

**Minutes of the meeting of the
Fusion Energy Sciences Advisory Committee.
January 13, 2009.
Gaithersburg Hilton, Gaithersburg, Maryland.**

As the chair, Dr. Martin Greenwald, was unable to attend, Dr. Riccardo Betti, the vice-chair, started off the meeting at 8:00. It was brought to attention that there is a new agenda and that there will be no discussion of the Strategic Plan Overview drafted by the Office of Fusion Energy Sciences. Dr. Stephen Eckstrand noted that FESAC is an open forum with all the discussions available to public. A plan requested by Congress cannot be distributed, in a draft form or final form, to such a public panel until Congress has had chance to review the document. Thus, there will be no discussion of the plan – however, the FESAC panel’s individual comments will be considered in the final version of the plan that will be sent to Congress.

There were seven presentations during the day followed by two public comments:

- Dr. Patricia Dehmer on the Office of Science perspective – she discussed her positive interaction with the transition team for the new president.
- Dr. Eckstrand on the Office of Fusion Energy Sciences perspective – he mentioned strategic planning activities for this year, including the ReNew workshop, and workshops on high energy density laboratory plasmas (HEDLP) and fission/fusion hybrids.
- Dr. Betti presenting highlights of an extensive final report by the panel on HEDLP.
- Dr. Richard Hazeltine on the ReNeW workshops – he talked about the motivation of the workshops, the five theme workshops leading to the final workshop in June, and the expected product.
- Dr. Mark Tillack and Dr. David Whelan on the use of Technical Readiness Levels (TRL) in planning the fusion energy sciences program, and the use of TRLs at Boeing.
- Dr. René Raffray presented a summary of the 2008 International High Heat Flux Component Workshop on readiness to proceed from near term fusion systems to power plants.
- There were two public comments – by Dr. Wayne Meier and Dr. Richard Majeski

Before the start of the afternoon session of talks, Dr. Betti discussed the cover letter from FESAC that will be sent to Dr. Dehmer and to Mr. D’Agostino, Under Secretary for Nuclear Security, endorsing the comprehensive HEDLP panel report that he had discussed in the morning session. The FESAC committee voted unanimously to accept the panel report and the cover letter following the inclusion of some minor changes to both.

The next FESAC meeting will be held in November 2009.

The meeting was adjourned at at 15:10.

Dr. Dehmer

She was the primary person from the Office of Science interacting with the transition team for the new president. The transition team wanted to understand the workings of the DoE Office of Science (SC) and would eventually report to the central transition team. Dr. Dehmer was impressed with the quality, knowledge, and professionalism of the transition team.

The transition team was interested in the mission of Office of Science

- to advance the national, economic, and energy security of the nation;
- support of science of scale (large projects and ITER);
- coupling of grand science with practical applications.

The SC supports discovery science in six science program areas and supports mission-relevant research to advance DoE's missions. The transition team wanted to know about the organizational structure of DoE and, in particular, the role of the under secretary for science. Some of the information passed on to the transition team was as follows. The SC has about 994 employees – 264 in headquarters and 730 in the field. The budget request for FY 2009 is about \$4.72 billion – an increase of about \$750 million over the previous year's appropriation. The SC manages 10 national laboratories. The Office of Science supports fundamental research, oversees the construction and operation of the nation's most advanced user facilities (e.g., particle accelerators and colliders, and supercomputers and high-speed computer networks). The research supported by SC is both principal investigator driven and mission driven.

The transition team wanted to know about the various committees within the SC and the composition of its members. There was a lot of talk about program specific issues including ITER and its current status.

As pointed out by Dr. Dehmer, the SC is awaiting guidance from the new administration.

In response to the FESAC committee questions, Dr. Dehmer indicated that the transition team she met with gave no feedback but reports to the central transition team. However, they were interested to know how the SC programs affect the energy needs and the environment.

Dr. Dehmer mentioned that fusion fits in perfectly within the structure of SC. She noted that the fusion program is not yet in transition from fundamental science to energy production. While both are important, there will be no abandoning of the fundamental fusion science. In response to a question regarding the fiscal struggles of the fusion program as it moves toward ITER, Dr. Dehmer mentioned that the program is bound by the reality of funding and faces challenges similar to other programs within SC. She noted that other areas of science are also heading toward large science. She pointed out that the fusion program should map the path from its present state to being on the grid in the future.

Dr. Dehmer was asked about the view of the transition team on the balance between short term and long term research goals. She stated that short term goals can indeed cannibalize longer term goals. The senior managers have to make sure that this does not happen and that long term goals are sustained.

In response to another question, Dr. Dehmer indicated that the the six offices under SC have interfaces between them and the managing of these interfaces is a challenge.

Dr. Eckstrand

Dr. Nardella has completed his term, and Dr. Eckstrand has been named as the next acting Associate Director. Dr. Eckstrand covered topics that have changed since the last FESAC meeting.

1. A list of the OFES solicitation status and schedules was presented. Dr. Eckstrand noted that the deadline for the Plasma Science Centers has been changed to February 18, 2009.
2. OFES is considering upgrades to NSTX.
3. The ITER council met in Cadarache, France, during November 19-20, 2008, and has set a goal for the ITER Organization to deliver a baseline proposal by November 2009. There are no conclusions on cost but the council made recommendations to the organization to lay the foundation for a credible estimate. A major design change is the addition of magnet coils to control edge localized mode instabilities.
4. Among the various strategic planning activities are the June ReNeW workshop on MFES, a HEDLP workshop planned for August 2009, and a workshop on fusion/fission hybrids during fall 2009.
5. Dr. Eckstrand cannot discuss the Strategic Plan Overview until after Congress gets it on March 1, 2009. Prior comments by the FESAC panel members have validated findings of the OFES. One important point that is realized by all is that ITER is not going to address all the issues related to the fusion power plant. The Strategic Plan Overview will set the path from where the program is at present to where it will be in the future.

What drove the fission/fusion hybrid program? Dr. Eckstrand responded that the activity was motivated by the work being done in Texas, by an APS-DPP presentation, and other such presentations and publications.

Will the fission/fusion hybrid program include inertial confinement fusion? The answer; "Probably, yes." Dr. Eckstrand mentioned that this has not yet been determined since it will involve a number of other departments like NNSA, fusion waste, etc.

When asked about the three workshops, Dr. Eckstrand pointed out that the HEDLP workshop is likely to be similar to the ReNeW workshop while the structure of the fis-

sion/fusion hybrid workshop is not yet clear. The initial stage is to determine if there is something to the fission/fusion hybrid program that can be pursued on a longer time scale.

Dr. Betti

On behalf of the FESAC HEDLP subpanel, Dr. Betti, the chair of the subpanel, reported on advancing the science of high energy density laboratory plasmas. The subpanel report was in response to a charge by Dr. Orbach, Under Secretary for Science, and Mr. D'Agostino, Under Secretary for Nuclear Security, that, in part, stated: "FESAC should identify the scientific opportunities for a proposed HEDLP program that is exciting, challenging, and puts the United States in the position of a world leader in this field of research."

Dr. Betti summarized some of the important points in the report dealing with fundamental science and with energy related science. The subpanel determined areas of fundamental HEDLP science that offer interesting research opportunities. The subpanel pointed out that fundamental science, by its very nature, cannot be prioritized. The list of aspects of fundamental science is more of an assessment since all issues are interesting. For energy related HEDLP, the subpanel identified issues into three categories – high, medium, and low priorities.

Since the detailed subpanel report is readily available, these minutes will not include any additional mention of the presentation by Dr. Betti.

The FESAC panel members generally complimented Dr. Betti and the members of the subpanel for the comprehensive report which answered all aspects of the charge assigned to the subpanel.

It was mentioned by a panelist that since HEDLP is a joint program between NNSA and SC, some topics may become so interesting that NNSA may want to classify them. How do these programs work through that boundary? In response, it was pointed out that an attempt is being made to resolve such issues.

As an example, a panelist asked, if NIF were to announce ignition, would the relevant parameters be available so that the scientific community can analyze the results? The answer was in affirmative.

What about international programs? Should US work in partnership with other countries and try to answer questions through integration? Dr. Betti noted that the subpanel is well aware of the international programs but did not include them in the report as it would just make the list longer. Furthermore, in most aspects US is in a lead position so there would be less to gain through international collaboration. However, in ultra intense short pulse laser there are international facilities where collaborative experiments are being carried out.

In response to additional discussions, Dr. Betti mentioned that upgrades to NIF are included in the report. Also, one could compare results from short pulse fast ignition

experiments from various experiments.

In response to a question about the relation between the present report and a prior FESAC report on IFE, Dr. Betti noted that the present charge was different. The present report is very specific about HEDLP physics while the original report covered a much broader ground. Also, the present report was specific to a joint program between NNSA and SC.

A member mentioned that the report did not discuss the technology program. One would need a robust technology program to carry out the desired experiments, particularly for IFE, but there was no comprehensive discussion of this aspect. Dr. Betti noted that the IFE technology is usually related to the driver technology and the target technology. Issues of technology are addressed in Phase 2 of the program. Since the charge did not mention technology, the subpanel has been hesitant to discuss technology in phase 3.

From a committee member: what is the leap from the present status to where we need to be – for example, the repetition rate, and materials? Dr. Betti noted that these issues are not in the report since they are outside the charge.

From a committee member: How do you relate your program to others – like reconnection, dynamos, etc.? Dr. Betti pointed out that addressing HEDLP issues has just started. So the physics is not well understood to make connections to other fields.

Several committee members felt that executive summary should include a line on technology developments even though it is outside the charge. Dr. Betti considered that to be a good point and agreed to include such a statement.

Dr. Hazeltine

The status of the ReNeW project was reviewed. It was pointed out that everybody associated with this project will have to be familiar with three documents:

- the Greenwald report (priorities, gaps and opportunities panel);
- the TAP report (toroidal alternates panel chaired by David Hill);
- and the EPAct report (task group of the US BPO).

The framework of the ReNeW plan is to set about 15 scientific and technical initiatives that are intended to be basis for detailed program plan to be constructed by OFES. The aim is not to try to repeat previous studies. Rather than have its output presumed, ReNeW would like to have a say in the OFES Overview Strategic Plan. Otherwise, the hard work of ReNeW would not be fully worthwhile.

The final ReNeW workshop will be from June 7 through June 13, 2009, and the final report will be submitted on July 17, 2009.

The objective of ReNeW is to provide scientific and technical input to OFES in order to develop a domestic fusion research plan in the ITER era. It also intends to introduce the fusion program to the new federal administration.

In response to a question about foreign participation, Dr. Hazeltine mentioned that they are interested in having foreigners participate. However, their own domestic plans will not be included in the ReNeW plans. Dr. Zarnstorff pointed out that white papers will be accepted from “everybody.”

It was pointed out by a committee member that the burning plasma issues were not included in the Greenwald report, even though a substantial part of the report deals with burning plasmas after ITER. Dr. Hazeltine noted that one of the ReNeW themes is “Burning plasma in ITER.” It is important for ITER to succeed and ReNeW does not exclude other burning plasma issues.

Discussion on the HEDLP subpanel report led by Dr. Betti

Dr. Betti discussed about modifications to the report following comments by the FESAC committee members. He noted that some Phase 3 recommendations were a bit vagues and will be made more specific. He also noted that a mention of international collaboration relevant to short pulse programs will be indicated.

The HEDLP report was unanimously approved/endorsed by the committee.

Dr. Betti displayed the cover letter which will go along with the report. The letter will state that FESAC voted unanimously to endorse the comprehensive report. Minor changes to the letter were recommended by some committee members.

Dr. Betti indicated that he will circulate the final version of the report within a week to the committee members.

Dr. Tillack and Dr. Whelan

Dr. Tillack started off this joint presentation by discussing the ARIES pathways study that began in 2007 to evaluate the R&D needs and gaps for fusion from ITER to Demo. Given these goals, the study examined a methodology that is widely recognized and utilized outside the fusion community. An active communication has been established with OFES, TOFE, FPA, ANS news, IHHFC, ReNeW, and FESAC, and their feedback has been incorporated in the study.

The use of technical readiness levels (TRL) in planning a program was first developed by NASA. The ARIES study relied on studies from the aerospace industry for evaluating R&D needs. TRLs express increasing levels of integration and environmental relevance. There are nine levels of achievement where the final level is the actual system proven through successful mission operations. The use of TRLs was encouraged by DoE and the

GAO.

An example of TRLs for light water reactor spent fuel processing was mentioned. It was noted that presently this particular R&D is at level 5 – the mid-way point on the proof of principle part.

Dr. Whelan elaborated on the use of TRLs in the aerospace industry, using Boeing as an example. He noted that TRLs are a common language for understanding technology maturity, a common input for evaluating technology risk, and a common framework for understanding risk. TRLs are not product specifications, or a complete program management system, or a complete progress tracking system.

After Dr. Whelan's presentation, Dr. Tillack continued his presentation on the application of TRL methodology to fusion energy. They used a five step systematic bottoms-up approach – the first step is to identify customer needs, and the last is to evaluate status, gaps, R&D facilities and pathways. The study came up with 12 top level issues. Some of these issues are common with those identified by the Greenwald panel which had 15 top level issues. The TRL methodology was tried on issues identified in the Greenwald report and was found to work on some of them.

The study found that the ITER program contributes in some areas, e.g., issues related to plasma and safety, and very little in others, e.g., reactor relevant technologies.

A committee member noted complemented Dr. Tillack and pointed out that such a study is exactly what is needed. There is a big gap between what is being done in fusion at present and where the program needs to be. Such a study is important for CTF.

Another committee member found the study interesting and wondered if TRLs were suitable for everything within the fusion program since there are differences with the Greenwald panel report. Dr. Tillack responded that materials science, as an example, may not be suitably addressed by TRLs. Dr. Whelan noted that, however, there is a metrics for checking progress.

A committee member wondered if the TRLs gave any surprises that may not have been in the Greenwald report. Dr. Tillack responded that they have not done that. Moreover the ARIES study was conducted before the Greenwald panel completed their work.

A committee member noted that, as an example, in going from step 3 to step 4 could be determined. Can one find a pathway from step 3 to step 7? The response was that it is very difficult to project the pathway from one step to another which is several steps down. This delves into the realm of risk analysis. Dr. Whelan noted that it require discipline to determine how to go several steps in TRLs – time and cost have to be worked out carefully. He noted that one could use a roadmap as another part of the strategy to complement TRLs.

Dr. René Raffray

The ARIES program organizes town meetings and workshops to provide a forum for discussions between scientists from R&D programs and power plant studies. The International High Heat Flux Components (HHFC) workshop held in December 2008 was a forum to discuss design concepts for plasma facing components for power plants, in particular, divertors. The workshop discussed five areas of interest in five different sessions. All the details of the workshop will be provided in a report/publication.

There was an extensive discussion of the ITER divertor and what is needed for a reactor. The ITER divertor is based on non-reactor relevant materials, coolant, and operating conditions. The divertor loads in a DEMO will have to be able to handle 10 MW/m² in steady state and 20 MW/m² transiently. The power plant divertor design load is much more limited than for ITER. It has to operate at higher temperatures which reduces the margin on the design. Avoidance or mitigation of off-normal events, like disruptions, vertical displacement events, and ELMs, is a key requirement for power plant applications.

A committee member asked if ITER could use segmented divertor? Dr. Raffray indicated that this question has been posed to ITER personnel. It turns out that there are a lot of interface issues that make it very complex to incorporate a segmented divertor. The committee member noted that this could be tried in JT-60.

Public comments

There were two public comments.

The first was by Dr. Wayne Meier with respect to the Research Needs Workshops (ReNeW). He was well aware of the focus of the OFES on science and in particular plasma science, especially over the past 10 years. However, the MFE ReNeW planned for June 2009 includes a theme called Harnessing Fusion Power. Dr. Meier is the chair for that theme and is very pleased that the gaps on the way to an MFE demonstration power plant are part of that workshop. He noted that, from an earlier presentation by Dr. Eckstrand, there will be two additional workshops this year; one on HEDLP and one on fusion-fission hybrids. He would like to suggest that FESAC recommend OFES to include consideration of the gaps on the path to an inertial fusion energy (IFE) demo in the HEDLP workshop and not just consideration of HED or IFE-related science. Dr. Meier mentioned that the fusion-fission workshop will include consideration of both MFE and IFE based concepts. He felt that this workshop will almost certainly include technology aspects related to the fission blanket, fuel cycles, and the fusion systems in an integrated hybrid plant. To be consistent with and provide comparable information as the MFE ReNeW, he thought that it was very important that the HEDLP ReNeW include an evaluation of research needs on the way to an IFE demo.

The second public comment was by Dr. Richard Majeski. He indicated that liquid metal plasma facing components (PFC) may provide a wall solution for DEMO and beyond. Liquid PFCs could provide considerable reactor design freedom compared to solid materials. Even though the liquid metal PFCs require significant development, such com-

ponents may shorten the qualification cycle for reactor walls. The near-term US effort is small and focused on the thin-film approach. He felt that more emphasis should be placed on alternates (to the tokamak) to help speed the development of fusion power. Small and medium scale devices could study, for example, lithium walls and super-X divertor with strong pumping. Charge exchange losses do not dominate a small plasma with low recycling walls. A small non-recycling tokamak has virtually no edge. Dr. Majeski noted that a few small to medium scale tokamak experiments can effectively, and rapidly, do exploratory studies.

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2008-2010**

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Attendance at FESAC
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