

**FUSION ENERGY SCIENCES ADVISORY COMMITTEE
to the
U.S. DEPARTMENT OF ENERGY**

PUBLIC MEETING MINUTES

**Hybrid Meeting
December 13, 2023**

**Fusion Energy Sciences Advisory Committee Meeting
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The U.S. Department of Energy (DOE) Fusion Energy Sciences Advisory Committee (FESAC) convened on Wednesday, December 13, 2023 at the Rockville Hilton in Rockville, MD, for a hybrid in-person/Zoom meeting from 10:00 a.m. - 4:48 p.m. Eastern Time. 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 can be found at <https://science.osti.gov/fes/fesac>.

Committee Members Present

Dr. Anne White (Chair), Massachusetts Institute of Technology (MIT)
Dr. Halima Ali, Hampton University
Dr. Emily Belli, General Atomics
Dr. Luis Chacon, Los Alamos National Laboratory (LANL)
Dr. Luis Delgado-Aparicio, Princeton Plasma Physics Laboratory (PPPL)
Dr. Franklin Dollar, University of California Irvine
Dr. Ane Lasa Esquisabel, University of Tennessee (UT)
Dr. Brenda Garcia-Diaz, Savannah River National Laboratory (SRNL)
Dr. Beth Guiton, University of Kentucky
Dr. Stephanie Hansen, Sandia National Laboratories (SNL)
Dr. Paul Humrickhouse, Oak Ridge National Laboratory (ORNL)

Dr. Ralph Izzo, TerraPower
Dr. Carolyn Kuranz, University of Michigan
Dr. Edward Lahoda, Westinghouse Electric Company
Dr. Tammy Ma, Lawrence Livermore National Laboratory (LLNL)
Dr. Richard Magee, TAE Technologies
Dr. Carlos Paz-Soldan, Columbia University
Dr. Susana Reyes, Excimer Energy
Dr. Erica Salazar, Commonwealth Fusion Systems
Dr. David Senior, Pacific Northwest National Laboratory (PNNL)
Dr. Bhuvana Srinivasan, University of Washington
Dr. Derek Sutherland, Zap Energy
Dr. Howard Wilson, ORNL

Committee Members Absent

Dr. Eva Kostadinova, Auburn University
Dr. Lorin Matthews, Baylor University
Dr. Andrew Sowder (Electric Power Research Institute – EPRI)

Dr. Mitchell Walker, Georgia Institute of Technology

Ex Officio Members Present

Dr. Lauren Garrison, representing the American Nuclear Society (ANS), (Commonwealth Fusion Systems)
Dr. Edward Thomas, representing the Division of Plasma Physics, American Physical Society, (Auburn University)

Dr. John Verboncoeur, representing the Institute of Electrical and Electronics Engineers, Nuclear Plasma Sciences Society (IEEE), (Michigan State University)

Ex Officio Members Absent

None

DOE Personnel Present:

Dr. Jean Paul Allain, Associate Director for
Fusion Energy Sciences

Dr. Sam Barish, Designated Federal
Officer, FES, Department of Energy
(DOE), Office of Science (SC)

Dr. Asmeret Asefaw Berhe, Director, DOE
SC

Dr. Harriet Kung, Deputy Director for Science
Programs, DOE

Dr. Geraldine Richmond, Under Secretary for
Science and Innovation, DOE

Dr. Josh Shiode, Chief of Staff, DOE SC

Approximately 345 individuals were present in person or online for all or part of the meeting.

December 13, 2013

Welcome and Opening Remarks, Professor Anne White, Chair, Massachusetts Institute of Technology

Dr. White convened the meeting at 10:00 a.m., thanked panel members for their service and reviewed the purpose of FESAC.- New members were welcomed.

Under Secretary for Science and Innovation Perspective, Dr. Geraldine Richmond, Under Secretary for Science and Innovation (pre-recorded remarks)

Dr. Richmond expressed excitement over the new inclusive international partnership strategy announced at the 28th Conference of the Parties to the United Nation's Framework Convention on Climate Change (COP28), which will foster the completion of the Bold Decadal Vision (BDV) of commercial fusion energy and a fusion pilot plant (FPP) within a decade. While international partnerships are necessary for an inclusive energy future, fusion is an area of intense international competition, and the United States (U.S.) and DOE must use Congressionally appropriated funds for maximal positioning. To this end, SC will issue a new charge to FESAC to reassess the alignment of FES program elements with the FESAC long range plan (LRP) and the BDV, as well as with the evolving roles of public sector fusion research and user facilities.

There continues to be strong technical progress in fusion energy, including landmark achievements at the National Ignition Facility (NIF), Joint European Torus (JET) tokamak and the private sector, all of which have been supported by decades of public funding. Over \$6B in private funding has been invested in the fusion private sector. The Milestone Program has produced new public-private partnerships (PPPs) and aims to catalyze future public-private collaborations. The collaborations will spur private investments in fusion energy, encourage industry participation in public efforts, and accelerate the timeline to fusion demonstration.

There is growing recognition that fusion energy has a role to play in a net-zero carbon future and is a potential climate solution. Dr. Richmond commends the Decadal Plan subcommittee in including a diversity of experience and perspective, representing stakeholders from national laboratories, universities, private sector, and people from all walks of life, which is sure to benefit current efforts.

Office of Science Perspective, Dr. Asmeret Asefaw Berhe, Director SC

Due to technical difficulties, Dr. Berhe's remarks were presented by Dr. Josh Shiode, Chief of Staff, SC

Dr. Jean Paul Allain was announced as the new FES Associate Director (as of July 1, 2023), and excitement was expressed regarding Dr. Allain's vision for accelerating work in FES. FESAC members were thanked for serving on the panel. Dr. Shiode mentioned recent visits, along with Dr. Berhe, to the International Thermonuclear Experimental Reactor (ITER), the Wendelstein 7-X (W7-X) stellarator, and the Tungsten Environment in Steady-state Tokamak (WEST).

In consideration of the COP28 international engagement strategy, the community must double its efforts to address relevant scientific gaps in the field. The success of fusion energy relies on SC maintaining a diverse portfolio of fusion and plasma science research, understanding the direction of the commercial fusion industry, the continuation of engagement with strategic international partners and industry leaders, and being aware of all areas in support of fusion energy research, particularly at SC.

Regarding the two charges issued to FESAC, charge one (C1) requests a reassessment of the alignment between the LRP and BDV. Charge two (C2), issued to all six DOE SC advisory

committees to scientific programs, asks for identification of new or upgraded facilities to best serve DOE's needs in the next 10 years. C2 follows the best practices established by SC Director Orbach in 2002, that led to the influential report "Facilities for the Future of Science, a Twenty-Year Outlook," which set foundations for growth and mission impact. The completion of ITER was a priority of the Facilities for the Future report, highlighting the decades-long focus on fusion energy in SC portfolios. To address C2, a rigorous justification for each facility identified is required and must describe the following: 1. The facility's potential to contribute to world-leading science and 2. The facility's readiness for construction. The final report will strategically position SC in planning and executing projects across its portfolio for the next 10-20 years. At COP28, Special Envoy John Kerry mentioned the "Potential for fusion to revolutionize our world," which sets the stakes of what is being done at SC, as each member's expertise is applied in service of the nation.

Discussion

Dr. Paz-Soldan asked for a list of all facilities being considered in C2 across SC advisory committees and a timeline for list availability. **Dr. Shiode** replied that each list will be published on the respective advisory committee's webpage. Availability will be on a rolling basis as the lists are finalized. At this time, three of six have been posted.

Dr. Barish asked if additional time for questions could be allocated once Dr. Berhe has joined the meeting. **Dr. Shiode** confirmed.

Dr. Berhe joined the meeting at 2:50 p.m.

Dr. Berhe greeted the committee and invited additional questions.

Dr. Ma asked for insight into the process of integrating all six advisory committee C2 reports, likely containing divergent priorities and ideas. **Dr. Berhe** explained SC does not want to make budget decisions in isolation. The charges are mental exercises for the advisory committees to identify and prioritize needs, and will allow SC to thoughtfully balance budgetary items, such as foundational science and facilities, across all programs. Stakeholders in Congress want to see a thoughtful, long-term strategy across budget requests.

Dr. Paz-Soldan asked how facilities designated as scientifically important but immature in C2 could receive support. **Dr. Berhe** explained that SC is not opposed to accelerating an immature facility's Critical Decision (CD) process if warranted.

Dr. Hansen asked if there is a path forward for future DOE - National Nuclear Security Administration (NNSA) collaborations. **Dr. Berhe** explained that SC is open to committee recommendations on improving partnerships and coordinating efforts with NNSA.

Dr. Reyes asked how the Milestone Program aligns with FES, BDV, and the two FESAC charges. **Dr. Berhe** explained that both the public and private sectors have important roles to play in addressing the current science and technology (S&T) gaps in fusion energy. The Milestone Program moves science forward through mutually beneficial relationships for all players in the space.

Dr. Chacon asked for the reasoning behind C2 focusing on facilities with a minimum investment of \$100M, which seems contradictory within the current reality of constrained budgets. **Dr. Berhe** disagreed with C2 being contradictory and explained that in times of constrained budgets the most expensive items need the most scrutiny. However, SC would like to know if the committee believes a smaller facility is important enough to be considered.

Dr. Agonafer expressed appreciation for **Dr. Berhe's** leadership and guidance.

Dr. Kuranz noted that an FES- National Science Foundation (NSF) partnership no longer exists and asked if SC is interested in re-establishing or even expanding the partnership. **Dr. Berhe** replied that whenever there's an opportunity for partnership that allows public resources to go further, or to accomplish the goals of the scientific community, SC is interested.

Dr. White conducted roll call at 10:18 a.m. There was a quorum.

Vision for the Fusion Energy Sciences Program, Dr. Jean Paul Allain, Associate Director for Fusion Energy Sciences

Dr. Allain expressed thanks for the service of FESAC members and FES staff, and briefly described his academic background. The mission of FES is to expand the fundamental understanding of matter at very high temperatures and densities, and to build the scientific foundations needed to develop a fusion energy source. Therefore, the mission requires the study of the plasma state and its interactions with its surroundings. The Energy Act of 2020 expanded the scientific mission of FES to support “the development of a competitive fusion power industry in the U.S.” The five priorities of FES are to: 1. Accelerate fusion development as a carbon-free energy source via PPPs, as described in the BDV; 2. Support Fusion Innovation Research Engine (FIRE) Centers to establish the S&T basis of an FPP; 3. Have U.S. participation in ITER to leverage engineering and study burning plasma science and technology at power plant scale, while expanding Inertial Fusion Energy (IFE) programs; 4. Support discovery plasma science and technology; and 5. Broaden participation in fusion and diversity, equity, inclusion and accessibility (DEIA) activities to enable the program.

There is a global race to secure leadership in fusion energy. It is imperative for the U.S. to maintain its role as leader. There has been \$6B in private sector investments towards fusion energy. However, major investments from other countries, including China which surpassed the U.S. in fusion technology patents in 2023, put the U.S. in danger of losing the lead. The current challenges faced by FES are: 1. The political climate for big spending has waned; 2. There are order-of-magnitude technology and science gaps, not found in other energy sources, to be bridged before an FPP can be built; and 3. Access to workforce is strained by competition from other energy sectors and non-energy industries. The current opportunities for FES are: 1. Energy security will drive investment priorities and 2. Shared technology gaps with other industries can open the door for fusion to lead in partnerships.

The vision for a balanced FES program builds on the FESAC LRP and includes three key elements. The first is the U.S. National Fusion S&T Roadmap (Roadmap), a metric-driven plan that focuses on the remaining S&T gaps reported in the LRP, which include sustaining a burning plasma, engineering for extreme conditions, and harnessing fusion energy. The second and third elements are to support PPPs and to leverage international collaborations, respectively. The Roadmap utilizes a staged approach towards the development of an FPP. The three stages involve: 1. Innovation, research and development to de-risk S&T gaps, support PPPs, seed the supply chain, and leverage international partners (occurring in the mid-2020s); 2. Integrated and integration facilities to grow the supply chain, expand facilities, expand IFE, and translate to a Public-Private Consortium Framework (PPCF) (occurring in the late 2020s to mid-2030s); and 3. FPP to First-Of-A-Kind (FOAK) to support additional approaches towards fusion energy, expand bridges to supply chains, start the ITER burning plasma era, and innovate new facilities (occurring in the mid-2030s to the 2040s).

Foundational and enabling research in FES incorporates funding at 61 universities, 14 national laboratories, 23 private companies, >1,500 full-time employees, >300 graduate students, and >120 postdocs. In addition to fusion energy, the program also consists of plasma science discovery, advanced nanomaterials, quantum computing, and artificial intelligence/machine learning (AI/ ML). A new FES program was announced, named Emergent Plasma Concepts, which aims to address critical scientific gaps from advanced tokamaks and transition to other emergent plasma core approaches over time. Beyond fusion, there is the plasma science and technology ecosystem. FES is establishing Plasma Frontier Research Centers (PRFCs). The centers will focus on the emergent science in the plasma discovery area and how the science is broadly impacting society. Looking at plasma technology applications, the Centers could stretch the ability to apply plasma in every part of life.

Reshaping FES could involve the following funding elements, which are reflected in the LRP: Theory and Simulation, Fusion Materials and Internal Components, Emergent Plasma Concepts, Closing the Fusion Cycle, Discovery Plasma Science and Technology, and Cross-threads. However, FESAC's input on C1 and C2 will guide the final FES configuration. Another vision of FES's role is in creating innovation engines and bridges between foundational science and technology deployment, through public-private consortium (PPC) frameworks and FIRE Centers. Important FES PPP elements include 1. The Innovation Network for Fusion Energy (INFUSE), which aims to leverage national laboratory and university infrastructure/capabilities for industry use; 2. The Milestone-Based Fusion Development Program, in which fusion companies partner with national labs and universities to provide viable FPP designs and technology roadmaps; and 3. A new PPP funding and financing program to create a new bridge between the public and private sectors in fusion science and technology, design and/or build facilities to de-risk low-technical readiness level (TRL) fusion technologies, and provide the public sector an opportunity to leverage strategic private sector infrastructure.

Upcoming in 2024 are the following: 1. An FES Virtual Town Hall Series, hosted by participants from both the public and private sectors, focused on emergent topics in fusion science and technology; 2. New FES opportunities, including engagement with FES leadership and program managers to help establish the Roadmap, and a new program for early-career scientists to gain experience in policy and program management; and 3. An evolving FES which involves a re-structuring of the FES budget, facility studies, and new PPP bridges and activities.

Discussion

Dr. Esquisabel asked for clarification of the term “bold realignment”. **Dr. Allain** explained the intention is for the evaluation of every aspect of the program, in a thoughtful and strategic manner.

Dr. Kuranz asked if there is a plan to reinstate the FES/NSF partnership. **Dr. Allain** is willing to reinstate the partnership once an area of focus is identified.

Dr. Paz-Soldan noted difficulties in the Milestone Program and asked how the community could help. **Dr. Allain** explained that help is needed in structuring PPPs to ensure that they are beneficial to both the public and private sectors.

Dr. Wilson asked how the results from all facilities will be integrated, how the data will be extrapolated, and how will there be confidence in the extrapolations? In addition, will there be a coupling of physical facilities with their virtual simulations? **Dr. Allain** explained that a lot of effort and modeling is currently focused on integration and extrapolation. Models capable of

extrapolation require validation, which is envisioned to take place at FIRE Centers. Secondly, digital twins, the coupling of physical and virtual facilities, will absolutely be utilized.

Dr. Verboncoeur noted an opportunity for FES in materials manufacturing and foresees incentives for non-thermal plasma as a tool to improve efficiency, reduce carbon, control product formation, and engage in out-of-the-box applications. **Dr. Allain** appreciated the comment and expressed excitement over future talks with the Department of Commerce for the application of non-thermal plasmas through the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act.

Charge to FESAC on (1) an FES Decadal Plan and (2) Facilities Construction Projects, Dr. Jean Paul Allain, Associate Director for Fusion Energy Sciences

The two charges issued to FESAC were read. C1 asks FESAC to form a subcommittee to reassess FES program elements and their alignment with the FESAC LRP science drivers and the BDV, within the four major categories of the FES budget structure: Burning Plasma Science: Foundations (which includes Advanced Tokamak, Spherical Tokamak, Theory & Simulation, PPPs, and Inertial Fusion Energy); Burning Plasma Science: Long Pulse (which includes the FES international collaborations under Long Pulse: Tokamak, international collaborations and domestic efforts under Long Pulse: Stellarators, and Materials & Fusion Nuclear Science); Burning Plasma Science: High Power (which includes ITER Research); and Discovery Plasma Science (which includes General Plasma Science, High-Energy Density Laboratory Plasmas, and Measurement Innovation). C2 asks for identification of new or upgraded facilities, relevant to the advisory committee's discipline, that will be necessary to position SC at the forefront of scientific discovery. Subcommittee members should report each of the identified facilities in terms of its potential to contribute to world-leading science in the next decade and its readiness for construction.

Discussion

Dr. Ma noted the great effort required to realign the many ideas and reports previously produced, and asked whether there is any additional guidance regarding funding and how the two charges relate to each other. **Dr. Allain** replied that budgets are currently constrained and will likely remain so in the foreseeable future. A way to think of overlap between charges is that both reports will serve as input for the Roadmap.

Dr. Reyes noted that C1 instructed committee members not to consider U.S. contributions to ITER and asked whether the contributions will ever be evaluated, as they will play a major role in the future of FES. **Dr. Allain** committed to looking at everything in the program, including ITER, as ITER should not be regarded as a project but as a part of the U.S. strategy to realize fusion energy.

Dr. Kuranz asked for confirmation that the goal of C1 is not to relitigate the LRP and asked for a general timeline for report completion. **Dr. Allain** confirmed that there is no expectation to redo the LRP, although the charge can be considered as the next step for the LRP. An estimation for the timeline would have the report done by early to mid-Fall.

Dr. Chacon asked for feedback on the C2 process for universities and national laboratories to make proposals for new facilities with a minimum investment of \$100M. **Dr. Allain** explained that the process is still under development and will be a topic of future discussion with Dr. White.

Dr. Allain was asked whether the committee's task during the FES restructuring will entail defining new funding elements or commenting on the existing elements. **Dr. Allain** instructed the committee to focus on the existing elements and simply provide perspective on alignment.

Dr. Paz-Soldan asked for clarification on the process to obtain additional information on the facilities listed in C2. **Dr. Allain** explained that the process is still under discussion and will be provided to the community when available.

Dr. Esquisabel noted the constrained budget and asked if there is a quantitative aspect to C1, and whether elements in C1 include costs for facility development and maintenance. **Dr. Allain** explained that nothing in the charge requires quantification, just the qualitative evaluation of element alignment with the goals of the BDV.

Dr. Dollar referenced the four major categories listed in C1 to which program alignment will be evaluated and asked whether the categories are fixed or should the subcommittee be cognizant of a possible change pending future discussion and needs. **Dr. Allain** responded to evaluate program alignment in terms of current fit to the current categories.

Dr. Thomas referenced the elements in C1 not to be considered as part of the realignment, asked what percentage of the budget is tied up in those elements, and asked how freely could resources identified in PPPs be considered for use by the subcommittee. **Dr. Allain** responded that the information describing element size is public, and therefore guidance on each element's budget could be provided, but the numbers will change with each budget cycle. In addition, there is a strong intention to engage the private sector, and PPP resources like FIRE Centers will be big drivers in the program.

Dr. Reyes observed that the due date for C2 is earlier than C1, although the C1 report would provide guidance for C2, and asked whether there would be open communication between the two subcommittees during preparation of the reports and communication among all SC C2 subcommittees. **Dr. Allain** responded that it would be preferable for the due dates to change and for open communication, but neither is likely to occur to a large extent due to logistics and the fact C2 is assigned to all six SC advisory committees.

Dr. Paz-Soldan noted the different metrics of C1 and C2 and asked if it would be helpful to apply C1 metrics to C2 as well. **Dr. Allain** explained that this would cause FESAC to evaluate C2 differently than the other offices in SC, which is not desirable.

Discussion of the Charge to FESAC on an FES Decadal Plan, Professor Anne White, Chair, Massachusetts Institute of Technology

Dr. Esquisabel asked how to reconcile the overall short timeline of the charge with the workforce development component, which traditionally requires longer timeframes. **Dr. Allain** confirmed the difficulty of the situation and explained that careful thought is required as decisions made will impact entire careers of the workforce.

Dr. Hansen asked for the reasoning behind the project exclusions found in C1, as many of those projects are currently making significant contributions to FES. **Dr. Allain** explained that crosscuts, or projects that involve multiple areas of SC, were left out to ensure feedback collected in C1 related to items solely in FESAC's domain.

Dr. Garrison asked for clarification on whether community input was encouraged, and for guidance on obtaining community input. **Dr. White** explained that input is never restricted and is mainly limited by logistics. Options for obtaining input on items with short timelines include the broad use of Zoom and soliciting expert speakers who represent different parts of the community

to address the subcommittee. **Dr. Barish** added that the subcommittees for C1 and C2 may operate independently and have few limiting rules, but the C2 deadline of May 2024 is firm and must be observed. **Dr. Allain** expressed his preference for inclusivity and mentioned that some flexibility exists in the C1 deadline to allow for community input.

Dr. Thomas asked whether the C2 deadline of May 2024 is the report due date or the date the report is voted on by the committee, which would put the actual report due date in early to mid-April. **Dr. Barish** explained that the report must be voted on and approved by FESAC and then submitted to SC by May 2024.

Dr. Srinivasan asked for clarification and context on the phrase “reassess program elements.” **Dr. Allain** explained that reassessment is in the context as written in C1 and mentioned that further insight into the elements could be obtained by reading FES publicly published records.

Dr. Chacon asked for modification of the C1 language to include work being done at universities. **Dr. Allain** explained that the intent of C1 is to look specifically at new national user facilities in the program. The current user facilities are the National Spherical Torus Experiment - Upgrade and DIII-D.

Dr. Magee asked for clarification on the Milestone Program’s fit in the BDV regarding C1. **Dr. Allain** explained that the project is a catalyst for investment from the private sector and for public sector engagement, but it will not be the sole mechanism to realize fusion due to the magnitude of the costs.

Dr. Chacon referenced language in C1 stating “identify specific elements that can be deferred with minimal or modest impact on the FES program” and asked for clarification on the meaning of “minimal or modest impact.” **Dr. Allain** explained that the language referred to elements gaps needing immediate attention.

Dr. Wilson commented that enacting the BDV will require managing and quantifying uncertainty at a level not only constituting an entirely new research field, but also a field that has to be led by FES. How does this fit into the Roadmap? **Dr. Allain** explained that there may not be a program per se that dictates the answer, but there may be indirect ways for how FES can address some of the questions. Stage two of the Roadmap presented an intermediate step which looks at integration and integrated facilities, which will serve as a driver in this direction.

Dr. White dismissed the committee at 1:01 p.m. for lunch and reconvened at 2:01 p.m.

Discussion of the Charge to FESAC on the FES Decadal Plan (continued), Professor Anne White, Chair, Massachusetts Institute of Technology

Dr. Agonafer asked if there was any perceived interest in building bridges with the semiconductor industry. **Dr. Allain** replied that there are already aspects of FES involved with the semiconductor industry. There are also important overlaps and opportunities with the semiconductor industry for fusion developers to consider such as advanced materials, advanced materials supply chains, and components for fusion energy systems.

Dr. Wilson asked what type of companies are envisioned to be a part of the fusion supply chain and whether there is interest and a strategy for engaging multi-national engineering companies in the U.S. **Dr. Allain** explained that the chain could initially be the fusion developers themselves, who adopt leadership roles in bringing along other companies and work together to establish the supply chain in the current pre-competitive phase. A role of FES could be the development of technology that drives innovation around the supply chain. The nurturing of the

supply chain cannot be done solely by FES but must be an effort across all government. There is a desire to engage the big engineering firms, which is part of the role of PPPs.

Dr. Thomas asked how the U.S. workforce, particularly students, could get involved in international opportunities and how can the community leverage scientists from international laboratories in U.S. activities. **Dr. Allain** explained international engagement is a good way to create ecosystems, and the best way to realize those engagements will require further discussion. However, it is the community's responsibility to not only interact with the biggest fusion destinations but also include all regions of the world, which could lead to the recruitment of new talent.

Dr. Verboncoeur commented that the cost of manufacturing components for the fusion industry supply chain must be de-risked. **Dr. Allain** agreed and noted that in addition to de-risking there must be a mechanism to build in confidence, which is necessary to attract investments.

Dr. Chacon asked for clarification on the scope of C1 language requesting the identification of opportunities or plans to address gaps. **Dr. Allain** interpreted the language with the understanding of there being a diverse set of companies and approaches, and to use that as the backdrop to assess specific gaps.

Dr. Ma mentioned that the multiple references to U.S. leadership and competitiveness may no longer be accurate due to the age of the reports from which the references were drawn and asked how much the subcommittee should think of U.S. leadership when aligning those older reports. **Dr. Allain** replied to look very broadly into where it appears innovation can help the U.S. be a leader and where there are opportunities to spur innovation.

Dr. Verboncoeur commented that at the current R&D stage, it matters less if things are manufactured offshore, as very few are being bought, so both cost and resilience are less crucial. However, if the economy was based on fusion reactors, and there were international incidents that prevented or interrupted the supply chain of some of the components, it would shut down the energy economy. In a future in which fusion is a predominant energy source, resilience as well as cost will be crucial factors. **Dr. Allain** agreed.

Dr. Ma asked for the page length expected for the C1 report. **Dr. Allain** replied succinctness is important, and that the report should have actionable recommendations; however, an actual length will not be prescribed.

Dr. Esquisabel referenced the breadth of the work each subcommittee must cover and asked whether there were any concerns about having two subcommittees running concurrently; this may strain available expertise and diversity. **Dr. Allain** replied that it is definitely a concern and will require FES to be thoughtful about subcommittee makeup. **Dr. White** encouraged the committee to make comments and suggestions, in addition to asking questions, about the process of running concurrent subcommittees.

Dr. Humrickhouse noted the C1 filename as "Charge Letter on the Decadal Plan" and asked if the document is going to be presented as a separate plan or is the name just a way to refer to the LRP and BDV. How does C1 relate to the Roadmap, and on what timeline are things coming together upon completion of the C1 report? **Dr. Allain** explained that the decadal plan is just a shorthand name for the document, and the reports on the charges, as well as the LRP and BDV, will serve as inputs for the Roadmap.

Dr. Verboncoeur suggested the appointment of a liaison that worked with both subcommittees to facilitate communication. **Dr. White** agreed with the idea and noted a liaison could be beneficial even after the completion of C2 to inform additional discussions.

Dr. Delgado-Aparicio asked, in terms of PPPs, for suggestions to make the U.S. DOE complex more competitive, particularly in terms of cost. **Dr. Allain** mentioned asking similar questions within SC, and investment value was the topic of recent workshops in SC and Argonne National Laboratory (ANL). Investigation into suitable models of investment is in progress.

Dr. Kuranz expressed excitement for the meeting and appreciated the opportunity for FESAC members to act on and guide implementation of the BDV.

Dr. Lahoda commented that it is important to ensure a lab is capable of producing what is needed by the public and private industry, not just what is of interest to the lab's researchers, before the lab is built. **Dr. Allain** agreed.

Dr. Thomas commented on the process of coordinating multiple FESAC charges, stating the ability to request a preliminary output version of C1 to coincide with C2. The preliminary output would not be a full report but could be a helpful addition to the overall process. **Dr. Allain** expressed interest in the idea and added the possibility of adding guidance to C1 to tailor what is included in the preliminary output. **Dr. White** agreed with both comments.

Dr. Verboncoeur mentioned MSU's joint institute with the Fraunhofer Institutes, the successful model adopted by Fraunhofer, and offered to participate in C1 to explore the possibility of replicating the model with FES. **Dr. White** expressed thanks for the input.

Dr. White dismissed the committee at 3:23 p.m. for a break and reconvened at 3:32 p.m.

Discussion of the Charge to FESAC on Facilities Construction Projects, Professor Anne White, Chair, Massachusetts Institute of Technology

Dr. White announced the list of elements under consideration in C2 will be provided to subcommittee members.

Dr. Garrison asked if there are any roles professional societies can play in assisting with the charges, whether suggesting locations should be a part of the analysis for C2, and whether evaluating specific labs to house facilities would be in scope. **Dr. Allain** mentioned that there are still discussions to be had regarding the process but there is potential for engagement from the societies. Locations would be valuable information, and to the extent the committee can provide comments within existing time constraints, it would be good to have that information. It is in scope to mention specific labs or universities to house facilities.

Dr. Esquisabel asked how subcommittee members are chosen. **Dr. White** explained that a long list of experts are compiled, ensuring a diversity of breadth and depth. Then a chair is selected, and possibly a vice chair, and then FES and the chair consider who should be members, with a commitment to DEIA. Suggestions for possible members are welcome, but there are no guarantees of acceptance for membership.

Dr. Magee asked how to consider the International Benchmarking report in the context of C2. **Dr. Allain** replied that the context of international participation for fusion is critical; however, the international aspect is not necessarily embedded in the charge.

Dr. Humrickhouse noted the short timeline for C2 and asked for insight into the timeline for forming the required subcommittee, how the facilities listed in C2 were chosen, and for the reasoning behind the exclusion of Materials Plasma Exposure eXperiment (MPEX) from the facilities list. **Dr. White** explained that the committee formation process can extend beyond a month, and much of it depends on the people solicited having the time and willingness to help FESAC. **Dr. Allain** explained that MPEX was excluded because it is beyond CD-2, which is explained in the C2 selection criteria. Some of the facilities on the C2 list were already under consideration before C2 was formulated, due to alignment with the LRP, while others were included for purposes of inclusivity

Dr. Paz-Soldan referenced the budget envelopes presented in C2 and asked if it would be valuable for subcommittee members to provide feedback and alternate assessments. **Dr Allain** explained C2 makes no requests for budget assessment, but there is potential value in obtaining budget feedback from the subcommittee.

Dr. Delgado-Aparicio asked whether representatives for facilities considered in C2 could be invited to FESAC to deliver proposals of their ideas. **Dr Allain** replied that presentations from facility leadership is possible and worth pursuing.

Public Comment

Mr. Andrew Holland (CEO, Fusion Industry Association, FIA) expressed excitement for the new FESAC composition, which contains FIA members and mentioned the importance of industry having a voice in FES. It is important for the FESAC LRP, published in January 2021, to be updated to meet the BDV. But future efforts and programs need to be timelier to be relevant in the aggressive timelines of industry and global competitiveness. There must be similar levels of ambition and aggressiveness for moving forward to those of China, which invests \$1.5B in fusion energy a year. FIA supports the charges and looks forward to engaging with them, but does not want the charges to be an excuse for further delays. FIRE Centers seem to be the way to start moving forward, and FIA looks forward to supporting the Centers. There must be strategic choices for aligning the goals of building and delivering an FPP, which in the U.S., will be done by private industry. FIA comprises 25 American companies and roughly 20 more around the globe that seek partnership in the U.S. Private industry will build and deploy an FPP with or without federal support, but FIA does want to engage, help in any way possible, and would like to be considered as an ally.

Mr. Trent Bauserman (Head of Federal Affairs, Commonwealth Fusion Systems, CFS) thanked Dr. Allain for the vision of a fusion energy ecosystem and agreed with the importance of aligning the LRP and BDV. The road mapping exercise is useful but many of the Milestone companies, in addition to the national labs and universities, are already self-organized. CFS would like to engage with the exercise, but the government will need to move quickly and start building hardware to meet the timelines and close gaps. CFS agrees that the U.S. is in a race with other nations that are increasing their investments and ambitions in fusion energy. CFS also thinks about the race to deal with the climate crisis; the sooner a fusion grid is deployed, the better for humanity. It might be helpful to think through how each of the ambitious construction projects will help the U.S. achieve fusion goals within the current timeline and budgets. What does the public sector need to do versus what the private sector is already doing? How to avoid duplication and make efficient use of resources, both in public and private sectors? And how to leverage international partnerships? Private industry is best suited to build FPPs, and CFS is currently engaging with customers today about the plants they want to buy. While the Milestone Program targets first phase activities, such as developing pilot plant designs, it leverages what the public sector does best with what private industry does best. It makes efficient use of capital. CFS and the other Milestone Program companies can work with other national labs and universities to close R&D gaps, and the Milestone Program is suited to produce the first FPPs. Once designs are complete, there should be a second phase of the Milestone Program model to build the FOAK pilot plants in the U.S. Today's discussion is missing the integration of efforts of the current private sector with public sector efforts to ensure that what FES plans to do will support fusion, commercialization, and is relevant to both timescale and technology to current

fusion industry activities. CFS is appreciative of the work being done and is excited to work with this community. Through collaboration, fusion technology will be deployed as soon as possible.

Dr. Hantao Ji (Princeton University) expressed appreciation for Dr. Allain’s vision and presented two comments. The first suggested an FES – National Aeronautics and Space Administration (NASA) partnership, due to NASA’s growing interest in plasma physics within the heliophysics and astrophysics divisions. The mechanism for a partnership is already in place as referenced in a 2020 Memorandum of Understanding (MOU) between DOE and NASA. The second suggestion involved building a bridge between the Fusion S&T and Discovery Plasma Science communities by adding a Solar Wind Machine to C2’s facility list, as it will be critical to plasma science in the upcoming decades.

Dr. Venkat Bommisetty (Science Infrastructure and Operations Coordinator, PPPL, via e-mail read by Dr. White) submitted two items. The first explained that investing in the advancement of plasma fusion and plasma technologies across Science, Technology, Engineering and Math (STEM) disciplines will yield significant economic and sustainability dividends. Would FES consider a centers program connecting plasma scientists and industry to address critical challenges in microelectronics and decarbonization of manufacturing? These centers could fuel innovation and workforce development. Given the recent emphasis on materials, microelectronics, and mission alignment with the Basic Energy Science (BES) and the Advanced Scientific Computing Research (ASCR) programs, FESAC should explore a cross-cutting SC program. The second item asked for additional comments on PFRCs.

Dr. Benjamin Barrowes (U.S. Army Corps of Engineers (USACE), via e-mail read by Dr. White) noted that all four strategic goals of FES center around understanding the science of fusion in plasma. Enormous resources have been poured into this topic. The science of understanding materials, processes, control systems, magnetic fields, and all the necessary conditions to sustain hot fusion on Earth is worthwhile. But it may be at the detriment of other potential fusion pathways. A percentage of the budget for FES should be put into novel fusion technologies. Research into novel fusion pathways, even if the techniques are not generally accepted, may provide insights into alternative and more practical methods to obtain fusion in more benign environments. Knowledge gained from researching novel fusion pathways could benefit different branches of science as well as fusion energy. A fifth strategic goal should be added to FES. Five percent of the program's budget should be dedicated to research funding that focuses on novel fusion pathways, including non-thermonuclear approaches.

Dr. Chris Holland (Center for Energy Research, University of California, San Diego via e-mail read by Dr. White) was thankful for the opportunity to present remarks. Remarks stem from prior experience with DOE, including serving on the LRP subcommittee. The fundamental challenge in responding to the charges is the budget. The LRP report explicitly recommended in all budget scenarios that “resources for ongoing design and construction of major new experimental facilities should be established in the DOE-FES budget.” Under a constrained budget, “U.S. leadership, and fusion and plasma science, are at risk. New activities to address other key gaps are significantly delayed, and many opportunities for innovation and enhancement of U.S. leadership cannot be acted upon.” It that seems the LRP was not successful in growing budgets, which would have avoided some of the hardest choices that a bold decadal strategy must make. More bluntly, under a constrained budget, much of what is needed cannot be done, even with private sector contributions. In this fiscal environment, the BDV budget and strategy must include significant redirection of existing funding, not just exploration of what can be done with more funding. Recommendations in this direction were made in the LRP, but recommendations are not enough,

action is required. Three years ago, it was stated, “Now is the time to act.” The subcommittee will work diligently to present a plan a year from now, during which time the field will continue to evolve and advance. It is essential that some of the harder recommendations be acted upon in to move forward. Otherwise, no number of additional charges and subcommittee reports will be able to resolve this tension.

Discussion

Dr. Verboncoeur commented that alternate methods to obtain fusion is a fruitful area and should be supported in various ways. Even if something did not work 20 years ago, modern methods and materials may bring better results.

Dr. Paz-Soldan commented that a closer partnership with NASA is intriguing, and a representative from NASA could speak to the committee about areas of interaction.

Dr. Garrison asked whether FES or industry will build the FPP. **Dr. Allain** explained that the FPP is the destination of the Roadmap, but it will be built by the private sector.

Dr. Allain appreciated Dr. Holland’s comments, as the same gaps have been addressed for the past 20 years. However, there is a system and a process that must be followed.

Discussion of the Two Charges to FESAC, Professor Anne White, Chair, Massachusetts Institute of Technology

Dr. Srinivasan asked if advocates for facilities not yet completed could address the subcommittee. **Dr. Allain** confirmed the possibility and announced that **Dr. Troy Carter** will be the chair for the C1 subcommittee. **Dr. White** explained that a role of the chair will be to invite advocates and experts to address the subcommittee.

Dr. Senor referenced the concept of synergies. Will SC consider reaching out to facilities such as the Nuclear Science User Facility (NSUF), which historically was not interested in fusion science? Are there opportunities to leverage expertise in tritium management and production with the NNSA? **Dr. Allain** responded that there are opportunities for synergies with those agencies, and there is a cross-cut team with NNSA members.

Dr. Kuranz asked for clarification on the difference between C1 and C2. **Dr. White** responded that the C1 report deadline is in fall of 2024. C1 was the first charge presented today to realign the program elements with the LRP and the BDV. C2 has to do with the facilities and has been presented to all six SC offices.

Dr. Garrison agreed with Dr. Senor’s comments about utilizing non-SC facilities and mentioned the cost of working with national labs. Timelines could present barriers, but access to non-SC facilities would be greatly beneficial. **Dr. Allain** commented that logistics and program details will have to align before access would be possible.

Dr. Barish thanked the committee for attending the first in-person meeting in four years. The primary purpose of the meeting, as of six weeks ago, was to discuss C1. Everyone came together on short notice.

Dr. Allain thanked FES and ORISE staff and looks forward to further discussion and dialogue.

Professor White adjourned the meeting at 4:48 p.m.

Respectfully submitted on December 28, 2023.
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Science Writer, Oak Ridge Institute for Science Education (ORISE)



Prof. Anne E White
FESAC Chair
March 18, 2024