**FESAC Meeting Minutes– February 1-2, 2018**
**Gaithersburg, Maryland**

**WEDNESDAY, FEBRUARY 1, 2018**

**Welcome and Introductory Remarks – Dr. Don Rej, FESAC Chair**

- The skillsets of FESAC members represent the full mission of the DOE and FES.
- Thanks for being here – as part of academia, the National Laboratories, and the commercial sector.
- We bid farewell to five FESAC members – and thank you for your service (A. Dasgupta, J. Foster, C. Hegna, V. Izzo, and L. Sugiyama).
- FESAC welcomes five new members, whose terms will run to June 2020, and we look forward to your service (S. Close, D. Demers, P. Terry, M. Walker and A. White).
- FESAC thanks Ed Synakowski for his eight years of service as Associate Director for Fusion Energy Sciences. We wish Ed well in his new role as Vice President for Research and Economic Development at the University of Wyoming.
- FESAC thanks Dr. Jim Van Dam for serving in his current role as Acting Associate Director of Fusion Energy Sciences. Dr. Van Dam's leadership is greatly appreciated.

**Office of Science Perspective – Dr. Stephen Binkley, Deputy Director for Science Programs, Office of Science**

- Welcome and thanks to all FESAC members for your participation in this process. Thank you for your service – we understand this carries a significant time commitment. Thanks to Jim Van Dam for serving as Acting Associate Director. John Mandrekas has also stepped in to head the Research Division of FES – thanks to him.
- We are awaiting passage of the FY18 budget – the FY19 President's budget has been formulated, and the roll out is expected to be on February 12. The details of the FY 19 budget will be presented at a subsequent FESAC meeting. Secretary Perry took over the Department of Energy about a year ago. His priorities are to:
    - Modernize the country's nuclear weapons arsenal
    - Achieve exascale computing
    - Advance the Nation's nuclear waste management program
    - Protect our national electric grid from cyber attacks
    - Shift the Department's focus to early-stage research and development at our national laboratories to more efficiently and cost effectively advance American dominance in scientific and energy research

The message from the Office of Science is:

- Our job is to deliver the best science we can with the resources given by the President and Congress.
- There are challenges for the FY18 budget. We are awaiting final passage of the House-Senate conference.
- Our priorities clearly are:

- Deliver the best science we can with the resources we have
- Continue the tradition of excellence in SC-funded university-based research, lab-based research, and operation of scientific facilities

DOE Science organization and appointee status
- Deputy Secretary of Energy – Dan Brouillette – sworn in August 7, 2017
- Under Secretary Paul Dabbar – sworn in November 7, 2017

FY 2018 President's budget request
- Focus on cutting edge, early stage research and development.
- Continue operations of the national laboratories.
- Increase funding of Exascale Computing.
- Maintain all on-going projects and start two new construction projects.
- An 18% decrease in the SC budget was proposed.
- The ITER policy is part of the Administration's nuclear policy review.
- The Department is looking at regulatory reform. Secretary Perry's memo in December 2017 asked FACA committees for ideas on how to streamline operations of the Department. SC is taking this as a need to streamline operation of research. A charge will be issued before the next FESAC meeting.
- Conclusion: In the immediate future, continue to deliver on high-quality science across the program. We must be ready to execute when the new fiscal year starts on October 1, 2018.

**Q & A: Dr. Binkley**
Q: Dr. Stephen Knowlton: What is the nuclear policy review?
A: It was issued in June 2017 and is on the web. It is primarily about civilian nuclear policy. In August 2017, it was decided to add fusion, specifically what to do about ITER. A review is underway. It is not clear when it will conclude.
Q: Dr. Rej: What is the status of the new SC Director?
A: The process is underway, but I have not seen any specific actions. Nominations are being processed for the head of NNSA. The DOE CIO and CFO are in place.

**Quantum Information Science (QIS) – Dr. Stephen Binkley**
- This has been discussed in research agencies since about 2007. It has now advanced far enough to start activities.
- FES is looking at opportunities.
- QIS is at a tipping point: Companies are embracing QIS. Foreign competition is expanding.
- There are significant challenges due to its inherent multidisciplinary nature.
- SC has strengths in needed areas – quantum materials and science.
- There has been a parabolic rise in Chinese publications, and a steady rise in the U.S.
- We believe that SC has unique strengths to contribute to QIS research. SC has strength in fabricating quantum devices.
- ASCR is starting to explore quantum algorithms.
- The FY17 budget had an uptick for QIS. It is also in the FY18 President's budget.

- QIC for SC Grand Challenges is expected to become important in the next decade, probably after realization of exascale.
- This will have an impact on new calculations and sensors.

**Q & A: Dr. Binkley**

Q: Dr. White: Please describe slide #7. Please elaborate on the challenges of research structure.

A: It is an interagency effort that has been reporting QIS since 2008. The group looked hard at barriers to move forward. One of the issues from the discussions is the inherent multidisciplinary nature. There should be close cooperation between the groups, to essentially produce students who have computer science and quantum knowledge. How do you set up environments that can bring these disciplines together? The group sought out the universities to discuss this. FES is trying to foster cross-disciplinary activities in a university environment.

Q: Dr. Maingi: Concerning slide 8 on publication rates, please comment on the exponential rise in the China (CN) publication rate.

A: This is true in a number of areas, including fusion. There are other metrics, like patents. It is not just CN, but also broader Asia. This is due to strong public investments. The EU is very competitive internationally.

Q: Dr. Maingi: Are there any thoughts of U.S. world leadership and policy implications?

A: There is very strong budget pressure in the U.S. There is debate on the priority of science versus national security. There is also discussion on the importance of science underlying economics and security. The debate has to recognize that investments in basic science are important for national security, as it underpins economic security. This is complicated as it plays out with the Congress and the budget.

Q: Dr. Groebner: QIS is distributed across the different areas. Do the people interact with each other?

A: In FES we approach this as a team, with cuts across the multiple programs. There is cross connection between the programs. It is a team effort. The different departments are trying to coordinate the research. Normally, Barbara Helland, the AD of ASCR, would be giving this talk, but she has been on travel.

Q: Dr. Lynch: Concerning machine learning and plasma physics data, there is overlap between machine data and quantum computers. Would it change how you would approach machine learning?

A: This is an open scientific question. Work has been done on this question. There are published papers that draw the links between the theory and machine learning. Following that thread, there may be quantum algorithms and machine learning.

Q: Dr. Groebner: Are quantum computers and encryption algorithms further along?

A: Significant engineering challenges need to be overcome. IBM and Google are making available the technology in those machines. This is a significant engineering challenge. Most people agree that practical quantum computing is several years away, and for FES it is several decades away. There is a body of computer science that has to be developed.

Dr. Rej: Thanks, Steve, for a great talk.

**Highlights of Fusion Energy Sciences Research on the 40th Anniversary of the Office of Science – Professor Gerald Navratil, Columbia University**

- The U.S. Department of Energy was created in 1977.
- Concerning fusion energy research at DOE:
  - Office of Energy Research: 1977-1998
  - Office of Science: 1998-present
- I have attempted to organize 40 years of remarkable progress by thousands of highly-talented people on the grand challenges of producing practical fusion energy. The U.S. has played a leading role in all of the progress.
- Regarding science versus energy: In late 1995, there was a meeting of an FEC led by Dr. Michael Knotek that was charged with restructuring the Fusion Energy Program into what became the Fusion Energy Sciences program of 1996. A challenging question was: "What fraction of our fusion research program is science, and what fraction is energy?"
- The program is 90% science and10% energy.
- There have been four decades of FES research progress and fusion technology progress.
- I am very optimistic about the future.

**Q&A: Dr. Navratil**

COMMENT: Dr. Hutch Neilson: I have an observation: Comparing the authors cited in early versus later decades, the field seems to be more collaborative over time – another reason for optimism in the field.

**DOE/FES Perspective –Dr. James Van Dam, Acting Associate Director for Fusion Energy Sciences**

- Thank you to the outgoing FESAC members for their contributions to FESAC.
- Welcome to the four new FESAC members.
- Concerning the evolution of the FES Budget Planning Meetings, discussion of priorities in these meetings is important.
- The plan for the BPMs will be similar to FY17. The guidance letter will be sent out soon.
- During FY 2016 and FY2017, FES held individual budget planning meetings with laboratory, university, and major facility research groups, plus several community organizations.
- We plan to hold such meetings again this year, to prepare for the FY2020 budget.
- We are planning to continue the important Frontier Science Campaign on DIII-D.
- Concerning future research operations on NSTX-U, PPPL is developing a corrective action plan and proposed recovery activities to address the necessary repair and engineering issues for NSTX-U. The SC Office of Project Assessment has been charged to conduct an assessment of:
  - The science mission need for NSTX-U
  - The cost, schedule, and scope

- The laboratory capability to repair NSTX-U and resume operations

The assessment will be performed in two phases.

- Concerning SciDAC, FES received the largest amount of ASCR joint funding. FES funded its eighth project in FY18.
- We are planning a round table FES QIS meeting in the spring. Questions to be considered are: Is there science in our field to develop QIS? Are there applications of QIS for our science? A request for information has already been sent out.
- We are looking at high flux methods for Proto-MPEX. If they work out, FES will fund it.
- We have remote control rooms at GA and PPPL to support KSTAR, W7-X and DIII-D.
- The University of Wisconsin-Madison proposal for an intermediate-scale facility for plasma science research has been fully funded for five years due to enhanced funding from the FY 2017 appropriation.
- The 2020 Decadal Survey on Plasma Science is ready to be launched. There are multiple sponsors, including HEP, NNSA, ARPA-E, NSF, AFOSR, and ONR. It is interesting that there is no NASA involvement.
- Concerning the IAEA meeting, there has been a four-year oscillation in the number of U.S. papers
- For the U.S. contributions to ITER, 90% of the funding stays in the U.S.
- Pellet injection is the primary disruption mitigation for ITER. It will be tested on JET. Pellets may not be adequate.
- Concerning the NAS interim report, a demonstration device requires answering whether the program is focusing on science or energy.
- FES personnel changes
  - Synakowski – departed in 2017 – University of Wyoming
  - Van Dam – currently Acting Associate Director for FES
  - Mandrekas – Acting FES Research Division Director
  - Finnegan – left to join NNSA
  - Eckstrand - retired
  - Opdenaker -retired
  - Thio - retired
- Early Career Research Awards – among 23 university early-career awardees, so far 12 who were up for tenure have achieved it.
- Community workshops are seen as investments.
- Six ECR awards last year, 3 HEDLP, one basic plasma science. On the University side, almost all get tenure. They also get other awards rapidly, such as PECASE.
- DOE celebrated its 40th anniversary.
- Please remember to send scientific highlights to us.

**Q&A: Dr. Van Dam**

Q: Dr. Groebner: Do highlights need to be in a special format?

A: There is a template that you can use to download from the Office of Science.

Dr. Terry: Did the groups that did the basic plasma experiments on DIII-D have funding to do the analysis and see the experiments to full conclusions? Can they get support?
A: The PIs were already funded in their areas.
Dr. Cauble: The correction plan is in place for the deep-dive investigations after the NSTX hardware failure. Does deep-dive analysis apply anywhere else – to any other device or any other work being done?
A: PPPL reached out, and experts came in and served on reviews. There are two aspects of the review - the components of NSTX and looking at policies, procedures, and training at other parts of the laboratory. We need to increase the engineering rigor and quality assurance at PPPL. These were the contributing issues that resulted in failure of NSTX. We are doing it in a graded approach. We now have policies and procedures in place to achieve this. We are not done yet.
Dr. Patello: What numbers are being used during the Continuing Resolution?
A: The DOE's CFO, is taking a conservative approach.
Dr. Knowlton: Concerning international research, is there a strategy or is it opportunistic? Is there pressure from proposers?
A: Ideas and proposals come from the community, and developments come from the international partners. We certainly want to keep our domestic facilities healthy. We also want to be able to access cutting-edge capabilities available internationally.
Dr. Carter: What is the process for your acting title?
A: John Mandrekas and I had our interim positions renewed. I have no idea what is coming. There is currently a hiring freeze.
Dr. Groebner: Can you say more about the University of Wisconsin-Madison facility?
A: It is sort of like LAPD being part of a multi-device facility. It is intended to be a collaborative user facility. It appears as if it is not going to be an SC user facility. Wisconsin did not propose any facility upgrades in the current funding envelope.
Q: Dr. Greenfield: Concerning international collaborations, what is the balance from a strategic point of view?
A: JT-60SA will be a tremendous opportunity, and there is a long US-JP history. We have to navigate the Broader Approach agreement. LHD is having a deuterium campaign. We would like to see some increase in LHD activities. There are opportunities in HEDLP in ultra-strong lasers in the EU and in Asia.
Q: Dr. Groebner: Regarding collaborative experiments that involve international collaborators, is there a top-down DOE policy that would affect this? Will there be a survey this year?
A: We wish we had more funding overall for this. There will be a workshop to discuss this. Yes, there will be a survey.
Q: (unknown): It sounds like the international collaborations are one-offs. Other agencies have strategies and guidance.
A: Perhaps I gave the wrong impression. Three of the activities were from an explicit proposal competition. Also, there is the W7X team.
Q: (unknown): Other agencies make connections to other facilities separate from the proposals for science, to ease the interface.
A: There are programs in FES like that also.

Q: Dr. Neilson: The W7-X and LHD collaboration is an opportunity for two large important stellarators that are now operating. There is a contrast in design, but the focus is on stellarator science. I share your wish that things will expand in that area.
A: Yes. Also, we have collaborations with QUEST.
Q: Dr. Terry: With international collaborations on offshore devices, there is the danger of the U.S. program only engaging leading-edge facilities via international collaboration. Do you worry about this?
A: The high energy physics program is almost entirely offshore. We do worry about it. The domestic machines give us the expertise to be able to contribute to our international partners. It is a balancing act.
Q: Dr. Groebner: Are the community workshops that were held still central in FES planning for the future? There is confusion with SciDAC and integrative modeling. What is the horizon for exascale computing?
A: Yes. The final reports were received in 2016, and they are very important. Congress asked for more workshops. We are looking for more experimental opportunities. Our field is very strong in this area. We punch above our weight in this area. Transients and computing are big. The Exascale Computing horizon is 2021-2023. They are working very hard on this.
Q: Dr. Rej: Regarding the request for information for climate scientists, will that be expedited after the roundtable?
A: A dear-colleague letter and solicitation have been sent from the Office of Science.

**Report of the FESAC Subcommittee on Transformative Enabling Capabilities – Dr. Rajesh Maingi, Princeton Plasma Physics Laboratory**

- The charge: to identify promising Transformative Enabling Capabilities "that could promote efficient advance toward fusion energy, building on burning plasma science and technology."
- The FESAC panel was formed in February/March 2017.
- Community input was provided via talks at three meetings and white papers.
- The findings were four Tier 1 TECs (not prioritized) and one Tier 2 TEC.
- A draft report was sent informally to FESAC members and a few community leaders on January 17, 2018.
- We thank everyone who provided feedback, which we incorporated to the extent possible.
- We thank the panel, including the ex-officio members. It was an enjoyable experience.
- A working definition of a TEC is a game-changing idea, toward revolutionary and beyond evolutionary.
- A TEC would dramatically increase the rate of progress towards a fusion power plant.
- The TEC subcommittee (R. Maingi, Chair, and A. Lumsdaine, Vice-Chair) was sub-divided into three sub-panels corresponding to the following different areas of technology application:
    - Plasma Diagnostics, Actuators, and Control
    - Plasma Materials Interactions
    - Reactor and Balance of Plant

- There were three meetings for community input and one face-to-face panel meeting.
- Advanced algorithms will transform our vision of feedback control of a power-producing fusion reactor from one of basic feasibility to one employing intelligent systems, enabling operation at optimized points whose achievement and sustainment are otherwise impossible.
- For high critical-temperature superconductors, advances in higher critical-temperature and/or higher-field superconductors present a game-changing opportunity to enhance the performance and feasibility of reactor designs.
- The advanced materials area consists of new material design and processes, and promising advances in advanced manufacturing. This TEC includes materials by design, emergent fusion nuclear materials, divertor materials, and complex heat-transfer systems.
- Additive manufacturing can revolutionize materials and components for fusion energy reactors.
- Materials by design (MBD) combines predictive computational tools (e.g. machine-learning with robust advanced manufacturing) and synthesis approaches, such Additive Manufacturing (AM).
- Emergent fusion materials include adaptive and self-healing materials, complex hierarchical composites, complex alloys, and hybrid liquid/solid systems.
- Regarding control of the tritium fueling cycle, because D-T fusion power plants must self-generate their T fuel, novel concepts for fuel production, extraction, and processing show transformative potential. For tritium production with Dual Coolant Lead Lithium (DCLL) blankets, the challenge is to satisfy multiple conflicting material compatibility, structure integrity, and lifeline requirements while removing lead, breeding tritium, and providing a first wall.
- Concerning tritium production and cellular media blankets, while the U.S. favors DCLL, most blankets in the ITER TBM use ceramic breeders. Regarding tritium extraction and electrolytic membranes, recently Li and SnLi are being proposed for flowing liquid metal (LM) first wall and divertor concepts and for use in tritium breeding blankets (PbLi) for the next step U.S. fusion reactor.
- For tritium processing, a driver of both the fueling plant's inventory and processing rate is the tritium burnup fraction (TBF). ITER and the EU DEMO are at ~0.35% to 1.5%.
- The promise of fast-flowing liquid-metal plasma-facing components is to supplement head conduction through the substrate with heat convection via liquid metal flow.
- There are challenges of fast-flowing, liquid-metal plasma-facing components.
- Concerning foundational and enabling activities, in addition to the identified TECs, a number of activities were identified as foundational on the path toward a fusion reactor, but not transformative.
- In summary, the panel identified several promising Transformative Enabling Capabilities "that could promote efficient advance toward fusion energy,

building on burning plasma science and technology." There were First Tier and second Tier TECs. Each of these presents a high opportunity to accelerate fusion science and technology toward power production.

**Q & A: Dr. Maingi**

Q: Dr. Pedersen: For high temperature superconductors, what is the risk, the size, and the shape for the prototype conducting coil?
A: Because of the higher current densities, you can get higher fields and possibilities of a small device. Trying to design a facility was beyond the scope of what we were doing.
Q: Dr. Terry: Technology is changing rapidly. What is the process for identifying all possible technologies? Did you miss something?
A: We did start with the 7-8 areas listed in the charge and identified 6 additional areas. The resources we used were white papers, and the process of technologies of the tritium fuel cycle. We found things that we didn't think we would find. We received input from community experts. We may have missed something – we don't have a crystal ball. We did reach outside of the fusion community for expertise. We should be doing more of these types of reports going forward so we don't miss anything. A lot of what was considered were enabling but not transformative. There is progress, but it is more evolutionary, not revolutionary.
Q: Dr. Groebner: You received good input from a wide range of communities. Is there really good expert input in all of the areas?
A: Concerning input we received from outside the community, it was from strong subject matter experts in their field. The white papers will list this information, which was documented.
Q: Dr. Verboncoeur: The challenge in deep learning is understanding how it works. How can this be done without starting from scratch every time the theory changes? How closely is this theory coupled with experimental measurements?
A: These are all interlinked - each strand is connected to another strand. In the technology assessment, the machine learning and AI communities are important. We recognize those risks and they cannot be separated.
A: Dr. David Humphreys (panel member): Technology as a tool for fusion will be used as a bridging technology. Power plants will have a small region for diagnostic access.
Q: Dr. Carter: Tritium fuel cycle control is unlike the rest in not having strong drivers outside fusion.
A: In this area, there are not strong external drivers. It is being driven through work that is being funded by fusion.
Q: Dr. Demers: How are you sure you are not missing a TEC? How do we ensure we are not mischaracterizing? Are there areas that are not fully characterized?
A: We shrunk down those categories. Advanced materials is a catch all for things. It could be more descriptive for a first tier TEC. We sent the draft report to the laboratories for feedback and tried to respond to suggested changes.
Q: Dr. Walker: The tritium fuel cycle could increase industrial involvement because, eventually, it will be required. How quickly are advanced materials characterized and quantified?

A: It is a goal to achieve. The challenge does not have a lot of other applications. For industrial involvement, they want to see some ROI. This is a real challenge for us, due to limited investment and involvement.
You do need a test bed to evaluate these materials (section 6.8). You need capability to do testing – rapid cycles to design, test, and construct. We don't have integrated test beds. Industry is trying to involve small businesses.
COMMENT: Dr. Verboncoeur: Industry is pursuing an external driver for testing.
Q: Dr. Patello: The U.S. could be world leading in superconductors. How about other areas?
A: There are many different areas where technology assessment was done, which was documented in the report. Global strength and gaps are areas of assessment. Tritium extraction techniques are current.
Q: Dr. Cauble: Were the Technology Readiness Levels agreed upon by consensus?
A: We asked for this in white papers. There was a wide variation in response because there was no clear definition of what we meant by TRL. What is the TRL for a power fusion plant? The best we could do was a 6. Most items are 3 or less. We tried normalizing this according to the definition. We need to clarify the TRL information.
Q: Dr. Lynch: There are areas of the report where people don't exist. Is it in the scope of the report to address this?
A: We make investments now and hope to bear fruit later. The connections to scientists are across fields. This is a good suggestion.
Q: Dr. Neilson: What is it going to take – time horizons in years/decades – to fulfill the promise of promoting fusion energy? Fusion needs to be involved. What did you assume about the level of fusion involvement? What will it take as far as resources to make an impact on fusion?
A: For high-temperature superconductors, the goal is to identify the transformative enabling capabilities. There are areas we asked for input from the whitepapers. We didn't try to figure out what resources would be needed to accelerate the process. What would it take to get to a TRL? Not everyone was responsive to that.
COMMENT: Dr. Rej: If you have specific recommendations on the report, please provide them.
Q. T. Pedersen: You did a great job on this report. High-temperature superconductors is an area where we need to jump into. Experts mention that the cables are not being made because the customers are not there (and there are no cables). The companies are crying for investment in this – this needs to be developed. This area should be highlighted.
A: In that particular chapter, the sense of the committee is that it is primed and ready to use that technology. It is ripe for this type of technology.
Q: Dr. Terry: The description of activities for machine learning can be applied. Did you consider if the area of control can be applied to other items? Can machines help us extract knowledge in ways we haven't done previously? We should be careful as to how this is being addressed.
A: White papers have described what you are questioning. There was one white paper that addressed this. The goal was to call the TEC groupings open ended

places. We will think about putting that language in. The intent was to identify linkages between machine learning.
Q: Dr. Groebner: I am excited by the transformative ideas in the report. The panel worked very hard. I think that the charge was addressed. Are there places that could be ripe for doing work in advanced materials? Is it a little too early?
A: It is a little too early to say specifically which advanced materials can be manufactured. The entire area is one that could be ripe for investment.
Q: Dr. Verboncoeur: The report is very well written. DOE should invest in the coupling between advanced algorithms and advanced materials versus leverage from the outside.
A: Thanks for the comment.
Q: Dr. Carter: It is an excellent report. The tritium fuel cycle stands out. It is a critical path element for fusion.
A: We tried to refine the wording. We can try to strengthen it in the executive summary.
Q: Dr. Demers: I suggest renaming advanced materials and manufacturing technologies: "complex heat systems."
A: It is a narrow phrase. But, we will think about changing the wording. That is a reasonable suggestion.

**Reports of the NAS Committee on a Strategic Plan for U.S. Burning Plasma Research - Professor Michael Mauel, Columbia University and Professor Melvyn Shochet, University of Chicago, co-chairs (presented remotely by Professor Mauel)**

- The origin for this study is the CONSOLIDATED APPROPRIATIONS ACT, 2016 - PUBLIC LAW 114–113, December, 18, 2015. No later than May 2, 2016, the Secretary of Energy shall submit, to the Committees on Appropriations of both Houses, a report recommending either that the U.S. remain a partner in the ITER project after October 2017 or terminate participation.
- Message from Secretary Perry
    - ITER remains the best candidate to demonstrate a sustained burning plasma.
    - After studying the U.S. contributions to ITER, I recommend that the U.S. remain a partner in the ITER project through FY 2018, focused on achieving First Plasma.
    - DOE will request the NAS to perform a study on how to best advance the fusion energy sciences in the U.S.
    - The study will address the scientific justification and the needs for strengthening the foundations for realizing fusion energy.
    - The NAS will form a committee to study the state and potential of magnetic confinement-based fusion research in the U.S. and provide guidance on a long-term strategy. An interim report will assess the current state of U.S. research and the importance of U.S. burning plasma

research. A final report will provide two scenarios: the U.S. is a partner in ITER, and the U.S. is not a partner in ITER.

- The committee members are M. Mauel, M. Shochet, C. Back, R. Betti, C. Forest, T. Fowler, J. Friedberg, R. Gilgenbach, W. Heidbrink, M Hermann, F. Jenko, S. Kaye, M. Kikuchi, S Reyes, C. Robinson, P. Snyder, A. Wendt, B. Wirth, and D. Lang.
- Background: "Achievement of government consensus on rejoining ITER, along with broad support within the U.S. scientific community, was a major accomplishment over the past decade." And, "once the [ITER] decision is made, fulfilling the international commitment to help construct the ITER facility and participate in the ITER program will necessarily become the highest priority in the U.S. program."
- Data gathering for the report involved
  - Government reports on U.S. ITER participation
  - Previous reports on burning plasma research and strategy
  - U.S. DOE fusion strategy reports
  - Community input
  - Physical and engineering sciences literature
  - Committee membership expertise

**Committee member Stan Kaye is now presenting due to technical Zoom issues with Professor Mauel's connection.**

- Importance of Burning Plasma Research: "The committee reaffirms the importance of burning plasma research to the development of fusion energy, as well."
- Controlling a Burning Plasma: "A burning plasma experiment would address for the first time all of the scientific and technological questions that all magnetic fusion schemes must face. Such an experiment is the crucial element missing from the world fusion energy sciences program and a required step in the development of practical fusion energy."
- Fusion Technology: "While burning plasma science has progressed since the 2004 NAS burning plasma assessment, significant advancements in fusion technology are needed for a burning plasma reactor."
- Importance of Plasma Science and Other Science: "The process of creating a fusion-based energy supply on Earth has led to technological and scientific achievements of far-reaching impact that touch every aspect of our lives."
- Status of U.S. research that supports burning plasma science: "Since the NRC report in 2004, the U.S. has undertaken an enormous effort in experimental, theoretical, and computational research in support of burning plasma science. The U.S. research program motivated world-leading contributions to science and technology in support of ITER and other major international fusion experiments. However, the closure of domestic fusion research facilities and the failure either to upgrade or to start new medium-scale experiments, together with substantially-decreased funding to fusion nuclear science and technology

research, create concern as to whether the U.S. will continue to be a scientific leader in the field."

- Burning Plasma Science: "U.S. fusion scientists and engineers have contributed a substantial number of new, innovative ideas to the study of burning plasma science."
- Fusion Technology and Engineering Science: "Many of the program contributions to burning plasma science are interrelated to advancements in fusion technology and engineering science."
- U.S. Participation in International Fusion Activities: "Fusion energy research is international. The U.S. participates actively in Europe and Asia, and international scientists from around the world participate in fusion experiments and research programs within the U.S."
- Role of ITER in Today's U.S. Burning Plasma Research: "DOE Ten-Year Perspective (2015) (p. 8) - "The global magnetic fusion research community is focused primarily on the commencement of the 'burning plasma' era."

- Assessments
  - Importance of burning plasma research: It is essential to the development of magnetic fusion energy and contributes to advancements in plasma science, materials science, and the nation's industrial capacity to deliver high technology components. Construction and operation of a burning plasma experiment is a critical, but not sufficient, next step toward the realization of commercial fusion energy. Further research is needed.
  - Status of U.S. Burning Plasma Research: The U.S. fusion energy sciences program has made leading advances in burning plasma science, and we are confident that a burning plasma experiment such as ITER will succeed in achieving its scientific mission. Recent closures of domestic experimental facilities, and a reduction of fusion's technology efforts, threaten the health of this field. International partners have strategic plans leading to a fusion energy demonstration device. The U.S. does not.
  - Any Fusion Strategy Requires a Burning Plasma Experiment: A study is required for this. ITER is the only existing project to create a burning plasma at the scale of a power plant. As an ITER partner, the United States benefits from international cooperation. A decision by the United States to withdraw from the ITER project could have negative impact by isolating U.S. fusion scientists from the international effort.
  - The U.S. Needs a Long Term Strategy: To maintain scientific and technical leadership in this field, the U. S. needs to develop its own long-term strategic plan for fusion energy. The committee also recommends continued progress towards the construction and operation of a burning plasma experiment leading to the study of burning plasma, continued research, innovation in fusion science and technology, and a mission for fusion energy research that engages the participation of universities, national laboratories, and industry.
- Strategy towards Completion of the Final Report: The following meetings are being held:

- Feb 1-2 in Cadarache, France
- Feb 26-28 at General Atomics
- April 11-13 at PPPL
- May-June TBD

The final report is schedule for September/October.

- If possible, the final report will include considerations of the health of fusion research sectors within the U.S., the role of international collaboration, the capability and prospects of private-sector ventures, the impact of science and technology innovations, and the research strategies that may shorten the time and reduce the cost required to develop commercial fusion energy. The report will present strategies that incorporate continued progress toward a burning plasma experiment, research to improve and fully enable commercial fusion power, a focus on innovation, and participation of universities, national laboratories, and industry in the national program.
- The committee welcomes input in any form.
- All input provided will become part of the committee's public record.

**Q&A: NAS**

Q: Dr. Greenfield: All of the input goes into the public record. Where is the public record located?
A: The staff is working now to get the record online, and it will be connected to the website shortly.

**Discussion of FESAC Subcommittee Report on Transformative Enabling Technologies: Dr. Rajesh Maingi**

COMMENT: Dr. Rej: FESAC members should provide their comments on the report.
COMMENT: Dr. Walker: Industry commercialization should be included. The committee has done a great job on the report.
Q: Dr. Patello: You have done a great job on the report. The subsection/categories, but not all subsections, have all of those sub headings. Why is this? Is there a lack of parallelism?
A: This is not intentional. We will take a look at this. Probably if it's not there, it has not been evaluated. It is not intentional if anything has been missed.
Q: Dr. Cauble: The report seems to be thorough. How is the report going to be used? What happens now?
A: We have identified several areas that we think have transformative potential. FES suggested to look through the report and make evaluations about transformative potential, and alignments with their priorities, and maybe do solicitations, if they deem it is possible. We would like to see an innovation process done. How can we accelerate this activity?
COMMENT: Dr. Lynch: The timescales on the capabilities are 10-15 years. How do you attract people to these problems/challenges? The plasma physics community should use these reports to attract students to the program. Young students don't know anything about this report.

Q: Dr. Neilson: Transformative Enabling Capabilities are driven by cost, timelines, and potential attractiveness and unattractiveness of the product. The committee did a great job on the report. What made it exceptionally powerful was input from outside of the fusion community. So this is not more of the same, it is well documented. The report tells us what transformation looks like. This is a real challenge to the status quo. It is too early to know how the report will be used. The charge was executed, and the report is ready to be approved.
Q: Unknown: Are you clear about what needs to be revised?
A: We have a good set of notes. Some items are actionable, and it is easy to put items in the report. Other comments need to be more thought out. We will discuss this tonight with the subcommittee.
COMMENT: Dr. Rej: The vote on approval of the report will be at the end of the session tomorrow. We need FESAC members to vote then. The public comment session will be tomorrow. Please contact Sandy Newton if you would like to make a public comment.
COMMENT: Dr. Van Dam: It is a very good report and was very well done. Given our budget authority, we will look at the report very closely. It will be useful on the Hill when talking with legislators.
COMMENT: Dr. Barish: Any FESAC member who would like to suggest changes in the report should send them to Dr. Maingi and Dr. Lumsdaine by tonight.

**MEETING ADJOURNED at 4:40 P.M.**

**THURSDAY, FEBRUARY 2, 2018**

**2017 U.S. Magnetic Fusion Research Directions Workshops – Dr. Mickey WADE, General Atomics**

- Community Workshop Program Committee members: J.P. Allain, L. Baylor, J. Canik, T. Carter, C. Collins, F. Ebrahami, D. Gates, M. Greenwald, D. Hatch, N. Howard, S. Hsu, I. Joseph, C. Kessel, D. Liu, and D. Maurer
- Goals of community workshop process:
    - Provide an open forum to hear community views on strategic charge questions I2 and F2 and opportunities in charge F1, and provide

community feedback on these views.
    - Identify key aspects of a long-term U.S. fusion strategic plan (both with and without the U.S. as a partner in ITER), including both domestic and international research.
- Ensure the credibility and broad support from the community for any work product resulting from the workshop(s). Engage with community leaders, FES leadership, and the NAS panel co-chairs at timely intervals for feedback on the process and goals.
- Brief timeline of community workshop:
    - December 2016 – NAS Task description released
    - February 2017 - Leadership group "commissioned" to coordinate development of community workshops
    - March 2017 – program committee established
    - July 2017 – first workshop – Madison, WI
    - December 2017 – second workshop – Austin, TX
- Strategic elements: called for community white papers which fed into the Madison workshop. Working groups were formed on programmatic questions, which fed into the Austin workshop, and then work towards a strategic plan.
- High level summary
    - The U.S. program has strengths, although it is not healthy overall. Funding for universities and technology are areas of concern.
    - The discussion centered on being a science or an energy program, but there was no clear consensus.
    - Achieving a burning plasma is still an essential step for our field.
    - There may be support for a focus on developing HTS magnets for fusion applications.
    - There was general interest in and support for a stellarator component to U.S. program
    - Theory/computation is an important component of the U.S. program.
    - PMI/divertor problems are very important.
    - FNS/TB/blankets are a critical element on the path for fusion energy development. There are concerns about the timeline.
    - The Austin workshop touched on all levels of strategic planning due to the urgency of such an effort. An important goal is community engagement.
    - The leadership team for each group was established by the program committee. The working groups were open to everyone.
    - WG-1: discussed Principles, Values, Metrics, and Criteria.
    - WG-2: discussed the Impact of Access to ITER.
    - WG-3: discussed Attributes for Market Attractiveness.
    - WG-4: discussed Potential Mapping of Strategic Elements to the Various Strategic Approaches.
    - WG-5: discussed Fusion Science/Plasma Physics/Materials Science Unification/Program Integration.
    - WG-6: discussed Future Planning Activities, moving forward from Austin.
- Strategic Plan vs. Strategic Approach

    - Strategic plan: A comprehensive framework that defines mission, vision, principles, and a roadmap.
    - Strategic approach: Singular paths to accomplish the mission of the plan, that are typically differentiated through assumptions with regard to the current situation, risk uncertainties, risk tolerance, time frame, and competitor positioning.
- Some Points of Consensus from the Austin Workshop Summary Presentation
    - The burning plasma mission is an essential step on the path to fusion energy.
    - Operational and experimental experience (including failures) is very valuable. "Reading the papers" is insufficient to understand burning plasmas and technology.
    - HTS magnet development should proceed.
    - Emphasis should be increased on advanced divertor and PFC concepts.
    - Emphasis should be increased on steady-state, high-performance regimes.
    - The community planning process should continue beyond the NAS study.
    - A path that includes ITER, and IFMIF+FNSF+DTT is the most reasonable path of those presented by this strategic approach.
    - The U.S. should pursue a more-innovative research path than any of proposed path(s) outlined in this strategic approach.
    - We recommend a complementary approach of utilizing the delineated innovations as a "toolbox" for all the strategic approaches to consider or use.
    - The program should carry out a merit-based, scientific and technological review of magnetic configurations.
- The planning committee has commissioned white papers on nine strategic elements emerging from the Madison/Austin workshops:
    - Burning plasma
    - Developing HTS magnets for fusion applications
    - Configuration research
    - Stellarators
    - Theory/computation
    - Plasma-material interactions and divertor
    - Fusion nuclear materials
    - Tritium fuel cycle
    - Sustained high performance tokamaks
- White papers will have a common format, including benefits, current status, programmatic context, a 15-year U.S. research agenda, etc…
- The goal is to provide these to the NAS panel prior to the February 26-28 meeting in San Diego.
- We are in the process of requesting a white paper from each of the pre-Austin strategic approach working groups.
- We are targeting ~ April 15 for sending completed white papers to the NAS panel.

- The planning committee will discuss the possibility of a third workshop in its next conference call.

**Q&A: Dr. Wade**

COMMENT: Dr. Wade: Everything generated is on line and is available to the public.
Q: Dr. Rapp: I hope that an affordable strategic plan is possible. Can everyone in the community contribute to the white papers? Will there be a third workshop?
A: The intent is to open it to the community to contribute to the white papers via a process. The window to contribute may be limited. When transmitted, it will be a draft document - a work in progress. On a longer timescale, community ownership is an important goal.
Q: Dr. Greenfield: You produced a white paper in a very short period of time. You did a good job summarizing the workshop. Would you like to comment on plans for the future? In looking at the past two decades, the meetings involved a lot of community work. The result was a level of community consensus which hasn't been seen before. We should also think about how to continue to build community consensus.
A: Yes, I agree with this.
Q: Dr. Pedersen: Thanks for making this an open process. I am confused where this fits in. What is the stellarator path? Is there a white paper coming on this? What is your thinking about this being a part of the strategic plan?
A: There is a stellarator white paper that exists in the community. Strategic plan – to innovate the strategic approach 3. There are elements of stellarators in strategic approach 3. We have tried to note that the stellarator group is strong. But, we want community buy in, not just from the small stellarator community. We encourage folding the stellarator path into a broader path including tokamaks and other paths. The community should comment about how this folds into the broader community. There is no consensus for a significant opportunity for what to do with stellarators. There should be more dialogue about this.
Q: Dr. Terry: The sampling of the community is self-selected. Are there ways to broaden this so more people are involved? The process has been driven by meeting deadlines. Can it be paced out so that people can remain in the process? How do people get into the process?
A: Participation in the workshops has not been driven by the program committee. People self-select to be in the process. We are open to ideas as to how to widen the net to broaden the participation. The timescale for the future community process will be streamlined. We need something that is a driving function for this.
Q: Dr. White: It appears that strategic approach 2 was an outlier and did not come to a consensus, compared to working group 1.
A: There were recommendations that those two strategic approaches work together as one group. The working group was passionate about the plan. The community response was shown. There were many people who were excited about this.
Q: Dr. Groebner: Is there a charge to develop a strategic plan?
A: The way the advice about ITER came to FES was through a community workshop. The community came up with a recommendation, and FES gave a charge

to FESAC to provide advice. To receive information from the community, it has to go from DOE through a FESAC charge. Some processing still needs to happen. We will have more binary group discussions.
Q: Dr. Knowlton: Thanks for a good talk. There are generational difference of opinion as to how to proceed. Is there a generational difference on how younger scientists may perceive a strategic plan? This seemed to be an undercurrent at the workshop.
A: Early career scientists generally want to change the world in any way they can, and do something that is new and different. The older generation has been stuck in the same place for a while. Sometimes, we don't want to take risks. The older generation wants to be careful about moving forward.
Q: Dr. Demers: This has been a great process. There was tension between coming up with information to inform the NAS report versus developing a strategic plan. The benefit has been the brainstorming among people. If the process goes forward, how can we perpetuate and encourage continued brainstorming?
A: This is a great point. We are time constrained. Moving forward will be about some aspect of brain storming. But, it should be more intentional instead of part of a process. We need to figure out how to do this. This is a good idea.
COMMENT: Dr. Rej: Thanks for putting the workshops together. It really is a process. Getting the most important things is what is needed for fusion in the U.S.,

**FESAC Charge Letter on a Committee of Visitors – Dr. Don Rej**

- January 16, 2018 letter to D. Rej (FESAC Chair) from S. Binkley (Deputy Director for Science Programs).
- The letter requests that the Fusion Energy Sciences Advisory Committee establish a Committee of Visitors (COV) to review the management processes of the Fusion Energy Sciences program. The COV assessment should review the entire FES program for activities from FYs 2014 through FY 2017.
- Dr. Gert Patello has agreed to be the chair of the subcommittee.

**Q&A: Dr. Rej**

COMMENT: Dr. Rej: FESAC members should recommend people to serve on this subcommittee, including self-nominations. Please send me your recommendations by February 5.
Q: Dr. Terry: Panel members should not be involved in research being funded by FES. They need to manage their own and institutional conflicts of interest. One third to one half of subcommittee members are not funded by DOE.
A: Dr. Patello: The guidance document says 25%.
Q: Dr. Greenfield: For people who are considering serving on the panel, where are the lines being drawn on conflict of interest?
A: The panel membership is divided into six categories: project experts, and the other five on the FES research program. The national and international standing of the portfolio will be evaluated as well.
COMMENT: Mr. Joe May: They are not actually reviewing projects. They are reviewing the process for managing projects.

Q: Dr. Demers: So, 25% of members outside of the community can participate. Is there any restriction on past committee participants?
A: No.
Q: Dr. Cauble: Who determines the makeup of the panel?
A: The final authority is FES.
Q: Dr. Demers: Should the committee members be domestic and international?
A: That doesn't matter. The primary objective is getting the right people.
Q: Dr. Groebner: What is the process for information gathering?
A: Advance information will be sent out ahead of time. All of the information comes from FES. The information will be provided by FES.
A: Dr. Patello: There is a website with the information for the FES COV.
Q: Dr. Groebner: For the meeting in Germantown, when is the report written?
A: The COV will have pre-reading. When panel members arrive in Germantown, there will be meetings, and members will have access to the reports. The first draft report will be written while onsite.
COMMENT: Dr. Greenfield: I served on a COV, and it was a great once-in-a-lifetime learning experience.
COMMENT: Dr. Lynch: The scope at Goddard was different, with a different process. But, it is a very educational process.
COMMENT: Dr. Neilson: For the 2008-2009 COV, I learned a lot about the pressure people in the office are under.
COMMENT: Dr. Patello: I am looking forward to this opportunity – to look "behind the curtain." The deadline to reply is Monday, February 5 - to recommend others or self-nominate.

**THERE ARE NO PUBLIC COMMENTS.**

**Other Business – Dr. Rej**

**Q&A: Dr. Rej**
Q: Dr. Cauble: Dr. Binkley mentioned regulatory reform policy. Is there any other information on this?
A: There is a memo from Secretary Perry on regulatory reform. A charge will be formulated. The memo said that regulatory reform should be on the agenda at all DOE advisory committee meetings. Each program office should report back on what the advisory committee has recommended about regulatory reform. Dr. Binkley believes that a charge will be issued.

Concerns were expressed about the summary of the FESAC TEC report. Dr. Rej thanked Drs. Maingi and Lumsdaine for their presentations.

There was a proposal to vote on approval of the TEC report, giving Dr. Maingi the authority to revise the summary, which would be reviewed by Drs. Rej and Knowlton. The revised report would be submitted to the Office of Science.

Q: Dr. Pedersen: Can additional comments be made on the document, and we can see the final document?
A: Dr. Barish: Yes. Comments from FESAC members on the report should be sent to Dr. Rej one on one (separately).
Q: Dr. Greenfield: What happens if a FESAC member has substantial comments?
A: Dr. Barish: If this happens, a FESAC conference call can be scheduled, which will be published in the federal register.

A motion was made by Dr. Knowlton to approve the revised TEC report. The motion was second by Dr. Pedersen. The motion passed unanimously.

The meeting was adjourned at 11:30 a.m,

**Certified as Correct by:**

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Dr. Donald J. Rej, FESAC Chair

September 20, 2018
Date