FUSION ENERGY SCIENCES ADVISORY COMMITTEE

U.S. DEPARTMENT OF ENERGY

PUBLIC MEETING MINUTES

Virtual meeting via ZOOM
June 23-24, 2020

Fusion Energy Sciences Advisory Committee Meeting
June 23-24, 2020

The U.S. Department of Energy (DOE) Fusion Energy Sciences Advisory Committee (FESAC) convened on Tuesday June 23, 2020 from 11:00 a.m. – 5:30 p.m. EDT and on Wednesday June 24, 2020 from 11:00 a.m. – 1:30 p.m. EDT. The meeting was open to the public and conducted in accordance with the requirements of the Federal Advisory Committee Act (FACA). Information about FESAC and this meeting is available online at https://science.osti.gov/fes/fesac.

Committee Members Present:

Dr. Don Rej (Chair), Los Alamos National Laboratory (LANL)
Dr. Troy Carter, University of California, Los Angeles
Dr. Charles Kessel, Oak Ridge National Laboratory (ORNL)
Dr. Stephen Knowlton (Vice-Chair), Auburn University
Dr. Tammy Ma, Lawrence Livermore National Laboratory (LLNL)
Dr. Rajesh Maingi, Princeton Plasma Physics Laboratory (PPPL)
Dr. Lorin Matthews, Baylor University
Dr. Scott Parker, University of Colorado, Boulder
Dr. Gertrude Patello, Pacific Northwest National Laboratory (PNNL)
Dr. Thomas Sunn Pedersen, University of Greifswald
Dr. Susanna Reyes, SLAC National Accelerator Laboratory
Dr. Fred Skiff, University of Iowa
Dr. Philip Snyder, General Atomics
Dr. Paul Terry, University of Wisconsin
Dr. Erik Trask, TAE Technologies, Inc.
Dr. Mitchell Walker, Georgia Institute of Technology
Dr. Anne White, Massachusetts Institute of Technology (MIT)
Dr. Brian Wirth, University of Tennessee

Committee Members Absent:
Dr. Ralph Izzo, Public Service Enterprise Group

Ex-Officio Members Present:
Dr. John Verboncoeur, IEEE - Nuclear and Plasma Sciences Society, Michigan State University
Dr. Paul Wilson, American Nuclear Society - Fusion Energy Division, University of Wisconsin-Madison

Ex-Officio Members Absent:
Dr. Ellen Zweibel, American Physical Society – Division of Plasma Physics, University of Wisconsin-Madison

DOE Personnel:
Dr. James Van Dam, Associate Director for Fusion Energy Sciences (FES), DOE
Dr. Samuel Barish, Acting Designated Federal Officer, FESAC, DOE
Dr. Harriet Kung, Deputy Director for Science Programs, Office of Science, DOE

Other attendees:
Dr. Julie Carruthers, Senior Science and Technology Advisor, Office of Science, DOE

Dr. Mark Kushner, University of Michigan
Dr. Gary Zank, University of Alabama

Other members of the fusion community attended the meeting.

July 23, 2020

Dr. Rej congratulated Dr. Kung in her new position in the Office of Science (SC). In directing the six SC programs, Dr. Kung oversees approximately $6B of science funding. This represents the Federal Government's largest investment in basic science.

Dr. Rej stressed the importance of the long-range plan and offered his personal observations for FESAC members. Phase 1 of the FES Long Range Strategic Planning process was led by the American Physical Society with its community planning process, and it was a great success in bringing the community together. Phase 1 was completed in March 2020. The FESAC Subcommittee to develop a long-range plan for the FES program, under the direction of Dr. Carter, is leading the second phase.

Dr. Rej attended almost all subcommittee meetings as an ex-officio member since March 17. The subcommittee has been impressive in its leadership, technical and balanced experience in fusion energy and plasma physics, community awareness, quality work, teamwork, and commitment. The work of the subcommittee will enable FESAC to deliver the report to SC in December 2020.

Dr. Rej introduced Dr. Kung to present *News from the Office of Science*.

Dr. Kung expressed gratitude for being chosen as the Deputy Director for Science Programs; she is interested in working with the SC community. Dr. Kung provided a brief overview and updates of SC activities, including the SC reorganization, a budget update, the community's response to the long-range planning activity, and how DOE as an agency is responding to the science and technology challenges and opportunities, while dealing with COVID 19.

The major motivation of the programmatic reorganization of SC is to better align the organization to achieve strategic goals, as reflected in the new organizational chart. The primary realignment is at the top levels of the organization; there are very few personnel changes at the levels below the deputy director. Dr. Stephen Binkley has been promoted to the newly established Principal Deputy Director position in SC, resulting in the elimination of the position of Deputy Director for Resource Management.

The new structure became effective April 12, 2020, with Dr. Chris Fall as the Director of SC, Dr. Binkley as the Principal Deputy Director, Dr. Kung as the Deputy Director for Science Programs, and Juston Fontaine as the Deputy Director for Field Operations. This organizational structure highlights important directions and priorities, including the following new offices: Office of Diversity, Inclusion, and Research Integrity; Office of Strategic Planning and Interagency Coordination; Office of International Science and Technology (S&T) Cooperation and Trusted Research; and Office of Crosscutting and Special Initiatives.

In addition to the six program offices currently under the Deputy Director for Science Programs (SC-3), there are four offices. These are the Office of Communications and Public Affairs (CPA), Office of Scientific and Technical Information (OSTI), Office of Workforce

Development of Teachers and Scientists (WDTS), and Office of Grants and Contracts Support (GCS). This organizational structure is intended to foster more closely integrated relationships and partnerships between the Offices of Science Programs and Communications and Public Affairs. It also facilitates better portfolio analyses available through OSTI's various functionalities. This includes using the information and data regarding the impacts of the scientific outputs of the Science Programs and working with CPA to tell a more compelling story. SC-3 will also need to work more closely with GCS in trying to lower barriers to engage with the community as well as with the training and education opportunities supported by the WDTS program.

Regarding the budget, FY20 annual appropriations for SC equaled $7B. Additionally, the CARES Act provided $99.5M for COVID response. Considering just the annual appropriation, SC generally maintained funding levels across the programs as well as a balanced portfolio to support operating facilities and maintaining projects. For FY21, SC requested a lower budget of about $5.84B. In the previous three fiscal years, there has been a significant reduction in the level of requested appropriations. Congress has continued to appropriate more than has been requested, showing strong support for SC activities. This is especially true for FES. The FES program has had strong support from both Congress and the fusion community.

This is an important time to build on the credibility and progress the subcommittee has achieved to expand the diversity and reach in the activities outlined by the Long-Range Planning activity. These types of tasks, if done well, will have significant, lasting impacts on both the FES community and the SC community as a whole.

One example of such a successful planning process is that of the Office of Advanced Scientific Computing Research (ASCR). According to the "DOE Roadmap to Exascale Systems," the DOE National Laboratories have remained at the forefront of accelerated node systems. In 2012, the High Performance Computing community was relatively fractured and divided. The ORNL NVIDIA graphical processor unit (GPU) accelerated node system was a radical concept and not fully embraced by the community. ASCR was able to unite the community, build a unified vision, and develop a compelling and implementable plan. The community has started working together for a robust plan for future exascale systems. This required significant collaboration among the laboratories as well as between SC and National Nuclear Security Administration (NNSA) laboratories specifically.

The success of the exascale roadmap is due to very systematic community engagement, beginning with information sharing. There are many information and requirement gathering workshops. DOE engaged with vendors and the training community to share lessons learned from the pre-exascale GPU machines. This established broad foundations and allowed the community to move towards staff sharing and vendor engagement through the Laboratories' Centers of Excellence, which in turn led to the co-design concept of hardware and software integration. The exascale roadmap is a successful example of systematic planning and execution of a vision with a clear and implementable plan.

The exascale roadmap provides the structure for the Exascale Computing Initiative (ECI). ASCR recognized that hardware alone will not address the entire Science mission for the Department. Rather, the hardware should be closely integrated and co-developed with the applications. There are two components to this effort. The first is ECI's Selected Program Office Application Development, primarily supported by the Offices of Biological and Environmental Research (BER), Basic Energy Sciences (BES), and NNSA. The second component is a

dedicated Exascale Computing Project (ECP) that is co-developing exascale hardware and applications to optimize the value of the exascale computers planning to be developed.

One way to portray the success of ECP is in numbers. It is a seven-year, $1.8B effort launched in 2016. There are six core DOE National Laboratories involved: Argonne, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, and Sandia. The cross-laboratory partnership utilized lessons learned from the Spallation Neutron Source (SNS). The success of SNS illustrates that any program's long-range planning and execution should not be done in isolation. There are many "lessons learned" shared by the community that should be considered. Consulting the collective bodies of knowledge with experience that supports fusion energy science in general can be useful in finalizing a concrete plan for the future.

Another example of a successful and impactful planning process is the BES community consensus building guided by BESAC. The BES light source has received significant attention relative to other user facilities, but the complexity has led to reconsiderations in technology choice and facility design in light of rapidly advancing technologies. This is an example of conducting two sequential long-range planning prioritization studies. During one of the upgrade projects, two of the sub-projects were redirected to take advantage of advances in technology to ensure the DOE remains at the forefront of the scientific field stewarded by these machines. Program success is evident in funding and community support.

It is critical to understand that a unified vision and community is the most powerful and important message you can send to DOE, the community, the administration, and Congress. The unified message should show priorities, and it should be clear, compelling, credible, defensible, and affordable.

Congress allocated $99.5M for DOE to respond to the COVID-19 crisis. While DOE is not a response agency like the Federal Emergency Management Agency (FEMA) or the Centers for Disease Control (CDC), there are many capabilities across the laboratory complex that could be relevant. These include large-scale facilities, light and neutron sources, nanoscience centers, and high-performance computational resources. Additionally, there is broad expertise in novel testing for viral antigen and antibodies, drug discovery, vaccine development, supply chain bottlenecks, modeling and understanding disease spread, and molecular and structural biology.

To apply DOE resources and capabilities to the COVID pandemic, Dr. Fall developed the concept of a virtual laboratory. Although there are no DOE laboratories dedicated to biotechnology, there is significant expertise, capabilities, facilities, and experience that could be utilized. Thus, the first National Virtual Biotechnology Laboratory (NVBL) was created. The NVBL represents a consortium of 17 National Laboratories and takes advantage of DOE user facilities. This construct has operated since early March 2020, and has successfully served as a clearinghouse for responding quickly and systematically to COVID-19 S&T challenges.

The CARES Act funding has been used to both support DOE SC and NNSA user facilities, as well as a number of R&D projects that are not long-term basic research projects. These research projects are three- to six-month studies that take advantage of DOE core strengths and facilities. Initial research topics include epidemiology and logistical support, addressing supply chain bottlenecks by harnessing advanced manufacturing, medical therapeutics such as computational drug discovery and structural biology, innovations in testing capabilities, and understanding the fate and transport of viruses in the environment.

Dr. Kung briefly discussed three of the COVID research projects in more detail. The epidemiology modeling project takes advantage of DOE high-performance computing resources to project and model the spread and transmission of COVID. Advanced manufacturing of

medical supplies utilizes broad manufacturing capabilities to address supply chain issues in medical supplies, including tubes, swabs, testing plates, masks, respirators, and consumables. Finally, DOE capabilities in supercomputing, materials characterization, and nanoscience research are being used to inform the development of medical therapeutic interventions to target the SARS-CoV-2 virus.

Discussion

Dr. Brian Wirth asked Dr. Kung to discuss international diversity. International inclusion and diversity is an important aspect of the diversity and inclusion mission of the DOE. The recent executive order limiting immigration and its effect on international students and post-docs is concerning as all of the offices are reliant on international collaboration. **Dr. Wirth** asked how the executive order affected the mission and activities of SC. **Dr. Kung** replied that the fusion community has demonstrated the success and mutual benefits of international collaboration. DOE advocates mutual benefits while protecting intellectual capacity and property as well as sensitive information. This is a delicate balance, and the Department is working with an intra-agency group to address these issues. There are several on-going efforts to determine the optimal process to vet the proper posture of the Department's approach toward foreign engagement, including considering the postures of other agencies such as the National Science Foundation and the National Institutes of Health. The concern about international collaboration in light of this executive order is shared by many, and SC will continue to work to steward the best science possible and with the best partnerships.

Dr. Scott Parker asked if the historic spread between requested and allocated funds will continue into to FY21 and beyond. **Dr. Kung** noted that, starting in 2018, there has been a pattern of fiscal constraint. Much to the credit of FES, fusion science and SC have maintained support in Congress. The gap between appropriation and request has presented challenges in funding, but SC has continued to present a compelling and convincing research agenda that shows the value and reason for sustained support.

Dr. Carter asked about the execution of the BES strategic planning process in particular. The BES community was very intellectually diverse. User facilities serve scientists coming from biology, physics, chemistry, and other fields. **Dr. Carter** asked Dr. Kung to describe how that community was engaged in the process, the steps of the process, and how community support was developed amidst such diversity. **Dr. Kung** stressed the importance of inclusivity. There were many stages, such as the Basic Research Needs Workshop and the Facilities Prioritization studies, which ensured the disciplines' leaders were part of the planning process. The credibility of the strategic plan that BES presented was also a major contributing factor. Note that the target audience of that report is ultimately policymakers. Yet without community support, recognizing that the directions identified by the strategic plan are truly the most current priorities in research and technology for each of the respective fields, the strategic plan will not be successful. The community has been engaged at every step of the process to ensure concerns are addressed to the extent possible. This prevents the strategic plan from representing only a subset of advocates' views. Another advantage of BES was the inherent diversity, facilitating early adoption of diverse viewpoints.

Dr. Tammy Ma expressed interest in the new Office of Accelerator R&D and Isotope R&D, now under Dr. Binkley. **Dr. Ma** asked Dr. Kung to explain the implications of having these and other topical science programs pulled out of Science Programs, particularly on the strategic planning process. **Dr. Kung** stated that having dedicated offices on topic areas is

intended to give greater visibility to the topic areas' critical needs and priorities. Ideally, the ties with the scientific programs would remain strong. For example, four of the Science Programs participating in Accelerator R&D will retain strong core research in Accelerator R&D. There will also be a new office focusing on the engineering and production stages, such as covering the "Valley of Death" in Technology Readiness Levels. As the visions of these two offices in Science Programs mature, SC will assist with defining their vision. It will be a synergistic development.

Dr. Paul Terry asked Dr. Kung to elaborate on developing exascale capabilities compared with developing applications to science problems, specifically the process being followed to generate the best ideas on how to optimize the match between the scientific needs and the computing capabilities to ensure the most can be obtained out of new capabilities in terms of advancing the science. **Dr. Kung** said that the matching between science and capabilities is a continuous process. ASCR endured a systematic requirements gathering workshop engaging with the five other program offices. As part of the BES planning process, the highest priority science applications that would most benefit from the exascale computing platform were identified. The BES community and those planning the exascale computing platform developed the priorities through numerous iterations to build consensus. The process can be described as "review, assess, evolve."

Dr. Rej thanked Dr. Kung for her time and introduced Dr. Van Dam to present *Fusion Energy Sciences Perspectives.*

Dr. Van Dam discussed the official location of FES in the new DOE organizational chart. FES is under the office of the Deputy Director for Science Programs, and Dr. Van Dam expressed gratitude for Dr. Kung as the Deputy Director. Dr. Van Dam also extended gratitude to the FESAC members that are rotating off the committee, Dr. Robert Cauble and Dr. Diane Demers, as well as the continuing and new members.

The COVID pandemic has had broad-reaching effects. The community has adapted well to working from home, although there have been delays and cancelations. DOE has adopted a three-phased approach for returning to the workplace while work continues from home. Some DOE laboratories have entered phase one of reopening, such as Princeton Plasma Physics Laboratory, while General Atomics (GA) and Oak Ridge National Laboratory have maintained a low level of support. GA is beginning the process at the DIII-D National Fusion Facility. Many collaborators conducting the experiments are working remotely. There are also technicians on site setting up instruments and running diagnostics. DOE will enter phase two on June 29, 2020. Phase one applied largely to political appointees. Phase two will affect the Deputy Director, Division Director, and Office Director level. Meetings and conferences are being held virtually or are being postponed.

Regarding DOE's response to COVID, a "Dear Colleague" letter was published soliciting ideas and suggestions regarding what options DOE could pursue. FES received numerous responses, and all of them are being considered.

In terms of budget status, FES received a strong FY20 budget appropriation, but it was delayed by three months. That delay led to an abbreviated schedule for issuing solicitations, reviewing applications, reviewing proposals, and awarding decisions. These steps must be completed by July because procurement requests must be delivered to the Chicago Site Office before the money is released. In FY20, FES issued eight Funding Opportunity Announcements

(FOAs), which are for non-laboratories, four laboratory calls, a joint FOA with the Advanced Research Projects Agency – Energy (ARPA-E), an SC-wide call for the Early Career Research Program, the Innovation Network for Fusion Energy (INFUSE) request for assistance, and a LaserNetUS experimental call. In total, 15 solicitations are being executed. The congressional marks for the FY21 budget are expected in July.

There are numerous initiatives across SC, and FES is involved in many of them, such as quantum information science, artificial intelligence and machine learning, and microelectronics. Note that many of the initiatives are related to computing, which is an important subject for FES and SC more generally. The ECP is funded through the ASCR program office, and FES is participating in the *whole device modeling* application. Note also that the newest list of the top 500 supercomputers was published recently, and U.S. computers hold the ranks of two and three. Japan's Fugaku computer is now in first place. These are opportunities that could benefit the entire country, and they involve many SC programs.

DOE is in the budget formulation stage for FY22. To provide input to this process, FES has conducted individual budget planning meetings in which fusion researchers speak openly regarding their vision and current position.

Four active FOAs have companion laboratory calls. The status these are either *reviews completed* or *in progress*.

There has been significant progress on the International Thermonuclear Experimental Reactor (ITER), as shown in a photograph as visible from the sky. The large building in the center of the site is the assembly hall for the Tokamak Complex. It is roofed and walled-in. Inside, cryostat components are being installed, and the base was installed. The administrative offices are also complete and are connected to the assembly hall control room via a bridge and a tunnel.

DOE is producing a variety of components for ITER. Fabrication of the first central solenoid module is complete. The GA Magnet Technologies Center is building seven of these modules: six for use by ITER and one as a spare. An independent project review organized by FES is examining the plans for transporting the modules from San Diego to France. There are a significant number of safety precautions required in the transportation. It requires a wide variety of expertise, such as hoisting and rigging, oceanic transport, etc… Other large components DOE is producing for ITER include the Tokamak Cooling Water System and diagnostic components for heating systems, among others.

The ITER Council meeting that occurred June 17-18 was the first virtual ITER Council meeting. It included a presentation of the biennial Management Assessment, which contained 29 recommendations. The current Council Chair is Professor Luo Delong. The ITER Council commended the ITER Organization (IO) and the domestic agencies for the COVID-19 continuity plan. Staffing at the ITER site fell from about 2,000 to about 600 and is increasing again. There have been no instances of infection at the ITER work site. Productivity has been maintained in design and manufacturing, but there have been shutdowns. There will be a detailed report on the effect on productivity in a November ITER meeting. A number of milestones have been met, components have been delivered, and the project is almost 70% toward first plasma.

Dr. Van Dam extended congratulations to Japan's National Institutes for Quantum and Radiological Science and Technology (QST) for completing the JT-60SA, the world's largest superconducting tokamak, in March 2020. This project was completed under the Japan-European Union (JA-EU) Broader Approach program. While FES has not been a part of the process, FES has followed it closely and is discussing collaborative research with Japanese and European

colleagues. The Japanese-European Union collaboration began integrated commissioning, and they expect to have first plasma operation in autumn of 2020. Note that 2020 marks the 40th year of US-Japan cooperation in fusion and plasma physics research. This has resulted in many workshops, publications, and friendships.

Regarding LaserNetUS, there were 39 experiments during cycle one (July – December 2019). Nine lasers are involved in this network, seven of which were used during this cycle. Some received upgrades. Dr. Donna Strickland won the 2018 Nobel Prize for chirp pulse amplification and is a member of the LaserNetUS Scientific Advisory Board. This board gives advice about LaserNetUS facility access, capability development, new research thrusts, and facility priorities.

Regarding public-private partnerships, FES is unique in SC for pushing forward on this. The INFUSE program received about $4M in appropriations in FY20, and FES requested the budget to be doubled in FY21. Three new developments in INFUSE this year are expanding eligibility to foreign companies whose participation is beneficial to the U.S., raising the funding level and duration of awards, and relaxing the limits on the number of proposals. These were all contained in the Request for Assistance (RFA). Many proposals have been received, and FES may conduct a second RFA later this fiscal year if funding allows. In conjunction with the RFA, a Request for Information (RFI) was issued for Cost-Sharing Partnerships with Fusion Energy. There were 50 submissions, about 30 of which were unique (the remainder being joint submissions). These are being analyzed, and a summary is being prepared for Dr. Fall.

The 2020 Decadal Assessment of Plasma Science (2020 Decadal) is the fourth decadal assessment. It was scheduled to be developed before 2020, but the Secretary of Energy prioritized the National Academies of Sciences' Burning Plasma Research Report and allowed for the 2020 Decadal to be postponed. The public release of the 2020 Decadal was May 28, 2020. FES will take this report into consideration. Also, the FESAC Long-Range Planning (LRP) subcommittee will also use this report.

Dr. Van Dam thanked the LRP subcommittee for their hard work and dedication and reiterated the need for consensus. Funding goes to communities that reach consensus, prioritize, come together, and speak with one voice. Congress and the administration want to see coherence among the community and in the messaging.

On June 15th, 2020, FES announced that it will fund the National Academies to conduct a fast-track study on the development of a fusion pilot plant. DOE upper leadership was very interested in the 2019 Burning Plasma Research report and requested more research on the topic. FES worked with NASEM to author a statement of task, and NASEM will complete an eight-month, fast-track study regarding construction of a fusion pilot plant (FPP) that produces electricity from fusion at the lowest possible capital cost.

Note that reports from the National Academies traditionally came from the National Research Council. The reports are now published by the National Academies of Sciences, Engineering, and Medicine (NASEM). Traditionally, these reports have 1.5 - 2.5-year studies that are more than 100 pages. The National Academies have recently been asked to do these studies faster, such as for COVID. There are three new types of consensus studies. One is an interview forum and is six months, the second is the committee-driven workshop study and is seven months, and the third is an expert-judgement study that is 10 months.

FES requested the committee-driven workshop study. The statement of task is concise and succinct: First, in developing and carrying out a plan for building an FPP, identify the key goals that need to be established for all critical aspects of the FPP. Second, list the principal

innovations needed for the private sector to address, perhaps in concert with DOE, to meet the key goals mentioned above. This is a follow-up to a previous study for Business Process Reengineering (BPR) and is complementary to the FESAC long-range plan. Dr. Carter supports these new studies.

The statement of task establishes a committee to provide guidance for considering key goals for each of the FPP's anticipated phases of operation. Areas for key goals the committee may include are: scientific, for example materials and system performance and integration; technical, such as electrical output and availability; economic, including capital cost, time-frame, operating, and maintenance costs; environmental, for example, the level of radioactive wastes; and safety related, such as regulatory and tritium inventory goals.

In view of this charge, NASEM has proposed to utilize their Board on Physics and Astronomy (BPA) of the National Academy of Sciences, as well as the Nuclear and Radiation Studies Board and the Board on Energy and Environmental Systems, which are in the National Academy of Engineering program office. This represents the broad reach of the effort.

Regarding updates on personnel, Dr. Mickey Wade is now director of the Fusion Energy Division at ORNL. The former director, Dr. Phil Ferguson, is now the Division Director of Fusion & Materials for Nuclear Systems at ORNL. Dr. Wade was formerly the Deputy Director of the Magnetic Fusion Energy Division at GA. Additionally, FES is recruiting for three program manager positions. The results of the FES 2020 Early Career Research Awards have been published, and FES awarded three university awards and three laboratory awards. FES receives many applications for awards, but the awards are expensive. For example, the university awards are fully funded at the initiation of the research. FES tracks the recipients of these awards, and they quickly become leaders in their fields, so these awards represent strong investments in the respective field.

Discussion

Dr. Pedersen expressed interest in the FPP studies. Recalling that Dr. Van Dam indicated that the new NASEM studies should be device-independent, the answers to some of the questions will nevertheless differ by device. **Dr. Pedersen** asked Dr. Van Dam to elaborate on this. **Dr. Van Dam** noted that the charge requests the committee to identify "key goals, independent of confinement concept." The notion is to be concept-agnostic. The concept could be a tokamak, a stellarator, a field-reversed configuration (FRC), etc… As much as possible, the idea was to address the questions without getting into details. Note also that the LRP subcommittee is looking at a 10-year horizon. The FPP extends beyond that range. Regarding what technology will go into the pilot plant, the LRP subcommittee has its own ideas. This study is intended to be concept agnostic. **Dr. Pedersen** stressed that some of the technologies addressed would differ by concept and asked if all technologies would be considered or if certain types of technologies would be restricted by these concepts. **Dr. Van Dam** replied that it was the former; all technologies would be considered in the report.

Dr. Snyder asked about the NASEM follow-up study to the FPP. The details seemed to suggest factors like the cost of electricity would be considered. The wording that was included in the NAS report was chosen carefully to emphasize that the vision for the pilot plant was optimizing the path for realization of fusion electricity on the power grid while minimizing capital costs rather than cost of electricity. **Dr. Snyder** asked if the language in the report was clearly communicating that point. **Dr. Van Dam** stated that this new NAS study will not go in a particularly different path than that recommended by the burning plasma report.

Dr. Snyder noted that the budget process is still ongoing and asked if there was something from the LRP subcommittee that would be useful for FES in terms of input to the budget planning process and, if so, in what time-frame. **Dr. Van Dam** replied that all input is useful, and much is being offered. In terms of subcommittee input, there is a FACA process to follow for providing input. Dr. Carter will share information regarding what the subcommittee is doing, the results from focus groups, etc..., but the subcommittee is embargoed from discussing the content of the deliberation until the report has been published. Note that the CPP report is available, and FES has used the report for various purposes. For example, Undersecretary Paul Dabbar requested a briefing and requested the report in a different language for a particular purpose. FES also conducted data-mining on the CPP and other reports, which has been very useful.

Dr. Tyler Ellis asked when DOE might publish the cost-share program plan that was requested by Congress. **Dr. Van Dam** recalled that in the FY20 budget, there was language that requested an FES report regarding possible cost-share programs. FES worked diligently to write it, adapted it for our purposes, and asked for comments from SC including Dr. Kung, Dr. Binkley, and Dr. Fall. The report was then sent to Undersecretary Dabbar before the official concurrence process, which solicits more comments. The report is then formatted while FES officially responds to all of these comments. The report is presently at the Office of Management and Budget (OMB) for review. This is all part of the concurrence process. At some point, Congress will receive this report.

Dr. Scott Parker noted the difference between requested and allocated funds and asked two questions: first, what the extra money should be used for, and, second, if that difference is expected to continue into future fiscal years. **Dr. Van Dam** stated that the increase from the FY19 to the FY20 budget is almost entirely for ITER, which has been historically underfunded. In FY20, SC was able to repay its in-kind contributions in cash to ITER fully for both 2019 and 2020 calendar years. Again considering the FY19 budget, much of that budget was spent on mid-sized facilities upgrades and trying to bolster the work in several different areas. Several years ago, FES budgets were much more restricted by the level of appropriation. Other things the money is used for include solicitations for initiatives such as quantum information science (QIS) and machine learning, among others. Regarding the discrepancy between the budget request and allocation: Four years ago, Congress had budget caps, which led to unfavorable budget conditions. The caps were released for two years, re-imposed, and released again, due to COVID, which affected programs such as computing. There is a National High-Performance Computing Consortium across the Federal Government and is led by Dr. Barbara Helland of ASCR. Other examples include light-source machines and other facilities that have been maintaining operating status so that pharmaceutical companies and others can use the facilities. Also, the CDC and World Health Organization requested the Colorado State University Laser Lab undertake a project to determine if a specific spectrum of a laser could be used to disinfect PPE. **Dr. Parker** expressed concern in relying on the extra funding and emphasized the uncertainty it provides. **Dr. Van Dam** commented that Congress is happy with SC work. Other SC program offices have been effective in planning that supports budget activities. The SC budget has increased to $7 billion, and it may not decrease. It may not increase as quickly as it has in recent years either. The political situation could also affect this.

Dr. Rej introduced Dr. Mark Kushner and Dr. Gary Zank to present the *2020 NAS Report - Plasma Science: Enabling Technology, Sustainability, Security, and Exploration.*

Dr. Zank noted the breadth and intellectual diversity of the scientific field of fusion. Fusion is unique among some sciences in terms of its impact on all humans. Plasma Science and Engineering (PSE) has enabled many benefits, such as the Internet, jet turbines, medical implants, exploring our solar system, stockpile stewardship, hypersonic flight, and exploring if life can exist on exoplanets. In the future, fusion may provide nearly unlimited carbon-free electricity and compact particle accelerators used for medicine as well as new materials, forms of production, agriculture, and management of strategic weaponry, among others benefits.

The statement of task for writing this 2020 NAS Report is relatively generic for these types of projects. It is important to note that the recommendations were not to alter those offered in the Decadal Strategy for Solar and Space Physics, the mid-decadal assessment of that report, and the Strategic Plan for U.S. Burning Plasma Research. The study committee did an outstanding job. Diversity in sub-disciplines was well represented by the committee.

The report highlights five Grand Challenges in Plasma Science and Engineering. The first is understanding the behavior of plasmas under extreme conditions, and the second is mastering and understanding the interactions of the world's most powerful lasers and particle beams with plasmas. The third challenge is to accelerate the development of fusion-generated electricity. The fourth and fifth challenges are to demonstrate that lasers and pulse-power devices can produce inertially-confined fusion ignition, and to develop the capability for timely and actionable space-weather observations and predictions, respectively.

While the study committee was not specifically tasked with addressing diversity, equity, and inclusion (DEI) in the statement of task, the committee considered that DEI topics were important to discuss. The committee did not gather data to generate statistics, but there is a lack of diversity in core areas of PSE that does not reflect the society it serves. The significant level of underrepresentation should be addressed by increasing participation of women, ethnic minorities, gender-preference and gender-identity minorities including members of the LGBTQ+ community, persons with disabilities, and any other underrepresented communities in PSE. The significant looming turnover due to an aging workforce represents an opportunity to improve diversity in PSE professions in addition to the other efforts being taken.

Dr. Kushner presented the findings and recommendations of the report. There are two levels of findings and recommendations. The first is referred to as Chapter 1 recommendations, which are the highest level and the broadest recommendations. There are six individual chapters that address sub-areas of plasma physics, and there are recommendations that are more specific to these areas in each of the chapters. All of the findings and recommendations are in Appendix B. In this overview, the recommendations are presented in abbreviated form.

The first set of recommendations may be considered the theme of the report. The major findings are, first, that plasma science and engineering is an inherently interdisciplinary field of research. While the underlying science has common intellectual threads, the community is organized into sometimes-isolated sub-disciplines. The second finding is that interagency (and inter-program) initiatives would fully exploit the interdisciplinary and multidisciplinary potential of PSE in fundamental and translational research if properly stewarded. These and other findings lead to the following main recommendations. First, Federal agencies that directly support PSE, such as NSF, DOE, and NNSA, and those potentially benefiting from PSE, such as NIH, the Environmental Protection Agency (EPA), and the US Department of Agriculture (USDA), should better coordinate their activities extending into offices within the larger Federal agencies, such as BES or FES. Second, the Federal agencies and programs focused on fundamental plasma

research and those focused on science and technologies that use plasmas should jointly coordinate and support initiatives with new funding opportunities.

In Chapter 1, Table 1 lists 30 examples of interagency collaborations that focus on topics from fundamental issues to translational research. These 30 potential collaborations are examples and should not be considered recommendations. The examples came from discussions with the community, program managers in the agencies, and the committee as places to start the discussion, with one recommendation being that one interagency working group would help coordinate this.

The next set of recommendations are more specific for NSF. The committee found that there is significant potential for PSE to contribute to one of society's greatest challenges, namely the sustainability extending from fusion-based, carbon-free electrical power for electrification of the chemical industry. The committee also found that the translational nature of fundamental research in PSE needs greater recognition at NSF. The first follow-up recommendation is that the NSF Engineering Directorate should consistently list PSE in descriptions of its relevant programs and participate in the NSF/DOE Plasma Partnership. More strategically, the NSF should establish a plasma-focused program in the Engineering Directorate that broadly advances engineering priorities in energy, environment, chemical transformation, manufacturing, electronics, and quantum systems. This will require new funding to NSF. Note that the National Science Board (NSB) has recently released the *NSB Vision 2030* statement, and these recommendations are consistent with the goals outlined therein and the emphasis on translational research.

The next finding and recommendation address public-private partnerships. Although there are SBIR and STTR programs that address the inception of the innovation chain, such as the INFUSE program, there are few U.S. government programs designed to translate industrially relevant fundamental science into practice in established U.S. industries, such as microelectronics, biotechnology, and materials. This places U.S. industries at a competitive disadvantage internationally. The U.S. economic competitors, namely South Korea, Japan, China, and the EU, all have established programs to rapidly translate fundamental findings from plasma science to established industries. The recommendation is that Federal agencies that focus on plasma should develop new models that support the translation of fundamental research to industry. Programs supporting vital industries depending on PSE should be developed through relevant interagency collaborations.

The next set of recommendations address the PSE community. The multidisciplinary approach to PSE has been at the heart of its success and part of its ability to conduct fundamental and translational research. However, this multidisciplinary nature has worked against PSE's long-term viability in academia. There are no departments of plasma physics, and plasma physicists are a minority in nearly every department in which they reside. This lack of critical mass of faculty in PSE programs will lead to an erosion of U.S. capability in PSE. University leadership in PSE is rapidly aging and will need renewal in the coming decade. There will be significant turnover in the next ten years. It is unclear that those faculty will be replaced, let alone in greater numbers, in the coming decade. The recommendation is that Federal agencies should structure funding programs to provide leadership opportunities to university researchers in PSE and to directly stimulate the hiring of university faculty. This is the future of the discipline. If the faculty members in PSE are not replaced, the industry will be at risk.

The next recommendation to the PSE community addresses education and undergraduate programs. Plasma-specific educational and research programs that also provide opportunities to

diverse and less-advantaged populations are needed to ensure a critically-populated PSE workforce. PSE intern programs and summer schools are needed for undergraduate and graduate students, as are programs for students with incomplete preparation to progress in plasma physics. There has been an unfortunate decrease in the funding of these specific programs by several agencies including the DOE because of guidance from OMB and OSTP stating that that these programs may be a duplication of effort. It is the opinion of this research committee that more duplication in these areas can only strengthen PSE. The recommendation is that funding agencies, such as NSF, DOE, the National Aeronautics and Space Administration (NASA), and the Department of Defense (DOD), should structure funding to support undergraduate and graduate education training and research opportunities and encourage access to plasma physics for diverse populations. These would be direct scholarships and fellowships for plasma-specific activities. The report particularly emphasizes sponsoring undergraduate research at traditionally-undergraduate institutions to help diversify the field.

The next recommendations address the research enterprise. Given the impressive investments by other nations, there has been incremental progress in U.S. facilities, and this progress is insufficient to maintain leadership. A spectrum of facility scales is required by the sub-fields of PSE to address their science challenges and translational research. Mid-scale facilities, e.g. $1M to $40M depending on the field, offer particularly good opportunities or broadening opportunities within academia. This alludes back to the previous findings and recommendations regarding the 10-year window to revitalize the academic workforce. This implies universities should understand these reasons to hire plasma faculty. These investments address science and the need to renew the academic work force. The recommendation is that Federal agencies should support a spectrum of facility scales that reflect the requirements for addressing a wide range of problems at the frontiers of PSE.

Regarding facilities, the committee found that investments in PSE facilities without the concurrent support of research and operations is not optimum. The committee observes that, when facilities are constructed, it is common that the long-term viability of the facility is not accounted for in terms of renewal, upgrading, and use of the facilities. The committee recommends that Federal agencies provide recurring and increased support for the continued development, upgrading, and operations of experimental facilities at a spectrum of scales and for fundamental and translational PSE research using those facilities.

The next finding and recommendations specifically address Computational Plasma Science and Engineering (CPSE). The finding is that computation has become essential across PSE for experiment and mission design and diagnosis, idea exploration, probing of fundamental plasma physics processes, and prediction. The first recommendation is that Federal agencies should support the development of computational algorithms for PSE for the heterogeneous computing platforms of today and upcoming platforms, such as quantum computers. As important, the second recommendation is to encourage the development of mechanisms to make advanced computations, physics-based algorithms, machine learning, and artificial learning broadly accessible. There are other fields, like computational fluid dynamics, where highly-sophisticated computational tools can be used by non-computing experts. Plasma physics is not at that point.

The last recommendation addresses DOE FES in particular. Although most of the FES budget supports fusion science, the present office title does not accurately reflect its broader mission. Following the recommendations of the Plasma 2010 Decadal Study, FES very generously expanded its scope of programs, developing what is called the Discovery Plasma

Science program. The committee recommends that the national interest would be better served by renaming DOE FES to better reflect its broader mission, maximize its ability to collaborate with other agencies, and garner non-fusion plasma support. A possible title is *Office of Fusion Energy and Plasma Sciences*.

Discussion

Dr. Verboncoeur discussed the success of public-private partnerships in a number of DOE efforts, signifying the existence of a model for such arrangements. Noting the current estimate of about $3 of industry research funding for every $1 of U.S. government research funding currently in the U.S., there may be ways to leverage this discrepancy. **Dr. Kushner** alluded to several examples in the report of successful public-private partnerships, and those partnerships seem to be more common in the early innovation cycle. The report highlights the concern of supporting established industries. One white paper looked at this issue in the microelectronics industry, where there are large amounts of equivalent Federal funding from our international competitors that directly link university and national laboratory programs with these established, critical industries, for both economic and defense/national security purposes. There are few such programs in the U.S. that address these established industries. **Dr. Zank** added that the report discusses SBIR and related programs. Plasma physicists tend to use the SBIR approach frequently for funding resources and supporting small businesses. Regarding fusion, the fusion chapter also discusses public-private partnerships.

Dr. Rej commented that the needs of the workforce for the future are concerning. Multiple reports emphasize coordination across agencies, industries, and schools. **Dr. Paul Terry** noted that many of the recommendations require significant investments of a sufficient number to help stave off the loss of faculty over the next ten years. Understanding that the report did not address priorities, **Dr. Terry** asked if it were feasible to implement these recommendations with the current budget or if an increased budget would be needed. **Dr. Kushner** confirmed that the report did not address priorities. New funding may be required, but the societal benefit is more than sufficient to justify it. The next ten years will be important for the viability of the fusion discipline. This is not due to a single factor, such as the loss of faculty or lack of diversity. There is a perception of the value of plasma physics by society and the other agencies in the Federal Government. In the best case, ITER is successful, the compact reactor is built, fusion energy enters the power grid, and Congress and the utilities are happy. In the worst case, none of that happens. The decadal study implies that the subcommittee should aim for the best case while preparing for the worst. For the latter, plasma physics should be made so valuable to other Federal agencies, such as NIH, EPA, and USDA, that those agencies are willing to invest money in plasma physics to solve their problems. If the recommendations in the report are implemented, especially in regards to interagency coordination, if the worst-case scenario occurs in the next 10 years, FES has alternatives because plasma physics has made itself valuable to the nation and Federal agencies.

Dr. Gary Zank presented the individual chapters of the report, starting with the Foundations of Plasma Science. There was internal committee deliberation regarding the organization of the material in these chapters despite the theme of the decadal study being cross-institutional and cross-disciplinary. The committee is optimistic about the next decadal study and hopes it will have a more cross-disciplinary perspective. There are themes that run through the chapters, such as computational plasma science and its impacts on science as a whole. This is the

lead highlight from the first chapter, Foundations of Plasma Science. The project was led by Dr. Amitava Bhattacharjee, whose group studied magnetic reconnection. Major findings that emerge from the first chapter are that fundamental research can and does translate to societally-relevant technologies through a growing gap between fundamental science and applications. This growing gap between applications and science is discussed in many reports. Crossing the valley of death continues to be a challenge. Another major finding is that new theory and computation are essential to leveraging investments in experimental facilities. The first recommendation is forging partnerships among agencies in order to bridge the various gaps in, for example, theory, computation, and experimental facilities, and also translational research for applications and societal benefits. The second recommendation is that efforts to foster collaborative activities such as Plasma Science Centers are needed. Finally, there is a recognized need for upgrading and operating plasma facilities.

The next chapter focuses on Laser-Plasma Interactions. This chapter was led by Dr. Cameron Geddes of Lawrence Berkeley National Laboratory. The highlight is plasma-based accelerators. The authors identify transformational applications from X-ray sources to particle colliders as well as plasma optics and high field physics. High field physics is leading to new physics regimes. The major findings are that rapid advances are enabled by new lasers, such as ultra-short pulse methods that led to the 2018 Nobel Prize. The report also identifies strategic opportunities for U.S. leadership and finds that a range of scales is needed to advance the scientific field, from single PI opportunities to the largest of facilities. The major recommendations are the formulation of a national strategy to develop new classes of lasers, the extension of the stewardship program for application-oriented research, and the support of research at a range of scales and infrastructure.

The next chapter covers Extreme States of Plasma, High Energy Density (HED). The chapter was led by Dr. Gail Glendinning of LLNL. The highlight is that four major new facilities came online in the last decade, producing a wealth of new data and significantly impacting the field. Novel diagnostics enable unprecedented levels of detailed characterization, and new capabilities in simulations enable transformative insights into plasma behavior. Major findings are that university facilities and researchers play a crucial role in HED science; there are currently strong basic science programs at large facilities that utilize a small fraction of the facility's time; and atomic, molecular, and optical (AMO) physics play a critical role to HED. Major recommendations are that the Federal support for university mid-scale HED facilities, especially for pulsed power, should be expanded; basic science programs at large HED facilities should be expanded; and investments in new diagnostics for HED are needed.

The next chapter discusses Low-Temperature Plasmas (LTP). This field fills an important gap between fundamental research and applications, and many applications come from LTP being developed for societal benefit. One example is plasma-based water treatment. The chapter lead was Dr. Peter Bruggeman of the University of Minnesota. The major findings of the chapter are that LTP has made society-wide transformations in our quality of life, and that funding agencies have not embraced the multidisciplinary LTP science underpinning these advances, leading to a partial loss of U.S. leadership. The recommendations are that DOE FES should lead and coordinate a new multidisciplinary LTP Center Program, and the NSF should establish consistent inter-directorate support for emerging LTP science, including a program in the NSF Engineering Directorate.

The next chapter is Magnetic Fusion Energy (MFE): Bringing Stars to Earth. The chapter was led by Dr. Troy Carter. Two highlights included increased understanding of and controlling

the plasma edge, and the significant progress on the construction of ITER that will produce the first burning laboratory plasma. The major findings are that the absence of a consensus strategic plan and roadmap for future research is concerning, university programs are a key source of innovation in MFE but are at risk, and the state of DOE undergraduate and graduate fellowships in MFE is concerning. The report recommends regular strategic planning that is led by the U.S. MFE community, that DOE FES should structure funding to stimulate faculty hiring at universities, and that DOE SC should restore graduate fellowships and undergraduate programs.

The final chapter addresses the Cosmic Plasma Frontier. There are currently two spacecraft, Voyagers 1 and 2, which are furthest from the earth and are in the interstellar medium. There is also a spacecraft that is the closest to the sun, namely the Parker Solar Probe. It is drawing toward and away from the sun to study the corona and solar wind. Another highlight is the discovery of the gravitational waves and the imaging of black holes. This chapter was led by Dr. Judy Karpen of the NASA Goddard Space Flight Center. Major findings are that the inadequate support for theory and modeling has prevented progress in understanding cosmic plasmas, laboratory plasma experiments have untapped synergies with cosmic plasmas, and researchers should continue to work to standardize open data policies and formats. Recommendations are that the NSF/DOE Partnership in Basic Plasma Science and Engineering be expanded to include NASA, which would benefit cosmic plasmas (($4-5M/year) as well as support innovative joint projects and laboratory space science. Finally, interagency standards for data exchange should be developed for domestic and international collaboration.

These findings and recommendations can be summarized into various aspects. The first is stewardship. The finding is that PSE is highly multi-disciplinary and stretches into biology, information science, quantum physics, and materials science, among others, with extraordinary translational value. There in an opportunity to broaden interagency structures to support PSE, especially translationally. Structures are needed to facilitate discussion, and funding is needed to drive cross-agency collaborations.

The second aspect includes Education, Workforce, and Diversity. The aging PSE workforce is a concern. This represents an opportunity to diversify the workforce by establishing roots in both basic and translational science.

The third aspect regards the research enterprise and international competitiveness. There are multiple places where the U.S. is losing its preeminent position in PSE because of incremental progress at the mid-scale facilities, a lack of concurrent research and operational support to the facilities, and limited computational capacity. There are opportunities to support funding for a spectrum of facilities, particularly at universities, and for expanding fundamentals of PSE computations and expanding access to computation and facilities. The finding and opportunity are that industries that are reliant in PSE are at a competitive international disadvantage due to a lack of federally funded translational research.

Discussion

Dr. Rej recalled the discussions regarding the FES Early Career Awards. These awards have been good for careers at universities and national labs. **Dr. Rej** asked how these awards compare to those of other agencies over the last survey that was conducted. **Dr. Zank** expressed support for the Early Career Awards program. The concept of the program began in the NSF years ago. The NSF limitation was that the awards were to go to new faculty at universities, so they were unable to support researchers at the national laboratories. DOE fills a critical need in broadening the participation. The Early career Awards at NASA are not tied to faculty either and

can be awarded to researchers. It is laudable to see three of the plasma support agencies providing such support. Note also that the Space Physics section of the Geosciences Division in NSF provides faculty funding lines, and proposals can be submitted to the NSF requesting this line. The NSF will provide up to five years of support, during which the researcher may apply for tenure. At that time, the university would reduce the academic-year salary. That program has been successful in expanding space physics and heliophysics across universities that have not traditionally been focused in that area. This is one area where DOE should consider exploring. **Dr. Kushner** continued that the DOE Early Career Award program is valuable but noted that the recipients have to be hired as faculty. They look favorably upon hiring faculty in programs that have growing long-term funding prospects. The existence of an Early Career Award program in itself is likely insufficient to justify hiring by universities.

Dr. Verboncoeur observed that the recent accelerated move toward the Moon and Mars by NASA may provide opportunities for partnerships such as for programs like Artemis as well as for numerous plasma technologies, known and unknown, that may be integrated. **Dr. Zank** recalled that, during the committee deliberations, DOE had multiple opportunities to partner with NASA beyond the current programs, including basic plasma physics studies within interplanetary space. Thus, there are opportunities, especially when it comes to missions that are currently being designed with small clusters of satellites. One example is a study looking to make multi-point measurements of turbulence in interplanetary space using a swarm or cluster of satellites. This is an easy opportunity for DOE because the science is relevant, and DOE could produce some of the satellites. It would be a limited but consequential investment in DOE funding. There are other opportunities for mutually beneficial interaction, and they are only limited by imagination. It is not clear how much funding for fundamental science will be carried through from the current Moon to Mars mission, but it will be substantial. There are also technological opportunities where DOE can assist in developing those missions. These areas are where interagency discussions would be valuable. **Dr. Verboncoeur** raised manufacturing opportunities in addition to fundamental science. A significant portion of the Artemis effort will involve remote manufacturing and automated manufacturing in a hostile environment in which generating energy is a challenge. In such environments, densification and 3D printing provide opportunities beyond the traditional plasma-type tools. **Dr. Zank** agreed and referred to specific technology sections in NASA that aim to develop such new technology. There are opportunities in both fundamental science and manufacturing. **Dr. Kushner** mentioned that one of the mechanisms for interagency collaboration that the report discusses is the establishment of an interagency working group. This is an established way in which agencies discuss common interests. One example is the development of superconducting technologies and remote diagnostics being developed for ITER and other HLD applications. There are few superconducting technologies in NASA missions because NASA is not in that business.

Dr. Pedersen highlighted the importance of maintaining university programs. In fusion, there is a need to move toward larger devices, and this is true for space science and high-energy physics. The community is struggling to move towards that. **Dr. Pedersen** asked for examples of strategies to strengthen these ties and maintain university programs. **Dr. Zank** replied that the HED mechanism is working well. The three major facilities, NIF, Z, and Omega, have dedicated research space for basic science programs, and those programs are heavily populated by university researchers. While the university researchers may not be involved in the maintenance and operation of the facilities, they are engaged with bringing students and principals into the engagement. That is one model for engaging with universities to use large facilities. For mid-

scale facilities, the report recommends that university leadership be directly engaged, even if the facility is located elsewhere. For example, in the field of space physics, it is difficult for universities to maintain large engineering groups to build instrumentation and techniques. A new development allows university researchers to work with private research organizations to lead large programs and develop hardware. **Dr. Kushner** continued that the committee felt strongly about facilities being located at universities for hands-on experience for students. For example, LaserNetUS is very successful at establishing small labs at multiple universities with a range of laser capabilities that are used by researchers at the host university as well as others. FESAC should consider high energy density physics projects that do not require the capabilities of the large facilities and also offer research opportunities for students at universities in its strategic planning. **Dr. Pedersen** expressed hope that university faculty would embrace the concept of pursuing science that does not require large facilities. The universities, and especially the tenured faculty, have expressed the sentiment that, if the facility on the university campus is not of substantial size, the students and faculty may still experiment with the machines in large facilities.

Dr. Rej introduced Dr. Troy Carter to present the *Update on the FESAC Subcommittee to Develop a Long-Range Plan for the FES Program*.

Dr. Carter began by soliciting feedback from the community for the subcommittee to review during its planning process and noted the link for submitting feedback on the subcommittee's website.

The subcommittee's charge, received by Dr. Binkley in November 2018, is to initiate a FESAC-led long-range planning process for FES. The charge covers the entire portfolio, including fusion energy research and the broader stewardship mission in plasma science, now called Discovery Plasma Science (DPS). The process is operating in two parts and was modeled after the Particle Physics Project Prioritization Panel (P5) and the Nuclear Physics planning process. The American Physical Society (APS) Division of Plasma Physics (DPP) was identified as the leader of phase one, and that phase is complete. Phase two begins with a handoff of the results of the community-led process to the FESAC subcommittee, which is taking the input from phase one to develop the long-range plan.

The subcommittee has specific tasks it is required to perform, such as to consider current and future facilities, provide support for public-private partnership ventures, and identify potential international collaborations, among others. Importantly, there are budgetary constraints. FES was asked to consider three budget scenarios over ten years, FYs 2022 – 2031.

Phase one ended in March when the CPP co-chairs delivered their report to FESAC. This was a successful process. The CPP resulted in a community-led consensus report that is currently being utilized within DOE. This was a year-long, community-led process involving white papers, webinars, town halls, and five major workshops. Importantly, the process was open to the community reviewing and vetting draft reports. The process also provides guidance for prioritization within Fusion Science and Technology (FST), which includes Magnetic Fusion Energy (MFE), Fusion Materials & Technology (FM&T), and Inertial Fusion Energy (IFE); and within Discovery Plasma Science (DPS), which includes General Plasma Science (GPS) and High-energy Density Physics (HEDP). The CPP also considered four cross-cutting areas, namely theory/computation, workforce, diagnostics, and enabling technology, and made recommendations within each of those areas.

The importance of consensus has been a constant theme through the process. One example of its importance is in the success of the P5 planning process. That success is tied to two things. The first is a compelling report that lays out priorities. The second is the need for strong and broad community backing. There was a large number of endorsing signatures for the report, but also the community is speaking with the same message.

Similar to the finding of P5, the fusion community has the reputation in congress of being a fractious community. The P5 report, and the consensus behind it, were essential to changing that point of view. The report also had a significant impact on the budget. For example, HEP appropriations are significantly above the budget scenarios provided for the planning process. The reason for this, as identified in legislation, is specifically because of this consensus report. The goal of this subcommittee is to have the same result. The desire is to produce a plan that deserves the backing of the community.

The subcommittee differs from P5 in important ways. The subcommittee is more intellectually diverse as well as more diverse in stakeholders. The APS DPP was chosen to lead CPP, which is reasonable in terms of critical mass of people in the field, yet the FES-funded community spans many additional professional organizations. FES also has strong ties to industry, including fusion, semiconductor processing, aerospace, and medical applications, among others. This diversity presents challenges and opportunities. Broad community endorsement will provide a powerful message to DOE, congress, and all remaining stakeholders.

The subcommittee's process in the community phase went further than the HEP community process. For HEP, the phase one consisted of a single major workshop that was preceded by work in advocacy groups. A report that identified the major scientific questions was written by the committee organizers and was submitted to P5. This information was the basis for the workshops, webinars, and town halls. The result of these workshops and other activities was community-reviewed guidance on prioritization in subareas prior to the phase two hand-off.

The LRP process is now in phase two. The FESAC Long-Range Planning Subcommittee has diverse membership, including people from the CPP process. The DPS leaders in the subcommittee are Dr. Scott Baalrud and Dr. Tammy Ma. The FST leaders are Dr. Charles Kessel, Dr. Wayne Solomon, and Dr. Oliver Schmitz. Other important contributors include strategic planning consultant Laurie Moret and FES liaison Dr. Sam Barish. For costing information, the subcommittee subcontracted the expertise of Jeff Hoy (ORNL, retired), and Carl Strawbridge (ORNL, retired), both of whom have experience in costing large DOE facilities.

The subcommittee has been working on phase two since February 2020. The main format for conducting business is videoconferencing, with multiple weekly meetings among various subgroups.

The CPP provides the foundation for the subcommittee's work. The CPP report conveys a compelling story regarding opportunities and urgency. Importantly, the report expresses consensus prioritization guidance that resulted from discussions with the community. Thus, a top priority of the subcommittee is to maintain and build on that consensus.

The LRP subcommittee is tasked with going beyond the scope of the CPP report. The CPP report did not address budget scenarios or costing, which is a core activity of the LRP subcommittee's work. An important aspect that was not discussed in the CPP report is partnering with other agencies, industry, and international collaborators. The subcommittee is working on incorporating these aspects. Further, the CPP process did not achieve consensus guidance for prioritization within subareas, in particular FST and DPS, due to time constraints. Such prioritizations must be completed by this subcommittee.

The LRP subcommittee has been in communication with the community. The subcommittee is embargoed from releasing committee deliberation results until they are submitted to FESAC. Thus, the subcommittee cannot officially vet draft work. However, there are no restrictions on gathering additional input, and the subcommittee can tailor input requests to inform the community of the options being considered. The subcommittee has focused on gathering clarifying information on elements of the CPP report. To maintain consensus, all relevant parties are involved in the conversation.

The subcommittee also identified information gathering needs beyond those in the CPP report. For clarifying information, the subcommittee is gathering input via guest speakers and targeted requests. Otherwise, the information should be solicited broadly. The subcommittee allows feedback from any interested party and will consider all feedback submitted.

The subcommittee has invited a number of guests to meetings to gather input. These include the CPP co-chairs and FES staff. Relevant reports from similar efforts, such as the NAS BPR, were presented to improve understanding of the potential impacts of the report. Individuals from NNSA, NASA, and NSF have been invited to speak as well. The subcommittee is especially interested in collaborating with other agencies as well as leveraging public-private partnerships in developing a successful plan. The subcommittee also has submitted an information request to the Fusion Industry Association (FIA) requesting them to describe their current and planned activities that are relevant to CPP initiatives to better understand how opportunities for partnering can be incorporated into the strategic plan.

Regarding the budget scenarios, the subcommittee interprets the charge from FESAC in an important way. The charge asks the subcommittee to "assume that the contribution to the ITER project will continue throughout this entire period." Working with FES, the LRP subcommittee has focused on the non-ITER portion of the budget. The budget scenarios begin with the 2019 enacted budget appropriation levels with the funding for ITER construction (but not the related research or operation) removed. The FY 2019 remainder, $432M, will be the starting point and will be projected forward over the 10-year period of the charge. The subcommittee will account for ITER operating costs, for which FES has provided projections, as well as costs for the ITER research program.

The subcommittee will estimate costs for all programs and facilities in the CPP report. These estimates will be for those that fall into the ten-year time-frame of the report and those that exceed it. The costs of projects in the Critical Decision (CD) process will also be estimated.

Costing small facilities and programs is conducted by the subcommittee with guidance from Carl Strawbridge, Jeff Hoy, and Don Rej. A key focus for the costing for the FST subgroup is the need to estimate the number of full-time equivalents (FTEs) to assign costs to programs. A multiplier is applied to personnel costs to account for materials and small experiments, which are used to generate ten-year cost profiles for the various Strategic Objectives (SOs) and Program Recommendations (PRs).

The costing of DPS programs utilizes SOs and PRs to identify programs that address the science drivers and includes either bolstering or continuing current programs or creating new ones. Historic data from grants inform program size needs in terms of the number and size of grants for different sub-communities. Historical data for costs of small- and intermediate-scale facilities are also being analyzed. Where appropriate, the same type of "per FTE yearly cost" used by FST is applied.

The FST subgroup is producing a roadmap and timeline for fusion research leading to a FPP using the CPP report as guidance. The CPP report is being used to inform the scope of

necessary activities considering the ten-year time horizon. It is also being used to understand the impacts of reaching a FPP in terms of time and risk imposed by the constrained budget scenarios.

The LRP subcommittee needs to develop a strategy for a whole-portfolio plan with the community and subsequently devise that whole-portfolio plan. A natural starting approach is a "stay in your lane" strategy, in which each subarea gets its own proportion of the 2019 enacted budget, projected forward. Note that each subarea has a compelling reason for growth, and it is possible for both FST and DPS to grow together. One question that the subcommittee would like to propose to the community is how to convey independent, compelling cases for growth while building support for the entire community.

To initiate phase two, the subcommittee sought to share information regarding the elements of the plan with the community in order to garner community consensus. Some activities include advertising or sponsoring webinars and generating a list of frequently asked questions. One impetus is to correct factual misconceptions; another is to provide information regarding the planning process and the outcome of the consensus effort. This is a starting point, and there is a need for more interactions.

After education, the subcommittee sought input. Small focus group meetings were help to solicit input. Participants provided opinions on the proper way to account for the priorities of FST and DPS as well as any synergies between the two areas missed by the CPP.

The community expressed significant interest in the focus groups. The subcommittee plans to schedule additional focus groups to accommodate individuals that could not attend, and is also considering a virtual workshop. The goal is to hear from everybody. There are recognized risks in maintaining consensus within each area, and the CPP report provides a solid foundation from which to start the conversation.

In addressing the budget constraint scenarios, the subcommittee will be working on the prioritization assessment criteria (PAC) and values expressed in the CPP report for FST and DPS separately. The subcommittee would like to modify the DPS criteria. In addition to the PAC, which apply to facilities and programs, there are also overarching values applicable to the whole portfolio. The subcommittee is not proposing whole-program prioritization of values, but rather a set of shared values across the whole program.

Regarding project selection criteria, note that the DPS criteria, as written, are similar to values that do not facilitate the selection between projects. The values will remain, but the subcommittee will adopt additional selection criteria that reflect the FST criteria.

Whereas the selection criteria are specifically used in developing the various budget scenarios, the values across the whole portfolio should be apparent. Note that DPS did not call out specific values, and the subcommittee adopted as values the criteria mentioned above. The LRP subcommittee adopted an additional value, namely maintaining scientific and technological progress while developing future capabilities. This value expresses a sensible redirection of effort as projects end and begin.

In light of all this work, the subcommittee is interested in expressing a set of shared values across the whole portfolio. This would not necessarily prioritize programs or facilities but would rather express consensus. These values are available for review and comment by the community.

Mission and vision were also addressed by the CPP process. Currently, the mission and vision statements of FST and DPS do not express a unified sentiment despite constituting a single office. FES needs a single vision that embraces the entire portfolio. The subcommittee

proposes new vision and mission statements that incorporate the CPP missions and visions, and feedback is welcome on these statements.

The report is structured more closely on the most recent NASA strategic plan due to similarities in the intellectual diversity of the community, having strong mission-driven applications alongside fundamental science. This approach maintains separate plans for discovery science and fusion while including a discussion of shared values.

Regarding timeline, the subcommittee is developing costing estimates and addressing the "unconstrained but prioritized" budget scenario. Ideally, a draft report would be available by early fall. Our charge letter requested the report by December of this year, so there will be sufficient time to review and revise the draft. The subcommittee intends to work towards this December delivery but will take the time needed to ensure quality and consensus.

To stay informed or provide feedback to the subcommittee, visit the FESAC LRP Subcommittee website: https://sites.google.com/view/fesac-lrp-public/home.

Discussion

Dr. Parker noted the prioritization of scientific impact for DPS though not FST and asked about the discrepancy. **Dr. Carter** replied that the FST criteria were adopted from the CPP report and have not been altered. The subcommittee is working towards DPS criteria that can facilitate prioritization of projects.

Dr. Parker also asked for more information regarding the coordination between the National Academies' strategic planning and reports. **Dr. Carter** said that, at the hand-off of the CPP report, the 2020 Decadal from the National Academies was still on-going. Now that study is complete and is being used as input to the NAS strategic planning process; other NAS studies are being reviewed as well. NASEM was sent a new charge from DOE regarding more clearly defining the FPP and what is needed to achieve it. FES consulted with the FESAC subcommittee to ensure that the charge is synergistic. The FPP is a goal the subcommittee is targeting with the LRP strategic plan while looking at a ten-year horizon. The CPP process included a discussion of the definition of the FPP, but more work remains. **Dr. Paul Terry** asked if the strategic planning process will require input on the steps prior to the FPP, such as types of confinement devices, and how the subcommittee is addressing it. **Dr. Carter** indicated that it was unclear if the process will require such input, but having FPP as a goal for FST in the strategic plan helps drive the program. The LRP subcommittee's strategic plan needs to embrace multiple possible versions of the FPP, and it will not include a detailed statement about what it will consist of. The scientific and technological goals of the CPP are clearly established regarding near-term activities. The discussion regarding the definition of the FPP will continue to develop as studies lead to further discussions with the community.

Dr. Snyder mentioned that both the NAS BPR and the CPP benefited from having the FPP as a concrete goal that contributed to a single message and asked if the subcommittee considered specifically referencing the FPP in the new mission statement. **Dr. Carter** stated that the FPP is commonly added and removed during revisions of the mission statement. **Dr. Wirth** commented that it is important to maintain the energy mission in the mission statement, but the strategic plan should also address technology. Technology will be a key aspect of the path towards the pilot plant. **Dr. Carter** emphasized that while science underlies everything, the intention was for technology to be represented in the mission statement. The subcommittee is also trying to consider how to grow the economy, but also encourage commercialization of fusion energy.

Dr. Skiff commented that FST and DPS share similarities. They both have a basic science component and are driven by a desire for societal benefit. Further, it is not necessarily clear which side will ultimately deliver any given societal benefit. **Dr. Parker** offered support for the sentiment that priorities should be based on both societal and scientific impacts. **Dr. Carter** mentioned his support for including societal benefit as well as urgency in shared visions for FST and DPS. **Dr. Trask** supported including fundamental research and applications for societal benefit. **Dr. Matthews** expressed support for the vision and mission statements. The mission is not the pilot plant; the pilot plant is one way to achieve the mission. Societal benefit should be the mission. **Dr. Carter** noted that accommodating different visions is a struggle. Much time has been invested in devising missions that must now be accommodated into one vision, and the subcommittee is endeavoring to maintain the progress towards consensus achieved in the CPP report. **Dr. Kushner** said that one way to bridge the gap between science and technology is to employ the concept of *translational research*. Translational research is mentioned in numerous strategic reports as well as legislation, and it is a concept that multiple stakeholders can support.

Dr. Knowlton recalled Dr. Carter's concern regarding a fractious community and noted that it can be a positive sign of scientific diversity and discovery. The need for consensus is clear, and **Dr. Knowlton** asked how the subcommittee is working to prioritize issues and maintain scientific diversity while recognizing the need to create a definite plan. **Dr. Carter** indicated that the state of being fractious is partly due to the current environment. In a fractured environment, the lack of consensus is the natural state. The negative aspect of being fractured is the lack of a mechanism to reach consensus. The subcommittee is hoping to change the fractious culture. There is an opportunity for everyone to contribute to the strategic plan. The subcommittee also considers this as an ongoing progress. There will be opportunities to course-correct and to identify new opportunities for the community to contribute. Finally, the subcommittee intends to be as minimally prescriptive going forward. The community should be engaged in defining these elements, and the LRP subcommittee can accommodate the need for a different direction.

Dr. Patello asked if the subcommittee is accounting for all of the specifics of costing, as in a "bottom-up" approach, in the ten-year time-frame as a factor in the prioritization. **Dr. Carter** relayed the subcommittee's plan to not consider cost in prioritization. Understanding that costing is important to prioritization, the subcommittee is considering factors such as return on investment. **Dr. Skiff** expressed the sentiment that comparisons on costing are generally straightforward because of their value in dollars and asked how prioritizations are being made on other dimensions. **Dr. Carter** said that the subcommittee is starting the process of generating such criteria and is currently working on the methods and metrics to quantify and utilize priorities that are transparent and straight-forward. **Dr. Ma** noted that the subcommittee is working to avoid supporting any particular type of research over another. **Dr. Maingi** said that the difficult task seems to be addressing the unconstrained budget scenario. There are rough priorities and priority guidance that were both explicit and implicit in the report. The subcommittee is trying to follow the priorities and guidance from the CPP.

Dr. Paul Terry asked about prioritizing specifically for missions that have a sunset such that a range of small, medium, and large projects can be accommodated in a manner that advances a wide range of scientific priorities and entertain a broader range of questions than currently investigated, especially considering the plan to not consider costing in prioritization. **Dr. Carter** stated that the recommendations for projects across the entire portfolio are "do the

right-sized project for the question." The prioritization does not consider absolute cost, but it does factor in the return on investment.

Dr. Wirth asked Dr. Carter to discuss the timeline for finishing and delivering the report to FESAC, how FESAC will respond to the report, and the timing for turning the subcommittee report into a full report from FESAC. **Dr. Rej** recalled the schedule indicating a period of review and revision, with the report scheduled to be submitted by December. **Dr. Carter** stated that edits must occur before the subcommittee members sign off on the report. There would not be extensive revisions. **Dr. Wirth** expressed the importance that the review process involves FESAC and non-FESAC participants. **Dr. Pedersen** asked if the committee would be able to review the report prior to it becoming available after the official handoff in November. **Dr. Carter** noted that this is a more significant report than the CPP, for which there was a time-frame of two weeks where members of the fusion community could view the report and provide comments. **Dr. Rej** recalled that some reports require edits before being publicly released during which members are often granted access. **Dr. Barish** stated that there is a restriction regarding when comments may be submitted, questions asked, and suggestions for changes made in either individual interactions with FESAC members or very small groups. The subcommittee is not allowed to talk with any FESAC member individually because this must occur at a public meeting.

Dr. Knowlton offered support for the strategy to take ITER off the budget and asked how the subcommittee would feel about presenting the U.S. ITER program as part of the U.S. long-range program. There appears to be a concern in the community about the U.S. role in ITER. **Dr. Carter** shared the subcommittee's view that the U.S. contribution to ITER is absolutely essential. While a significant portion is removed, the subcommittee would like to include details about how the research team is funded. The subcommittee will consider the costs of ITER and will assume the program's progress throughout the period of the long-range plan.

Dr. Snyder asked if the budget scenarios assume the same level of growth for ten years and then trying to expand after that 10-year window or if the constraints last beyond that. **Dr. Carter** indicated that they only are constrained to ten years. There is a need for growth outside of the budget scenarios, but there needs to be a plan for staying within them.

Dr. Walker stated that it would be nice to see early thoughts on the subcommittee's communication strategy to inform the community of this new vision. **Dr. Carter** mentioned the two needs of the LRP, the first being to maintain community consensus. The subcommittee continues to solicit input from the community. The second need is communication of the completed report to the relevant stakeholders. Feedback is welcome. The CPP had fewer workshops than P5, but more workshops may be needed to develop consensus over the whole portfolio.

Dr. Van Dam expressed the importance of consensus.

With no public comments, Dr. Rej adjourned the meeting at 5 pm EDT.

July 24, 2020

Dr. Rej called the meeting to order and began the *FESAC Discussions on the FESAC Subcommittee Update*.

Discussion

Dr. Knowlton asked if there is feedback the subcommittee is particularly searching for. **Dr. Carter** noted that during the CPP process, there was little chance to prioritize across the DPS and FST parts of the program. The CPP team had to balance prioritization and consensus. The LRP subcommittee is working to avoid that trade off. Advice is welcome regarding how to merge the whole portfolio.

Dr. Pedersen noted that he had hoped to see a more aggressive path for the unlimited scenario. It seems like an opportunity to rapidly advance the program. **Dr. Pedersen** asked how those thoughts have been incorporated in the unlimited scenario and if it is advantageous to be less aggressive in that scenario. **Dr. Carter** noted that the subcommittee is working to understand the proper sequence of technological milestones and how fast those could be achieved.

Dr. Patello recognized the subcommittee's work on the constrained budget scenarios and asked about progress toward prioritization. **Dr. Carter** said that the subcommittee is working on both the budget scenarios and prioritization. There are sections of the report in which constrained scenarios are being considered, and the subcommittee is exploring mechanisms to make decisions between programs. Other sections require additional costing, which may lead to unforeseen barriers that delay the process. There are also contingencies built into the schedule. **Dr. Patello** asked if the criteria and values being applied to the programs are equally weighted. **Dr. Carter** recalled that the values in the CPP report were prioritized, but there was no guidance regarding quantification. The subcommittee is currently discussing implementation of these values and welcomes input on how to support growth-oriented plans; this should be recognized in the plan. **Dr. Pedersen** stated his willingness to be engaged in the process going forward, such as the review and revision process.

Dr. Verboncoeur reiterated that the subcommittee is seeking consensus while seeking to make progress on all fronts. At the same time, alternative plans must be considered, which may involve discovery science within and outside of fusion. Metrics should be consulted in the process of moving all areas forward, maintaining consensus, and prioritizing programs. **Dr. Verboncoeur** asked for an elaboration on such metrics and how they can impact both the direct- and indirect-path beneficiaries. **Dr. Carter** said that the subcommittee is still working on developing metrics and welcomes comments from the community. During the CPP process, there was a community consensus towards guidance on prioritization. The subcommittee will further address these issues. Risk has to come into the discussion of the path forward, although more on the fusion side rather than the discovery side. One approach is to develop a timeline, where achieving goals within budgets must assume some level of risk. Assuming a lower level of risk would imply a longer timeline under a constrained budget. **Dr. Verboncoeur** stressed the large number of unknowns, which can be opportunities for discovery. There are also positive economic side effects. Many fusion efforts have led to new tools, industries, capabilities, and occupational and training regimes, among other things. Including these other side effects is important when developing metrics. **Dr. Carter** noted that the CPP report sets forth principles in discussing the appropriate breadth of the program. This includes considerations of risk and discovery.

Dr. Knowlton emphasized the opportunities that this work provides. Trying to apply metrics, priorities, and rules to something of this scale is difficult. This also is an opportunity to engage more people in the FES program. It is important that FES remains visible, and researchers in threatened areas should reach into these other fields to identify collaboration opportunities. **Dr. Carter** agreed that there is a great opportunity to coalesce this intellectually

diverse community. The decadal study is aiming to identify mechanisms to maintain diversity in pursuits as this provides strength and is important for the health of the field.

Dr. Terry recalled the strong emphasis on the decadal review's assessment of the ten-year cliff for replacing faculty. Physics departments replacing faculty will do so if there is compelling science. Universities will do so if they have strong science. It is thus important to highlight the science that is represented in the fusion milestones. Fusion approaches milestones as "retiring risks," which sounds daunting, yet there are ways of describing efforts in ways of fundamental science learned. Doing so may help to generate support from the public regarding fusion and physics department workforces alike. **Dr. Carter** noted that DPS has a significant level of technological readiness despite the "discovery" aspect of its name. All of FES is using science, but there must also be an emphasis on technology. FESAC members have wide intellectual interests across our respective colleges and universities. Most of these programs remain independent, and there are significant efforts to find complementarities and bring them together. Embracing the engineering aspect is critical for this.

Dr. Snyder reiterated that this strategy is intended to convey the excitement of these opportunities and the results of investing in them. Considering the unlimited plan and having to pare it back into the constrained budget scenarios and different time-frames, **Dr. Snyder** pondered where FES will be in five or ten years following these scenarios and pursuing the options for optimizing the potential for growth. Further, it seems reasonable to adopt the CPP report's approach to including the "blue-sky" plan in the budget scenarios. Finally, consider including a brief reference to an Apollo-style scenario, i.e. sufficient funding to pursue multiple paths in parallel to mitigate risk. **Dr. Carter** indicated that conversation has started. The subcommittee is considering multiple unconstrained scenarios versus just one, the time-frame required to do what is needed to do, and options for partnering with industry, among other things. Our plan will be followed by FES and not industry, which complicates forecasting. There is an opportunity to leverage private investment, but that is beyond the control of the subcommittee. Discussing the fastest way to fusion also represents an important opportunity. **Dr. Wirth** expressed support for including an additional budget scenario.

Dr. Skiff noted the unique opportunity for an impactful report. This impact is contingent on unity and realism. Regarding unity, the idea of an organic connection between basic science, translational research, and societal benefit is important for the language of the report. High-level goals can unify us and congress and better inform them of our needs and goals, and the goals should emphasize the need for unity and intellectual diversity. Diversity is also important for sustaining the talent pipeline. For example, students interested in fusion enter plasma physics programs at universities even if these universities do not specialize in fusion research. The "stay in your lane" strategy implicitly communicates an inability to prioritize. Positively, it could mean that prioritization across lanes should occur first, and that would be the starting point of the estimate. This will be a continuous and iterative process. There are two aspects of prioritization worth mentioning. The first is costing/pricing, which is what is available or feasible now. The second is the opportunity cost. Congress is interested in what this subcommittee is doing, and the private sector is committing money. This is a unique opportunity that should be taken. Another important aspect of prioritization is the idea of technological readiness in the context of opportunity cost. Opportunity cost can thus be another cost to consider for prioritization. **Dr. Skiff** asked if fusion was sufficiently prioritized to warrant significant investment, or if there remains the need to decide on what to invest in. **Dr. Carter** noted that much of the progress is due to the efforts of the CPP. Their work was done with the entire community engaged. The CPP

also addressed the opportunity cost of projects in prioritization; it received input from the community. In terms of connections between programs and bringing people together, the FST group expressed a desire to move away from a pure science program and towards an energy program with applied societal benefits. This represents a culture shift in FES. The subcommittee is balancing the urgency to advance applications with the desire to pursue pure science. The "stay in your lane" approach is not a recommendation to act in isolation, but community building takes time and effort. The subcommittee needs to identify mechanisms to address the budget scenarios as a short-term goal, and seeks to join visions together rather than diluting and rolling them back.

Dr. Trask emphasized the need to be urgent. There is a compelling story to tell. The need for fundamental science and technological applications is inseparable. Pushing forward on both aspects is ideal. It will be difficult to compromise on broader values, such as distinguishing the value between application and fundamental research, workforce development, and other broad considerations. However, the compelling story in the plan will facilitate being broadly supported. **Dr. White** highlighted the importance of the sense of urgency and the compelling story. These are important to draw interest to the field. The intellectual diversity is important in facilitating this. The plan adopted by FESAC must be cognizant of how workforce development and continuity are impacted. It may be more of an issue for universities, due to their diverse funding streams, than for laboratories, which have more centralized funding. **Dr. Carter** agreed that the breadth of PSE is impressive. Each area stands as a discipline; that should be endorsed. **Dr. Rej** discussed how much of the work done by the subcommittee is working with agencies like NASA on heliophysics, transportation, and public-private partnerships. **Dr. Carter** noted the high-level interaction between DOE and NASA. There's an opportunity for both DPS and FST.

Dr. Terry raised the need to develop methods for discussing the questions that allow for relaxing the assumptions of the "stay in your lane" approach. The risk of separation is that it allows either FST or DPS to progress at a slower pace in an unsatisfactory way. There is a need to find a mechanism for identifying priorities between the two that does not decouple them. **Dr. Carter** noted the need for input and opinions from various stakeholders. The subcommittee has the goal of addressing the three budget scenarios and needs to find a way forward that the community supports. The "stay in your lane" approach is one way to do that. Note that "stay in your lane" does not mean status quo or "business as usual." It means stay in your budget, and ambitiously pursue your budget. The second goal is to ensure growth in the entire program. The subcommittee wants to make a compelling case that there are independent cases of growth but also wants to maintain the benefit of complementary efforts. **Dr. Carter** expressed his opinion that the programs should not necessarily be tied together in funding. Congress wants prioritization, and the subcommittee needs to express what is lost during such prioritization.

Dr. Matthews asked how the ability of cross-cutting initiatives to leverage aspects of multiple research areas is being accounted for in prioritization considering the "stay in your lane" budget approach being adopted by the subcommittee. These cross-cutting issues link FST and DPS together. Considering the four cross-cutting areas identified by the subcommittee, it seems reasonable to prioritize within cross-cuts rather than prioritizing the cross-cuts themselves. **Dr. Carter** agreed and requested input regarding new or alternative cross-cuts or other generally scientifically synergistic values. Where possible, the subcommittee is trying to tie scientific pursuits together. For example, the opportunities for the diagnostics program are effectively connected across FST and DPS. The subcommittee is striving to ensure that the community is represented while still progressing on the strategic plan. There is an additional need to express a

shared point of view across the entire program regarding the mission and values of FES, which requires compromise on issues like language in the mission statement. The "stay in your lane" strategy may be one way to build consensus.

Dr. Verboncoeur raised the importance of the challenge of sympathizing with non-constituents during negotiations of prioritization. The "stay in your lane" language could contribute to the challenge. Consider a *goal-based resource requirement* approach, which induces the right behavior from the government. Further, translation is absolutely crucial. The messaging should include both the implicit and explicit benefits of these activities and highlight the importance of collaboration. Also, Discovery Science may be more appropriately named General Plasma Science and Technology. It is crucial to recognize in the messaging that DOE played the key role in funding plasma science and technology, leading to more than $1T and economic activity due to the discoveries, models, and diagnostics created by this program. These are crucial side effects. These also help build critical mass in the program, which aid in developing technologies that further draw interest to the program.

Dr. Matthews asked Dr. Carter if feedback on the mission statement is being solicited solely to FESAC members or to the broader community. **Dr. Carter** stated that both were welcome to submit comments. The CPP worked very hard on mission and vision statements. The preference would be to maintain those statements, but they did not facilitate a compromise. The subcommittee wants to preserve the value while recognizing that the vision is diluted as other offices are considered. The trade-off of this dilution is bringing people together. The subcommittee seeks to express a mission and compromise that captures everybody's vision. **Dr. Matthews** inquired if the subcommittee has issued a solicitation or other communication to the community regarding the mission and vision statements. **Dr. Carter** indicated that the subcommittee has yet to do so but has considered options such as virtual workshops rather than just focus groups.

Dr. Terry asked if the focus groups represent a sample of the community similar to that of the CPP. **Dr. Carter** noted that the CPP statistics are not readily available but that one goal of the CPP was representation across sub-areas. The LRP subcommittee also wanted to ensure representation across levels of career as well. There was a relatively strong response from the late career group. The subcommittee will use this information while striving to ensure broad and balanced representation.

Dr. Kessel noted that the focus on translational research in the decadal study that breaks down the barriers between physics, engineering, and technology is interesting considering NASA has not considered these barriers in their strategic plans. As discussing these barriers has impacted the LRP process, consider omitting this distinction to provide a new look for the strategic plan and pieces of the portfolio.

Dr. Ma expressed gratitude to the community and the desire to grow the DPS as well as the FST portion of the FES portfolio due to the importance of fundamental physics to the mission of FES. While it is the subcommittee's goal to have a plan for the next ten years, it is understood that this plan will not be perfect and will evolve over time.

Dr. Maingi expressed interest in the role the subcommittee wanted in the report, specifically the desire to conduct due-diligence on the report in real-time. Typically, discussions and comments are constrained to a meeting. The subcommittee may consider having an additional meeting to accommodate further discussing and incorporating the comments. **Dr. Carter** noted the plan for the National Academies-style review. FESAC members could potentially be included in that review stage to allow for sufficient time for feedback in addition

to other feedback techniques if allowable. **Dr. Rej** mentioned that there will be another FESAC meeting in the fall. Recall also that members can meet in small groups of FESAC members. **Dr. Barish** stated that it is possible to have FESAC members in small groups communicate, and this occurred in past reports. Note also that there are 19 total FESAC members, and there are 17 present, constituting a quorum. Regarding Dr. Maingi's comment, Dr. Fall wanted this report right away.

Dr. Parker raised his involvement with fusion priority planning and strategic planning with universities at various levels. One persistent issue with strategic planning is implementation. It is common for businesses and other institutions to spend significant resources conducting strategic planning with little subsequent impact. The subcommittee should consider the nature and size of the impact this plan will make and how it will be implemented. **Dr. Carter** stated that part of implementation is out of the subcommittee's control, but the subcommittee is working toward actionable recommendations that maximize impact.

Dr. Parker asked for more details regarding closure on this process and the timeline. **Dr. Carter** said that DOE leadership is attentive toward FES activities, and congress has increased FES funding in anticipation of receiving this report. Dr. Fall relayed that he wanted it now, and there was discussion amongst the subcommittee of an interim report. However, Undersecretary Dabbar emphasized that trading off time for higher quality is acceptable. The subcommittee is willing to deliver the report before the December due date if possible and is targeting October for a draft report to accommodate for more review and revision. The goal is doing it right and building consensus. **Dr. Rej** expressed that Dr. Fall understands and appreciates the importance of taking the time to produce a high-quality report.

Dr. Reyes raised a question regarding the release and approval process. During the last vote for the strategic plan, many FESAC members were not allowed to vote due to conflicts of interest. Dr. Reyes asked if this issue has been explored and mitigated against. **Dr. Carter** noted that the committee is subject to conflict of interest rules. For the High Energy Physics Advisory Panel (HEPAP) strategic plan vote, the conflicts were distinguished by facility. Another strategy would be to make the plan less prescriptive and more general, such as avoiding naming facilities or institutions in the plan. **Dr. Barish** indicated that P5 has been the basis. That report identified several recommendations from which committee members were recused from voting. In anticipation to some of these issues with conflicts of interest during voting, a meeting was held last October between FES, the Office of General Council (GC), and staff members of HEP and the Office of Nuclear Physics to develop a plan for voting on the report. The conclusion was that if the GC, in conjunction with FES, feels that a particular FESAC member has a vested interest in a specific recommendation, that member will be recused. More generic recommendations also help to avoid conflicts of interest.

Dr. Rej introduced Dr. Julie Carruthers to present *Diversity, Equity, and Inclusion in the Office of Science*.

Dr. Carruthers noted the numerous Diversity, Equity, and Inclusion (DEI) initiatives SC has been engaged in. Four such initiatives include DEI and the DOE National Laboratories, SC's internal business practices, the SC statement of commitment, and DOE and the Office of Civil Rights at the interagency level.

In 2015, SC started examining the policies and requirements of the ten DOE national laboratories for fostering DEI as well as policies for prohibiting discrimination and harassment.

The national labs are required under their Management and Operating (M&O) contracts to have in place "innovative strategies for increasing opportunities to fully use the talents and capabilities of a diverse work force," including through the contractor's workforce, educational outreach, community involvement, subcontracting, and technology transfer. The laboratories are required to meet the Civil Rights Act legal requirements regarding the prohibition of discrimination and harassment and preventing hostile work environments. Before 2015, the oversight of these requirements was managed by SC Federal site offices. SC headquarters had little insight into what the national laboratories were doing.

SC adopted the methods of the annual laboratory planning (ALP) processes, by which laboratories are required to develop annual science and technology strategic plans that look forward five to 10 years. In October 2016, the (now former) SC Director issued a memorandum to the ten SC laboratories describing the steps SC would take to establish uniform guidance for SC laboratories to communicate their DEI strategies to SC and how SC would review and provide feedback on their strategies. The memorandum also contained a new requirement for the SC laboratories to publicly post their workforce demographic data on their public websites and to update the data annually. SC developed the guidance, and the laboratories were invited to provide feedback on the SC guidance before it was issued in its final form. Additionally, the National Laboratory Directors Council (NLDC) created a common set of job categories across the DOE laboratory complex that the laboratories would use to report demographic information in a consistent manner.

This represented a shift in oversight from a regime of compliance to one of requiring actionable strategies. SC asked the laboratories to describe their DEI strategies, including challenges, goals, leadership and staff roles and responsibilities for addressing these strategies, planned actions, measures of progress and accomplishments, and workforce data. This process began in 2017, during which SC received and reviewed the strategic plans. The timeline was initially coupled with the lab planning process. SC decoupled these in 2019 due to workload concerns and because more time was needed in reviewing the DEI strategies. SC held separate feedback meetings with laboratory mangers to provide feedback on their plans. After three years of this process, SC decided to commence an external peer review to evaluate the laboratories' DEI efforts. This review occurred in November 2019, and SC is finalizing its official feedback to the 10 laboratories. As part of this, the laboratories will be required to address the findings of the peer reviews as part of their Annual Laboratory Plans.

The results suggest that promising DEI practices are emerging from the laboratories. First, there is a strong commitment by leadership to foster a culture of DEI at the laboratory demonstrated through visible policies and actions. Leadership has communicated DEI as central to advancing science and innovation and not an exercise in compliance. It is important that each laboratory understand its DEI challenges by collecting input through multiple mechanisms, such as focus groups, laboratory-wide culture surveys, and exit interviews, among others, to obtain the views of employees, visiting scientists, users, and students. It is also important that laboratory DEI goals and strategies are data-driven and based on clear measures of success. Leadership is held accountable for the laboratories' DEI goals through multiple mechanisms, including incorporating DEI goals into performance appraisals with clear standards for evaluation.

Regarding recruiting and hiring, laboratories are implementing numerous promising practices. Examples include openly posting and competing all laboratory positions, including post-doc positions, and screening postings for gender-biased language, and using diverse hiring panels that review applications and conduct interviews. Labs may require management oversight

and review of the diversity of candidate pools before commencing interviews, and announcements may be reopened if the candidate pool is not sufficiently diverse. Other examples include requiring high-quality training in diversity and implicit bias for all hiring panel members and hiring managers with regular retraining; using a standard set of interview questions for all candidate interviews; and leadership oversight of hiring recommendations.

The professional and leadership development opportunities for employees are largely to promote retention. These are advanced by providing mentorship opportunities for existing employees in all stages of their career. It is important to approach mentoring responsibilities with intentionality, using evidence-based practices, and setting expectations for mentors and mentees. Pairing leadership with managers and supervisors for leadership mentoring, and ensuring processes for selecting employees for leadership development programs, including speaking opportunities, are fair and transparent, with attention paid to equitable decision making based on data when making recommendations can also be effective. Other examples include allowing a self-nomination process for certain professional development opportunities; and ensuring clear and objective criteria are used for assessing employees for promotion decisions, considering institutional data regarding access to professional development and leadership opportunities.

The laboratories are working to foster inclusive research environments. Each laboratory must understand its DEI challenges, particularly the laboratory culture, by collecting the information through multiple mechanisms to understand the experiences of employees and other members of the community. The laboratory must also have policies, procedures, and networks in place that support the needs of a diverse workforce, such as family-friendly benefits and policies as well as employee resource groups that represent the communities at the laboratory. The laboratories should have zero-tolerance postures towards discriminatory, harassing, and unprofessional behaviors, and this message must be reinforced at all employment levels. Students and employees should have multiple mechanisms for reporting issues or seeking advice. Assigning training as a response to inappropriate behavior is insufficient for an effective zero-tolerance policy.

The laboratories' demographic information has been posted on their websites. The NLDC also posted the aggregated data by job type.

Regarding SC internal business practices, a working group was initialized in 2018 to systematically review SC business practices and opportunities to better promote DEI in award making and management processes, and to better communicate policies, practices, and procedures to the research community. The charge to SC was to assess the current practices of programs to learn from them, and all areas of business with respect to program management were systematically researched. Areas of research included solicitation language and existing flexibility within current financial assistance policies and regulations; SC could improve its communication in this regard. Another area of research included peer review processes for both proposals and performance reviews, such as the reviewer selection process and the proposal review process. SC is also studying how guidance given can better communicate SC expectations of workshops, roundtables, and principal investigator meetings. Finally, SC researched FACAs and subcommittees as well as notional implementation strategies of the recommendations created by these discussions. The process for discussing each topic area included the aforementioned systematic review of SC policies and procedures, the existing practices of a subset of SC offices, analysis of the recommendations of the SC-sponsored equity workshops and Committee of Visitors (COV) recommendations, and policies and practices of other Federal agencies.

The working group generated 15 recommendations spanning all discussion topic areas. Each recommendation has multiple components, including the development of resources and tools as well as guidance and training needed to implement the recommendation. The recommendations are aimed at ensuring SC business processes are supportive and inclusive of women and underrepresented minorities in STEM fields; allow for more rigorous tracking of diversity of applicants, awardees, and reviewers; limit and mitigate implicit bias; and encourage inclusive and professional behaviors in all SC-sponsored activities. These recommendations are intended to balance demographics on review panels, apply a set of standard review criteria reflective of DEI initiatives, and train reviewers as well as program staff on implicit bias. Once the report is approved, SC will communicate the results to the community and will reconstitute a working group focusing on implementation.

The Office of Science has increased communication regarding the Department's policies prohibiting discrimination and harassment. The number of complaints increased in 2018, and questions arose regarding what SC should do if a complaint was submitted to a program manager or any staff, or what the requirements were of individuals that wanted to file a complaint. The answer to that question was complicated. DOE has long had policies in place prohibiting discrimination and harassment by the institutions DOE funds and the respective employees, but the individual to bring the complaint to and the party responsible for oversight and enforcement differed by agency and job title. All of this information has been collected and published online.

DOE senior leadership is fully supportive of SC DEI efforts and understands its importance to SC. Discrimination and harassment undermine SC's mission by reducing productivity, discouraging or inhibiting talent retention and career advancement, and weakening the integrity of the SC enterprise as a whole. Beyond issues that may rise to legal action, SC expects the scientific community to behave respectfully, ethically, and professionally.

The DOE Office of Civil Rights and Diversity (OCRD) administers DOE policies, practices, and procedures related to civil rights laws as they apply to employees and grantees under Title IX. There is significant coordination of SC and OCRD with other agencies, including joint Title IX reviews. These are very detailed and include interviews with students, faculty, and staff within a department to ensure the program is in compliance. Guidance is also provided during these reviews. If any issues are uncovered, the reviews ensure the university leadership addresses them promptly. These policies and procedures are of interest to the Office of Science and Technology Policy (OSTP), which has been developing a Federal strategy for addressing sexual harassment and unwelcoming research environments across all funded research environments.

Discussion

Dr. Rej noted that NNSA has taken this issue seriously for many years, and these initiatives have significant impacts.

Dr. Carter asked if the research group considered targeted programs that might be created. There are solutions that apply to all programs, but tying funding to DEI initiatives is one alternative that may be considered. One option is graduate and undergraduate programs, which have recently seen restrictions from OMB. Programs directed at higher levels, such as faculty lines that address this issue, may help also.

Dr. Carruthers said that it was not the charge of the research group to identify targeted programs, but there are relevant initiatives in other offices within SC. For example, the Office of Workforce Development for Teachers and Scientists funds over 1,400 internships across the

national laboratories each year. The Visiting Faculty program also supports partnerships between faculty at universities and national laboratories. The outreach efforts for those programs are fully dedicated to diversity of the applicant pool. SC is also researching the barriers to participation. For example, DOE laboratories do much outreach, such as attending conferences for underrepresented groups. The laboratories find that it is common for people in these demographics to come to the events, apply to the internships, and yet not accept an offer. One response to this was developed by Brookhaven National Laboratory, which implemented a winter semester internship. Underrepresented groups may be reluctant to commit to a 16-week internship if they do not expect to fit in with the laboratory culture. The winter semester brings students to the laboratory for a week-long exposure to the scientists and to tour the facility. The student then has the opportunity to apply for the full internship in the following summer.

Dr. Ma expressed that the national laboratories take pride in their workforce diversity, but it is understood that those laboratories are not always welcoming to underrepresented communities.

Dr. Matthews noted that the DEI initiatives are often discussed in terms of college students and career professionals. It is important to also consider the barriers for high school students.

Dr. Parker expressed difficulty in recruiting underrepresented groups in physics at the University of Colorado, especially women. Academia is a very competitive market, and the climate of the department can be an important factor for students deciding between programs.

Dr. Skiff raised examples of efforts examining the efficacy of DEI efforts. There are barriers that prevent the established mechanisms for sexual harassment claims being fully utilized. **Dr. Carruthers** stressed the importance of laboratories to have multiple opportunities for people to raise concerns in a confidential manner. If raising a concern triggers automatic reporting, that will suppress reports.

Dr. Snyder asked for further comments on how the community is doing as a whole and the biggest weakness. For example, the field of physics is only 8% women. **Dr. Carruthers** suggested that implicit bias is particularly important. Another topic is mentorship and sponsorship. Some laboratories do not offer mentorship opportunities to everybody, which prevents retention in STEM fields.

Dr. Terry asked for advice in maintaining visibility of these issues. **Dr. Carruthers** noted that SC plans to implement the 15 recommendations, and the associate directors of the program offices in SC unanimously agree with them. Implementing these will require changing SC policies and culture. As changes are made internally, SC will also communicate these changes externally. Also, a foundational recommendation is to establish a code of conduct, including expectations and consequences. There will be a series of recommendations specifically for the laboratories as well. One question for the review panel was how SC could improve its oversight activities. The general recommendation was that SC act as a catalyst to help the laboratories address these issues. SC can bring forth the newest data, although effective tools are also needed.

Dr. Trask asked **Dr. Carruthers** to expound upon what "right" looks like regarding demographic characteristics and the extent to which policies should be shifted towards prohibitions and consequences versus values and rewards. **Dr. Carruthers** said that, at the minimum, the level of participation in SC activities would reflect the demographics of the scientific community in various scientific disciplines. Regarding the pipeline more generally, either or both consequences and rewards may be appropriate at times, but policies like quotas are

not effective solutions. The focus should be on addressing disparities and identifying opportunities for everyone.

Dr. Walker expressed interest in the metrics, timeline, and performance indicators to ensure that leadership is focused on achieving DEI goals. Regarding the talent pipeline, one persistent problem is that a student that reaches any given level of achievement may not have support to proceed to the next step. **Dr. Carruthers** noted that each laboratory is different, warranting adopting or creating unique metrics. As these laboratories achieve their individual DEI goals, new metrics may be appropriate. **Dr. White** further noted that a connected talent pipeline is not sufficient. A multifaceted approach is needed, including climate, recruiting, and admissions. Quotas are undesirable because they do not maximize voluntary achievement, but unconscious bias has significant impacts. All of these barriers should be recognized and addressed.

Dr. Wilson asked if some of these DEI elements have been incorporated into the grant-making process. Also, intrusive peer reviews of organizations can identify best practices that prevent the need to file a grievance. It often includes monitoring DEI issues on small scales. **Dr. Carruthers** stated that these types of comments are especially important for DOE leadership. The first question relates to some of the recommendations for SC internal business practices. This includes developing standard merit review criteria and policy program factors that are part of a funding opportunity announcement that are clearly laid out in terms of how the proposal will be reviewed. Thus, the applicant should incorporate DEI aspects into the proposal where appropriate.

Dr. Carter recalled that one subgroup of the LRP process focused specifically on workforce development and DEI issues. Some of their recommendations aimed at peer review processes were to solicit help from subject matter experts (SMEs) in the community, and DOE should consider devoting resources to identifying and utilizing SMEs for this process where appropriate. **Dr. Carter** inquired about the timeline for publication of the final report.

Dr. Carruthers clarified that both the internal peer review and business practices processes are internal, and the final report will not be a public document. However, due to strong community interest, there will be an extensive executive summary. Also, the "promising practices" from the laboratories will be shared; these differ from "best practices" in that they have not been rigorously tested to be effective in all environments.

Dr. Rej adjourned the FESAC meeting at 1:30 ET.

Respectfully submitted
Nathaniel N. Murray, MA
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Certified as Correct by:

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Dr. Donald J. Rej,
FESAC Chair
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