunities in HEDP.

Twenty-five initiatives were presented and discussed at the first DPS workshop in Madison, WI. DPS will hold a web meeting in October and forums at three conferences in October. Expert groups are expected to provide new or revised initiatives by November 8, preceding the three web-based expert group meetings in late November.

MFE and FM&T held a workshop in July in Madison, WI attracting an audience of ~170. Approximately 100 white papers were submitted and ~60 presentations were given. All initiative proposals were discussed, and all received written feedback. The next MFE/FM&T workshop, in Knoxville TN, will focus on assembling the strategic plan, hold more plenary sessions, and concentrate on high-level questions. The goals of the Knoxville workshop are to develop a set of near-term actionable recommendations, a long-range vision, and prioritize the recommendations.

The Snowmass meeting in January 2020 will be used to combine input from the topical areas into a coherent plan for FES and get community feedback and buy-in. The program committee is pleased with the progress and level of engagement from the community. While challenges remain, the committee is optimistic for a successful outcome. The process is on track to deliver a consensus report by the March 2020 FESAC meeting.

Discussion

Dr. Reyes sought specifics on the deliverable in March, a consensus report or a strategic plan. **Dr. Ferraro** explained that the program committee is focusing on a consensus report to make FESAC's activity to develop a strategic plan smoother.

Dr. Carter asked if FESAC could endorse part of the NAS Burning Plasma study to address Dr. Fall's request for an interim report. **Dr. Solomon** said, in terms of delivering a report sooner, the output of the CPP is available to the community and FESAC. Before the Knoxville meeting, the report should be close to a consensus view as it represents input from expert groups. The community as a whole has implicitly endorsed the NAS report. Some of the discussions

have been framed using the NAS report as a starting point, as the guiding principle. **Dr. Kuranz** added that the program committee is being as transparent as possible and pointed to the output available on the website.

Dr. Terry noted that the 2017 Madison workshop saw a lot of contention and strong opinions. He asked if going forward the process will avoid contention or purposely bring issues to the fore. **Dr. Solomon** expects direct confrontation will occur by merging strategic pathways generated in the expert groups. The contention will be apparent and occupy the majority of the discussion time at the Knoxville workshop. At the Madison workshop, the committee tried to set a framework for ideas and engrain in the community the importance of having a consensus and maintaining what has developed from the CPP. **Dr. Kuranz** agreed, stating that the program committee has not tried to avoid contention, rather focusing on important science to agree upon. Going into the second set of workshops, a lot of these discussions will happen.

Dr. Patello inquired about prioritization and budget scenarios, and about polling versus voting. She explained her expectation was prioritization across topical areas. **Dr. Ferraro** said that prioritization across topical areas is possible but unlikely given the timeframe and the amount of interaction necessary. Unlike voting (leads to a decision), the program committee will use polling to take the community temperature and look for trends and priorities.

Dr. Skiff stated that the FES program has a mission-driven component as well as discovery science. Therefore, MFE and DPS should cross-prioritize; likewise, inertial fusion energy (IFE) and MFE. **Dr. Kuranz** said that HEDP sits in both the fusion and discovery science space. HEDP and DPS have contemplated a combined effort and decided to keep things separate. DPS's current purview is broad whereas HEDP is singularly focused and much larger.

Dr. Verboncoeur mentioned the gradual transformation towards a more distributed power system away from centralized, large plants. He asked if the fusion community should be engaging with the power grid technologies communities to ensure that the grid is in place to revert back to a centralized framework. **Dr. Solomon** explained that the CPP is trying to encourage that type of activity and is actively reaching out to private industry for input. **Dr. Verboncoeur** added there is a huge power grid community in IEEE and suggested engaging them at the Bi-Annual Power Conference. **Dr. Izzo** stated that this was not the limitation to fusion. He was confident that any large scale central fusion plant would be able to plug in to the constantly evolving high-voltage system.

Dr. Newman indicated that moving forward with an interim report is past the scope of CPP and more in FESAC's purview. He suggested structuring the report around the tent-pole initiatives or the cross-cutting initiatives to make the hand off and development of an early interim report easier. **Dr. Ferraro** clarified that a program committee writing retreat will occur in December. If FESAC forms the subcommittee to be ready to receive output from the writing retreat, the program committee could write something to align with the subcommittee's needs.

Dr. Wilson inquired about efforts in FM&T to reach out to the traditional nuclear engineering community. **Dr. Lauren Garrison** of the CPP explained that there has not been a large effort so far. The topics of safety, licensing, and reliability have dominated.

Dr. Skiff asked about the focus of Snowmass if cross-prioritizing everything is not the goal. **Dr. Solomon** explained that the plans for Snowmass depend on the accomplishment at that time. Snowmass will primarily be the time for community response and feedback and adapting those comments into the final product. A secondary activity is to make sure that the community as a whole understands the priorities and the plan. If there is an appetite to cross-prioritize

everything, it could be done. **Dr. Kuranz** added that being able to understand, explain, and support another area's goals will be a huge success to the co-chairs.

Dr. Patello remained concerned that FESAC will receive a non-prioritized community report and will produce something the community will not support. **Dr. Solomon** emphasized that the community needs to support whatever is produced.

Dr. Demers commented that the tension within the community is expressing two things: a lack of clarity regarding the goals of this process (10-year strategy within a 20-year global vision) and a framework, or context, in which the strategy is being developed (the mission and vision of FES for the 10-20 year global period). **Dr. Kuranz** said that stewardship of fusion and basic plasma science is broad. She noted that consensus must be reached on the broad topics in the strategic plan, and that drilling down too far in any one area can cause disagreements. **Dr. Ferraro** explained that the program committee has used the NAS report as a structure on which to base planning. The program committee is trying to highlight elements identified by earlier processes and address those within the CPP to find community consensus and identify and clarify the differences from previous reports. **Dr. Demers** asked if a compact pilot plant is within the purview of FES. **Dr. Ferraro** indicated that the CPP has attempted to engage the community on FES's and industry's roles in defining, designing, and constructing a pilot plant.

Dr. Terry asked about the differences among expert or cross-cutting groups, noting that some are more aggressive or more successful in engaging the community. He queried if this is a problem for consensus. **Dr. Kuranz** added that the groups started in different places and have different levels of engagement. **Dr. Solomon** suggested that the program committee members representing the expert groups would have the best vantage point to address the question. **Dr. Ferraro** explained that the expert groups are not working totally independently. In the case of MFE and FM&T, there are twice-weekly calls among the program committee to share their progress.

Dr. Trask recommended a top 5 or top 10 list be an output from Snowmass.

Dr. Sunn Pederson asked if the distinction between a compact power plant and a low-cost path is being discussed. **Dr. Ferraro** assured FESAC that the language within the NAS report is being discussed. There tends to be a fair amount of agreement that a low-cost pilot plant is a reasonable goal. However, the question of compact requires interpretation and exploration.

Dr. White asked if there is value in mapping the tent-pole initiatives to elements in the NAS report. **Dr. Solomon** explained that going into Knoxville, with larger strategic elements forming, the mapping should become explicit.

Dr. Rej encouraged the program committee to continue to lower the barrier to entry and appreciated the web meetings.

2018 NAS REPORT ON SEXUAL HARASSMENT OF WOMEN, Dr. Arielle Baker, Associate Program Officer, The National Academies of Sciences, Engineering, and Medicine

Dr. Baker stated that the NAS committee charge was to determine the prevalence of sexual harassment of women in academic STEM disciplines, examine how sexual harassment impacts the recruitment, retention, and advancement of women, and determine the most successful practices and strategies for addressing and preventing sexual harassment. The committee interpreted the charge to include women at all levels, from undergraduates up to faculty, as well as sexual and gender minorities.

Sexual harassment was found to be extensive and pervasive in academia. Three types of sexually harassing behaviors are sexual coercion, unwanted sexual attention, and gender harassment. Gender harassment is the most common form. Gender harassment undermines research integrity, reduces the talent pool, and harms targets and bystanders. The committee found that even when sexual harassment is nothing more than gender harassment, it does the same damage as a single event of sexual coercion.

Fifty percent of women in academic science, engineering, and medicine, and 20-50% of students, experience sexual harassment. Sexual harassment is most severe in medicine. Women with intersecting identities, and racial, sexual, and gender minorities, experience more harassment.

In the legal system, Title IX and Title VII require a sexual harassment policy to be in place but not that it be effective. The legal approach alone is not sufficient to drive prevention of sexual harassment. Prevention requires considering that targets are unlikely to report and often face retaliation.

Sexual harassment is most likely to take place in environments that are male dominated (number, leadership, culture) and tolerant of sexual harassment. Tolerance includes the perception that reporting is risky, sexual harassment is not taken seriously, and offenders escape sanctions. Climate is the greatest predictor of sexual harassment. Institutions are encouraged to create diverse, inclusive, and respectful environments; diffuse hierarchical and dependent relationships between trainees and faculty; provide support for targets; improve transparency and accountability; and strive for strong and diverse leadership.

The NAS has created the Action Collaborative on Preventing Sexual Harassment in Higher Education, a group of over 60 institutions. The first annual Summit of the Action Collaborative will occur November 19-20, 2019 at the University of Washington.

Discussion

Dr. Izzo was delighted to see this work, but he found the findings to be decades behind the standards that most companies are setting. He was surprised that implicit bias is missing from the study. He asked why the standard is set so low; the standard for respect should be higher. **Dr. Baker** remarked that in higher education sexual coercion, the least frequent form of sexual harassment, is addressed while the most common form, gender harassment, is not. One element of addressing the issue is education so it is understood that gender harassment is a form of sexual harassment. The other element is creating mechanisms by which individuals can report gender harassment in a way that will have consequences addressing and hopefully rectifying the issue without meeting the legal barrier. Implicit bias was outside the scope of this report.

Dr. Wilson asked if discussions about independent funding included the issue of detaching trainees from the mentorship of a research group. **Dr. Baker** was unsure if that was addressed in the report.

Dr. Verboncoeur agreed that industry is ahead of academia and government groups and commented that sexual harassment needs to be taken to another level, to a criminal offense. He recommended sharing best practices presentations at annual conferences. **Dr. Baker** said that the committee recommended establishing a scale of consequences for sexual harassment that correspond with the severity of the behavior. Presenting best practices is the direction NAS is headed and is hoping that the Action Collaborative can elevate those promising practices.

Dr. Sunn Pederson asked why sexual harassment is more prevalent in medicine when there is more gender balance in medicine than in physics. **Dr. Baker** said the gender balance in medicine is focused at lower levels. Sexual harassment in medicine is not just experienced from colleagues, but also from patients.

Dr. White noted that the social dynamic at universities is different, explaining that male students say things to her that they would never say to a male professor. She raised the issue of imposter syndrome and behaviors that lead to comments like "you were only hired because you are a woman." **Dr. Baker** said that imposter syndrome was out of scope for this report. However, a current NAS consensus study on the underrepresentation of women in STEM disciplines will be published in January 2020, and it is addressing implicit bias, imposter syndrome, parental leave, and other factors that contribute to the underrepresentation of women.

Dr. Parker noted the gravity of implicit bias and expressed hope that NAS will investigate the issue and provide recommendations. **Dr. Baker** said that they are forthcoming.

Dr. Kuranz announced that at the American Physical Society, Division of Plasma Physics (DPP) meeting in October in Fort Lauderdale, FL, Dr. Cortina, an author of the NAS study, will be attending an afternoon lunch and moderating an evening panel discussion.

Dr. Verboncoeur added that because professional societies are international, they also face cultural challenges. He suggested considering U.S. researchers interacting on the international stage. **Dr. Baker** agreed saying this is particularly relevant for those who do fieldwork in international settings.

Dr. Izzo stated that this is a leadership challenge; leadership must set the tone that sexual harassment is simply not tolerated, or the behavior does not change.

Wednesday, October 2, 2019
Afternoon Session

Dr. Rej invited topics for discussion in the afternoon.

Dr. Carter wanted to discuss the transition from CPP to FESAC and the formation of the strategic planning subcommittee.

Dr. Skiff stated that cross-cutting areas represent the unity of our field. He appreciated holding online meetings for the DPS community and communicated the need to emphasize that the CPP is a unique and critical process. **Dr. Carter** expressed that an awareness of the importance of CPP participation needs to be stressed, and emphasis should be placed on developing initiatives in the DPS community.

Dr. Newman reminded FESAC that it is important to hear the entire statement Dr. Fall made to maintain the integrity of the process, not just "go faster". **Dr. Sunn Pederson** added that Dr. Fall laid out a forward path by suggesting that FESAC does not need to agree on everything, just on the goals. Different ideas on how to achieve those goals can be written. **Dr. Knowlton** echoed Dr. Sunn Pederson's point about Dr. Fall's mention of accelerating the process, and found the fact that the government is interested, and eager to hear findings, positive. The CPP is a quality process, and it is important to ensure agreement on the vision and accomplishing goals in 10-20 years.

Dr. Cauble asked about scheduling and critical dates for a FESAC report. **Dr. Rej** said that scheduling is important in terms of the transition, it is important to be smooth and orderly. He suggested using phone meetings to facilitate interim reports.

Dr. Rej asked FESAC members for their thoughts on the reality of the public/private partnership (PPP) situation.

Dr. Carter was pleased that the co-chairs are considering PPPs as this requires leverage on both sides. Taking advantage of the private activities is beneficial.

Dr. Verboncoeur expressed that PPPs are a great opportunity and an interesting way to leverage resources. He encouraged FESAC to consider the impact on workforce. Providing students with a career path will be an important part of whether universities can engage in PPP.

Dr. Terry said that infusion of private funding will accelerate timescales. He stated that FESAC needs to think about how the public and private sources of funding can operate in a complementary fashion to get the benefits of speeding up the time where possible, but not shortchanging important areas of development with intrinsically long timescales.

Dr. Reyes was pleased about the growing interest in licensing future fusion plants and engagement with the NRC. **Dr. Wilson** added, in terms of licensing, various overtures have been made to those in NRC, particularly waste management, but he was unaware of the engagement with the NRC in fusion. He mentioned that the American Nuclear Society also has a lot of resources in the licensing framework.

Dr. Kessel explained that there are existing government processes for engaging industries, laboratories, and universities. He recommended that FESAC educate themselves on these processes and new programs being developed and determine how these can be elevated.

Dr. Newman cautioned that leveraging resources not reduce resources from the government side. The public side of funding is essential.

FES PERSPECTIVE, Dr. James Van Dam, Associate Director for Fusion Energy Sciences

The FY19 FES budget enabled numerous accomplishments. The House and Senate marks ($688M; $570M, respectively) for the FY20 budget are positive. FY20 will begin with a continuing resolution through November 21, 2019. The FES FY21 budget addresses the Administration's research and development (R&D) priorities for American leadership, the workforce, values, transformative research, and multi-sector partnerships.

The National Spherical Torus Experiment-Upgrade (NSTX-U) meeting held in August 2019 resulted in a baseline cost of $199.4M. Critical decision (CD)-2/3a was granted at the Energy Systems Acquisition Advisory Board (ESAAB) meeting in September.

The DIII-D National Fusion Facility was active in FY19 resulting in several achievements (Long Torus Opening activities, experimental science campaign, helicon antenna modules, and high-field-side lower hybrid system). For FY20, DIII-D intends to run for 20 weeks, install the helicon antenna, and fabricate a prototype for the mid-plane 3D field coil.

Eleven awards were made to interdisciplinary teams for collaborative research in the tokamak program. Two construction projects were launched for Linear Divertor Simulator (CD-1 is scheduled for October 16-18, 2019) and a Matter in Extreme Conditions (MEC) petawatt laser facility upgrade, possibly to be located at the SLAC National Accelerator Laboratory. FES has selected its first six awards in the QIS competition. In April/May 2019, FES and the Advanced Scientific Computing Research (ASCR) program held a workshop on machine learning in fusion

identifying seven priority research areas in the accelerator science and enabling fusion energy categories.

A new PPP, INFUSE, started in June 2019. Of the 21 proposals, 12 were awarded. There were nine funding opportunity announcements (FOAs) in FY20; some are new, and some are annual. The U.S. contributions to ITER project, for First Plasma, is almost 60% complete.

Through S.512 and S.97, Congress has expressed its interest in understanding the regulatory approach for advanced nuclear reactors. In 2019, FES and APRA-E started informal talks with the NRC. FES has enhanced interagency interactions with ARPA-E and the National Institutes of Health (NIH). Coordination between FES and NIH has been emphasized by the Secretary of Energy Advisory Board (SEAB) in 2016 and in the FY20 House markup language; possible coordination areas include data science, artificial intelligence, bioimaging, cancer therapy, and medical isotopes.

A presentation on DOE policies for Diversity, Equity, and Inclusion (DEI) will be made at the next FESAC meeting. SC has a webpage specifically for DEI, including a collection of all DOE policies and procedures and a statement of commitment. Lab plans this year will include peer review on these DEI reports. Dr. Van Dam thanked FESAC members for their service and welcomed new members.

Discussion

Dr. Rej asked Dr. Van Dam to say more on the budget. **Dr. Van Dam** said Congress is going into conference and there are differences between the House and Senate marks, although both are above FY19.

Dr. Carter asked about reinstituting the educational programs, stating that these are a great way to bring diversity into the program. **Dr. Van Dam** mentioned that several programs are still available to students, including the undergraduate program, a graduate student award, the Early Career Award, and the national undergraduate fellowship. Previously, the Office of Management and Budget decided that education does not belong to the DOE. At that time, the national undergraduate fellowship program was merged into the Summer Undergraduate Laboratory Internship (SULI) program.

Dr. Rej asked about the increasing budgets and FES's flexibility to obtain more personnel. **Dr. Van Dam** complimented the FES program managers, describing them as outstanding and credited with FES being able to handle the new demands. Increasing the number of programs, and considering national labs and construction projects, will require more FES staff.

FESAC DISCUSSIONS ON A LONG-RANGE STRATEGIC PLAN FOR THE FES PROGRAM, Dr. Donald Rej

Dr. Rej introduced the agenda for discussion on the long-range plan, highlighting three elements to be discussed: 1) further questions or comments with the CPP co-chairs, 2) observations on meetings FESAC members have attended since April, and 3) selection of and transition to the subcommittee.

Dr. Snyder asked how the co-chairs were going to address resource limitations in relation to the gaps mentioned in MFE. **Dr. Ferraro** explained that focusing on the gaps will ensure the co-chairs develop something comprehensive and compelling, illustrating a path from

the current state to the goal. **Dr. Solomon** added that some gaps can be dealt with later; international collaborations should be brought in to address the gaps.

Dr. Parker sought clarification on integrating interagency research areas. **Dr. Kuranz** said HEDP, supported by the National Nuclear Security Administration, currently has a collaboration. Because different agencies fund HEDP, there is specific language in the report that promotes the science.

Dr. Reyes asked when the subcommittee will be formed and active. **Dr. Rej** referred the topic to the afternoon, but added that one lesson from the High Energy Physics (HEP) P5 process was to wait until after Snowmass to avoid lobbying.

Dr. Ma inquired about participation across topical areas. **Dr. Kuranz** explained that there was minimal cross-topical activity.

Dr. Patello asked if costs for initiatives will be included. **Dr. Ferraro** said that cost ranges have been requested to provide guidance for the budgetary scenarios. **Dr. Rej** noted that HEP had an expert for cost and schedule on P5. FESAC will define this activity.

Dr. Terry remarked that in the transport and confinement expert group, some of the cost proposals were not viewed as credible. **Dr. Ferraro** admitted to the challenge and explained that the program chairs have considered establishing an expert group to determine feasibility of the cost estimates. Those few people who are good at this and qualified are in high demand. **Dr. Rej** mentioned the DOE guidance table. **Dr. Ferraro** explained that Technology Readiness Levels (TRL) have been used by some of the expert groups.

Dr. Trask asked about the process for soliciting a top 10 list at Snowmass and suggested collecting everyone's second choices. **Dr. Wilson** suggested using rank choice as a tool for polling the community's support of certain ideas.

Dr. White asked the co-chairs about FESAC's assistance to help inform the community of the direction the process is heading (FESAC to complete a charge), to manage their expectations, and to continue to build trust between FES and the community. **Dr. Kuranz** suggested telling colleagues how important CPP is, how seriously FESAC, FES, and SC are taking this, what impact there could be on the community, and how the CPP differs from a Decadal study. **Dr. Solomon** also suggested sharing that the community product will be used by the subcommittee. **Dr. Kuranz** noted her plans to alert colleagues to Dr. Fall's comment that people on the Hill are asking for this report.

Dr. Verboncoeur said that an important component to note is the positive side effects, economic benefits, and scientific consequences from the CPP activity.

Dr. Trask asked if the program co-chairs were capturing lessons learned. **Dr. Ferraro** explained that the co-chairs are collecting lessons and best practices. **Dr. Trask** requested the information be in an appendix.

Observations on Meetings since April

Dr. Carter was concerned about the lack of participation at the DPS workshop in Madison. He indicated that the DPS community needs to develop initiatives, but DPS does not have a long list of $100M initiatives like HEDP.

Dr. Patello liked the structure of the Madison workshop but said that one weakness was that remote participation did not carry over to the break-out sessions. Within the materials and cross-cutting groups, there were several joint sessions. She expressed disappointment that there was not a lot of participation from the materials group. Finally, she speculated that the NAS

report defined the materials gaps eliminating the need to rehash gaps. **Dr. Reyes** expressed the possibility of fatigue within the materials community because of the most recent concerted activities.

Dr. Kuranz said that at the HEDP meeting the remote connections were extremely challenging, especially due to the budget restrictions. **Dr. Ferraro** added that remote sessions presented logistical problems. **Dr. Solomon** commented that the program co-chairs were not convinced remote was the best way to get interaction, but mentioned an idea to have a dedicated remote break-out group.

Dr. Ma noted that the HEDP meeting in Maryland was well run and a valuable exercise. She thought that discussions on the larger international context and leveraging outside resources was missing. HEDP, as a community, needs to figure out how to build off of international activities to make sure the U.S. maintains leadership.

Dr. Cauble said that the HEDP workshop went smoothly. He asked if the program co-chairs envisioned any differences for the second HEDP workshop in November. **Dr. Kuranz** explained that the five tent-pole initiatives, cross-cutting topics, facilities, and diagnostics will be further developed and presented to the community. The goal is to reach consensus and have developed and costed tent-pole initiatives.

Dr. Carter described the MFE meeting and initiatives as well run. For the Knoxville meeting, the co-chairs are well-prepared, but he is concerned about meeting the progress goals.

Dr. Demers asked the co-chairs if they anticipate having longer sessions in Knoxville for open, moderated discussion about the FES mission. **Dr. Ferraro** said that is likely, but the agenda has not been set.

Dr. Cauble asked how the Snowmass meeting will be organized. **Dr. Solomon** said that the objective is to relay a status update on the plan and get community feedback on a framework. **Dr. Kuranz** added that a lot of Snowmass will be educating the community. **Dr. Rej** reminded the co-chairs about Steve Ritz and the P5 meetings.

Dr. Wilson expressed concern that the U.S.-China MFE collaboration workshop is scheduled the same week as Snowmass. **Dr. Ferraro** shared that the US-China meeting planners have moved their workshop to February to accommodate Snowmass.

Dr. Newman suggested that the best practices guide also reside at the DPP. He asked about an international crosscut. **Dr. Solomon** said that there is particular activity within MFE and FM&T that has an international component.

Transitions and Subcommittee Criteria

Dr. Rej invited comments on criteria for subcommittee members.

Dr. Cauble inquired what committee make up worked in the past. **Dr. Rej** said FES's portfolio is wide and the committee must be diverse in both membership and technical areas. **Dr. Barish** explained that only the High Energy Physics Advisory Panel (HEPAP) chair was on P5 in an ex-officio capacity. P5 had 20-25 people, with several from outside the U.S. However, NSAC had all the advisory committee members on the subcommittee creating a subcommittee of about 50 people.

Dr. Knowlton asked if CPP had been harassed or lobbied by community members. **Dr. Kuranz** said to some degree they had, but she did not think it was out of malintent. **Dr. Ferraro** added that the co-chairs have been emailed directly rather than through the formal process; the lobbying has not risen to the level of pressure to amend the report.

Dr. Trask asked who will select the subcommittee members. **Dr. Rej** responded that he and Dr. Knowlton will select the membership with guidance and approval from FES.

Dr. Wilson inquired if all subcommittee members will be required to attend Snowmass or other meetings. **Dr. Rej** said it is desirable but not required. **Dr. Kuranz** invited FESAC members to attend any upcoming workshop or webinar, saying CPP would appreciate it.

Dr. Knowlton asked FESAC for insight on interpreting the charge given Dr. Fall's statement about leeway on the language. **Dr. Van Dam** stated that Dr. Fall is aware that FES wrote the charge in December 2018, and four weeks later the NAS Burning Plasma report came out. He reminded FESAC that one of the three budget scenarios in the charge is a blue-sky scenario. **Dr. Rej** reminded FESAC of Undersecretary Dabbar's statement that this is a great opportunity.

Dr. Kessel noted the need to know what product the subcommittee would receive from the CPP. **Dr. Ferraro** explained that the CPP deliverable depends on consensus; hopefully, there will be agreement around the major scientific opportunities, but most likely not budget numbers or a list of prioritized items.

Dr. Snyder asked if there is any mechanism to gather more information on potential costing of projects. **Dr. Rej** noted that the data available have been brought in through white papers. He requested that Drs. Kuranz, Ferraro, and Solomon deliver something crisper to FESAC and pointed out that once it goes to the subcommittee, there will be a costing expert.

Drs. Izzo, Newman, Rej, Sunn Pederson, and **Carter** suggested that the subcommittee include a costing expert, non-plasma researchers, individuals who have institutional knowledge and can work together collegially, and scientists who represent the full FES portfolio and have longevity over the next 20 years.

Drs. Patello, White, Sunn Pederson, and **Trask** supported having the seven co-chairs of the CPP be on the FESAC subcommittee. **Dr. White** voiced concern about having a non-FESAC subcommittee, pointing to FESAC's sworn oath and special role and its responsibility to FES. **Dr. Wilson** noted that the Nuclear Science Advisory Committee members have expertise in licensing and facilities.

Dr. Verboncoeur and **Dr. Skiff** suggested leaving room for transformational disruptive opportunities and engaging the co-chairs concerning the subcommittee makeup. **Dr. Carter** recommended international membership and **Dr. Rej** agreed, stating that would provide independence and connections with global plans.

Dr. Patello asked if it was possible to add a day to the March meeting for a FESAC subcommittee meeting and recommended letting the CPP continue its work and create the strategic plan. **Dr. Rej** supported the CPP continuing as the subcommittee.

Dr. Carter brought up the issue of conflicts of interest (COI) and DOE's disallowance of conflicted persons serving on the subcommittee. **Dr. Sunn Pederson** disagreed stating that COIs must be addressed regardless. **Dr. Barish** explained that FES has engaged the General Counsel's office at a high level for clarification on any legal issues.

Dr. Parker pointed out that conflicted subcommittee members can still provide important input and stated that building community trust was critical.

Dr. Carter asked about specific legislation and the issue of COI. **Dr. Barish** noted that FES is aware of the legislation but has not yet received any guidance. He explained that HEP avoided the COI issue by recusing certain people from some recommendations. **Dr. Barish**

wants to avoid the problem with the last FES strategic plan from 2014 when few people were able to vote on the report due to COI.

Drs. Carter, Trask, and **Terry** supported FESAC taking advantage of the current positive budget position, responding as quickly as possible, and forming the subcommittee early. **Dr. Trask** added that timeliness is worth the risk of lobbying. **Dr. Terry** injected the usefulness of allowing the subcommittee members to attend Snowmass and perform their own evaluation.

Dr. Kuranz was unclear on the activities of the subcommittee prior to Snowmass. **Dr. Terry** described the need like passing the baton in a relay race; the subcommittee will need to interface with the CPP. **Dr. White** added that early formation is often about logistics.

Drs. Newman and **Reyes** supported forming the subcommittee after the writing retreat, but before Snowmass, especially if there will be an interim report. **Dr. Cauble** added that the subcommittee will have to read a large amount of DOE and NAS documents over the past 15 years in preparation for this process. **Dr. Trask** was concerned about the subcommittee members being able to make travel arrangements to enable a productive discussion time. **Dr. Kuranz** agreed that forming the subcommittee is necessary, but she was unclear on the reason for a December timeline.

Dr. Patello informed FESAC that it would take ~2 months to put the subcommittee together. She pointed out meetings that affect the due date of the FESAC report, including the Fusion Power Associates meeting and the COV report. **Dr. Trask** recommended that selection of the subcommittee begin in November to meet the January timeframe.

Dr. Trask inquired about the timeline for the FESAC subcommittee to finish its work and any remaining tasks after CPP. **Dr. Rej** said that P5 held global peer reviews; he would like the subcommittee to do prioritization and sequencing with assistance from the CPP. **Dr. Ferraro** explained that sequencing information through the technology readiness level will come out of the CPP, but there will be less information on sequencing related to budget. **Dr. Kuranz** relayed that the CPP co-chairs' biggest challenge is to finish the cost and prioritization by March.

Dr. Barish mentioned HEP's community engagement and Nuclear Physics high-level plan as good examples. He added that the chair of the subcommittee had to be fair and knowledgeable, as well as able to sell the plan to key members of the Administration and the Congress.

Dr. Patello said that all the community input is supposed to be in the CPP report. She described the subcommittee's activity as repackaging the CPP report to meet the charge. **Dr. Rej** expressed agreement, except in the case of gaps to address. **Dr. Patello** argued that the CPP could provide those notes to the subcommittee. **Dr. Kessel** said that if the subcommittee makes substantial changes from the community input, consensus would have to be recovered so the community understood why the change had been made and ensure their views were still being represented. **Dr. Rej** said that the report will have justification and explanations about choices and sequencing.

Dr. Reyes voiced support for an interim message for Congress and asked if FESAC could contemplate an endorsement of the NAS Burning Plasma report. **Dr. Carter** also supported endorsing the NAS report indicating that it could be an interim action either by the subcommittee or a FESAC decision. **Dr. Verboncoeur** said that an interim report has more utility if it is aimed at the community because it provides an outline of the direction and ensures nothing is missed.

Dr. White asked what the endorsement would be used for. She spoke of needing CPP's input on the risk of endorsing the NAS report. **Dr. Newman** opposed asking CPP to endorse the NAS report, stating that it creates undue influence. **Dr. Demers** said that the community should make a statement prior to any endorsement. **Dr. White** added that there are risks to endorsing the NAS report, risks to the CPP, risks to FESAC's final report, and risks to the charge. **Dr. Kessel** pointed out that there has been a fair amount of disagreement with the more detailed recommendations in the NAS report. **Dr. Snyder** indicated that FESAC should endorse the NAS report independent of the CPP. **Dr. Knowlton** explained that a formal top-down endorsement of the NAS report might negatively impact the CPP. The CPP allows people to state what they want to do and be inspired about ownership of a program.

Drs. Verboncoeur, **Sunn Pederson**, and **Carter** agreed that alignment between the CPP and the NAS report can be called out. **Dr. Carter** suggested that the subcommittee determine support for an interim statement that endorses the two high-level recommendations in the NAS report, augmented by community input. **Dr. Wilson** expressed caution on endorsement fearing that it might derail the enthusiasm of younger scientists who are actively participating in the CPP.

ARPA-E FUSION-ENERGY PROGRAMS AND PLANS, Dr. Scott Hsu, Program Director, ARPA-E

ARPA-E is within DOE. Its mission is to overcome long-term, high-risk barriers by providing applied R&D funding for rewards in transformational ideas. ARPA-E's FY19 budget was $466M; the House and Senate marks for FY20 are over $400M. ARPA-E bridges the gap between basic research and energy commercialization.

ARPA-E uses the Heilmeier Catechism, a set of eight questions to determine if the risks are worth taking in a venture, for all new programs. Fusion is trying to achieve a zero-carbon cost-effective grid by mid/late 2020. The cost is unknown, but estimates are based on competition and financing.

Accelerating Low-Cost Plasma Heating and Assembly (ALPHA) is a $30M program over 3-4 years. ARPA-E realized early that cost was the main reason for lack of fusion deployment. The ALPHA portfolio consists of three categories of projects (integrated concepts, driver development, and applied magneto-inertial fusion science) across academia, labs, and small business.

ARPA-E is interested in transformative fusion R&D, accounting for cost constraints and timeliness constraints. Two potential programs, A and B, will provide information to be able to say that the concepts will work and thus people who are commercially driven can secure funds for projects with potential promise.

Capability teams that support multiple concept teams allow ARPA-E to leverage expertise, avoid redundant activities, stretch limited funds, and build PPPs. ARPA-E's fusion tech-to-market (T2M) objective is to smooth the pathway to fusion commercialization. This requires supporting studies of first markets for fusion, weaving in programmatic structure and incentives for public-private partnering, building finance scaling through investor engagement, and helping establish fusion regulatory certainty and public acceptance.

Discussion

Dr. Izzo asked how the price point ($75mWh) was chosen. **Dr. Hsu** explained that the fusion program is pointing to a particular study and others like it, which illustrates the market sizes at different costs. This study suggests that there is a smaller market for fusion up to $75/mWh or higher. In terms of carbon pricing at $50/ton, the question is at what point will fusion begin dominating the market.

Dr. Sunn Pederson inquired about the $2B limit for the cost of a plant. **Dr. Hsu** said that looking at lessons from fission, when the cost of capital starts to dominate the capital costs and schedule risks come in, the cost will start to balloon. ARPA-E also looks at competition, utilities scale, renewables, and combined cycle natural gas being built for <$1B. Program A ($100M) was about the fusion core itself. Some of the cost studies ARPA-E has commissioned in fusion are 10th of the kind for the core, and nth of the kind for the balance of plant.

Dr. Newman asked three questions about high risk/high reward projects, ARPA-E's partnership with FES, and funding a demo or pilot plant. **Dr. Hsu** explained that all the ALPHA projects were considered successful to a point. However, ALPHA funded several different categories of research. Not all projects were trying to achieve triple product advance. One project had a 50-fold increase in triple product for a $30M program. Fusion needs more projects at $30M with triple product increases of orders of magnitude. ARPA-E has a different statutory authority than FES and can do things quickly. Fusion will benefit if FES and ARPA-E can find the right way to be correctly complementary to each other. There is synergy in the enabling technology piece and the fusion nuclear science and materials piece. Secondly, on the cost-share programs, ARPA-E has close relationships with the Fusion Industry Association and a good understanding of companies' needs and challenges. ARPA-E would like to stand up public-private cost-share programs that are the most impactful. In terms of demo funding, fitting fusion into the transformative energy technologies R&D model provides a chance for it to work. Private companies believe they will be able to raise private capital, but they also understand that there are still many fuel cycle and materials challenges. PPPs are necessary to get to a demo, but private interest has to drive the latter stages of development.

Dr. Verboncoeur asked, in terms of bridging from basic research to production, and with respect to the existing NSF/DOE discovery science element, if an increased partnership with FES is foreseen and can answer future potential in component levels and system levels with FES. **Dr. Hsu** said that fusion is difficult because of the mismatch in costs. While $10M is a huge amount of money for many of the energy technologies, it is hard to do anything in fusion for $10M. That is one impetus for driving down costs first to fit within the transitional energy technology model better, but secondly, there are pieces of the integrative problem where this model could work.

PUBLIC COMMENT

Dr. Steve Dean, Fusion Power Associates, explained his concern with the current charge to FESAC for the long-range plan, stating that it should be rewritten and resubmitted. He articulated his concern within a historical context and examples. The current charge was written prior to the NAS Burning Plasma report. **Dr. Fall** talked about his emphasis on industry partnerships and ARPA-E's program management and business, leaving one to imagine that these are elements he would like to see in the strategic plan. Therefore, it would be beneficial to get a charge letter that specifies what it is he would like to hear from FESAC.

In terms of strategy**, Dr. Dean** argued that one must be very clear what the strategy is for, in other words what is the end-goal of having a strategy. Over most of the history of the U.S.

fusion program, the mission and goal have been to develop something that makes power. The activities attempt to find the most effective route to the best product in the shortest amount of time and at the lowest cost. About 20 years ago, this committee was called FEAC (Fusion Energy Advisory Committee). In 1996, FEAC conducted a study called "a restructured fusion energy sciences program," and at that time the mission was changed from developing a demo to advancing the "plasma science, fusion science, and fusion technology knowledge base needed for fusion energy…," marking a major change in the mission of the program.

In the NAS report, the second recommendation states that the U.S. should *start a national program leading to the construction of a compact power plant that produces electricity at the lowest possible cost* and went on to say that a *new national focus on developing a compact pilot plant in the long term will help set priorities for the near and mid-term fusion program.* Presumably the community, and the FES strategy, is laying out near and mid-term fusion goals. The mission of FES needs to be changed back to something that is achievable, but also is a practical product.

Dr. Dean recommended looking at the mission of the program, the statement of the mission; the idea that the program is trying to get somewhere. Historically, the mission has been that FES is trying to get to something, until in the mid-1990s when FES was forced to abandon that as a statement. This is the 25th anniversary of the Contract with America, Newt Gingrich's successful attempt to cut government spending. After the Contract with America was passed, there was a big cut in the fusion budget as part of cuts in government spending across the board. When this happened, FES lost the Tokamak Fusion Test Reactor and was forced to pull out of ITER for three years. **Dr. Dean** described the community as planting all the trees and FESAC needs to determine what the forest should look like. He recommended getting a clear statement from the DOE in a letter of an updated charge to develop the strategy.

Steve Xiao, SRNL, suggested having a line item, or subcommittee, with tritium fuel cycle, radiological confinement, and safety. SRNL is the only place in the U.S. that produces large quantities of tritium. In past dialog, SRNL and the wider tritium community found that the fusion community was not aware of tritium differences. There are two issues with tritium; first it is a permeable gas unlike radiation (a solid matter like uranium) or contamination (a solid oxide). Second is that public perception is an issue with tritium.

SRNL has world-leading isotope separation technology called the Thermal Cycling Absorption Process (TCAP) for hydrogen isotopes. To support a tritium fusion application, SRNL will need to scale this up by a factor of 400 to 1,000. Because tritium permeates into the material, there is a decay of H_3 bubbles. SRNL has a material evaluation and aging development program, but it takes at least 5 years to see the results.

Dr. Newman asked if **Dr. Xiao** was aware of any interaction between FM&T and the tritium working group. **Dr. Xiao** explained that there is some. The U.S. is responsible for the tokamak exhaust system of ITER, supported by some scientists from SRNL and other labs. SRNL provides tritium for other national lab needs (Nevada test site) and private companies like Shine Medical Technologies in Wisconsin.

Dr. Rej adjourned the October 2, 2019 FESAC meeting at 5:27 p.m.

Respectfully submitted,

T. Reneau Conner, PhD, PMP, AHIP
Oak Ridge Institute for Science and Education (ORISE)

Certified as Correct by:

Dr. Donald J. Rej, FESAC Chair

Date
February 9, 2020