Summary of

A Forum on the Future of Fusion Energy and Plasma Science Research in the U.S.

Sponsored by the University Fusion Association (UFA)

A two-day forum on the Future of Fusion Energy and Plasma Science Research in the U.S. was held Dec. 14-15, 2015 on the University of Maryland-College Park campus. A remarkable degree of agreement was reached on the issues and approaches discussed for a strong and vibrant fusion and plasma science research community in the U.S – including the need for prompt action to address challenges to our University programs and many of the elements needed for a broadly-based and systematic approach to strategic research planning for fusion energy and plasma science. The Forum identified several follow-on activities that could help resolve critical issues for the success of fusion and plasma research in the U.S.

Background and workshop goals

The fusion and plasma science community has in recent years conducted comprehensive studies of research opportunities and needs for a broad spectrum of science and technology issues related to plasmas and fusion, but while these studies are generally well received, the outside world, including important policy makers, still does not perceive a consistent, cohesive vision coming from our community. As a consequence, the support for plasma and fusion science is constantly in jeopardy, despite the community's enthusiastic view of the vitality and importance of our science both now and in the future. The forum provided an opportunity for a broad segment of the research community to discuss key challenges and strategies needed to strengthen the position of fusion research and plasma science in the U.S. The need for this forum recognized that no recent or currently planned process would address the questions of the type that were discussed at the forum.

The forum was organized on two broad topics: (1) opportunities and requirements for nurturing the growth of fusion and plasma science in the academic environment and (2) means for developing a strategic plan for fusion and plasma science. Forty-eight scientists attended from the major segments of the research community: large laboratories, universities, privately funded research enterprises, and observers from federal funding agencies. The agenda (Appendix 1) included a plenary session on Monday morning that featured three invited speakers who helped set the stage for discussion, followed by breakout sessions on Monday afternoon and Tuesday morning, and closed with a plenary session on Tuesday afternoon with summaries from the breakout groups and discussion of follow-on activities. The forum website[1] includes links to the presentations in the plenary sessions. The plenary sessions were also streamed, with approximately 12 remote participants in total. While many of the questions posed in the breakout discussion are relevant both to fusion energy development and basic plasma science, scientists with active interest in magnetic fusion research dominated the attendance.

[1] https://sites.google.com/site/universityfusionassociation/forum

Opening plenary session

Prof. Gerald Navratil (Columbia U) was invited to help set the stage for discussion of the opportunities and requirements for nurturing the growth of fusion and plasma science research in the academic environment. Prof. Navratil has a long history in fusion plasma research having both local experiments at Columbia and collaborative research on major fusion facilities. He also served as Dean of Columbia's School of Engineering from 2007-2009. He reviewed the history of the federal-university partnership that is the basis for today's university research environment. Among the recommendations of the Bush report "Science–the Endless Frontier" in 1945 was that universities should be the principal sites to conduct basic research and the exclusive sites for graduate and post-graduate education. Typically, universities invest their own resources to recruit top researchers in any given sub-field, paying close attention to the anticipated support that will be available. In most DoE funded research areas, university researchers utilize national and international user facilities for much of their research. The national laboratories do not provide the majority of research personnel and scientific leadership for these facilities. The fusion program is distinctly different from other fields of research, given the adoption of a project-driven research model akin to that of NASA or the weapons program. This results in a relatively small number of university faculty and creates a disadvantage for fusion research in the intensely competitive academic environment. Prof. Navratil then summarized a stepwise erosion of fusion research at major research universities that has occurred since the major restructuring of the fusion program in 1990. He nevertheless emphasized that the situation is not hopeless, recommending a two-time-scale approach to first immediately "stop the bleeding" and then "start the healing" via 5-year strategic objectives.

Dr. Martin Greenwald (MIT) was invited to help set the stage for discussion of means for developing a strategic plan for fusion and plasma science. Dr. Greenwald is Deputy Director of MIT's Plasma Science and Fusion Center and has a long history in fusion research. He has provided important program leadership through his involvement in many research-planning exercises and served as chair of FESAC from 2008-13. Dr. Greenwald reviewed the history of research-planning exercises for the fusion energy sciences program but noted that strategic planning for the program is not seen as satisfactory. He outlined the general components of a strategic planning process and those parts the fusion and plasma science community does well, e.g., conveying scientific excitement and describing research needs. He also noted areas that tend not be done well, for example, assigning priorities and managing risk. He commented on how the community's recent strategic planning efforts have failed due to lack of a systematic approach and too great an emphasis on resource allocation, which is fundamentally an executive function. He advocated a systematic process that is transparent, involves active participation of all stakeholders, and avoids well-know cognitive biases. Citing examples from high energy and nuclear physics, their strategic planning processes have broad community participation and require 1.5 years or more to develop. He noted the importance of international research and ITER but emphasized the role of a strong domestic program with unique research facilities. Successful planning efforts provide many benefits: strong and bold advocacy, a framework for decision making, a roadmap to advance our vision, and a vehicle for reaching and documenting community consensus.

Dr. Michael Knotek, the former Deputy Under Secretary for Science and Energy, DoE , was invited to give his perspectives on the state of the U.S. fusion energy sciences program. One of

his main points of emphasis was the need for effective governance, citing examples from other communities and his own experience in leading scientific program change. In his view, there is a lack of effective governance in the fusion energy sciences program, and this compounds the challenges associated with ITER in particular. He offered a frank assessment of the status and nature of the ITER project, but he emphasized that the fusion community must accept liability for its direction and the need to provide leadership for its success. At the same time, he emphasized that the program must effectively articulate its research aims in addition to ITER, including dimensions other than fusion energy, e.g., plasma science and technology. An effective governance process is essential to deal with this complexity and allow the program to react and evolve. When asked for specific examples of effective governance, he outlined several general characteristics: an accepted decision making process vis-à-vis scientific goals and priorities, broad community involvement, agreement on purpose and deliverables, truthfulness with respect to the state of the science, and cooperation between the community and DoE via FESAC, given the legal ramifications associated with the Federal Advisory Committee Act (FACA). In reference to larger experiments, Knotek noted that "facilities do not set scientific priorities". Instead, community governance processes should set scientific priorities. He offered his opinion that major budget relief for the fusion energy sciences program is not likely in the near future and that the community needs to take advantage of available opportunities, stressing predictive modeling utilizing the DOE strengths in high performance computing, and the fleet of national and international facilities (ITER included) as examples.

Breakout sessions

The forum Steering Committee divided the attendance into three groups, each with 16 members (Appendix 2). These groups were charged to discuss the two broad topics with the guidelines shown in Appendix 1 and report their discussions in the closing plenary session. The distribution of membership in the three groups was balanced for representation by institution type (large lab, university, privately funded enterprise, and federal agency), and attendees from the same institution were assigned to different groups. Each group had a designated discussion leader and a scribe who were charged to moderate and summarize the discussion. For the breakout session on Monday, each group was charged to spend equal time on topics related to the two broad questions. This ensured that all attendees were allowed the opportunity to engage in and hear their colleagues' thoughts on all topics. In the Tuesday morning breakout, attendees were given the opportunity to make short presentations within their breakout group. Hence, the discussion on Tuesday was guided by these presentations and previous discussions during the breakout sessions on Monday.

While consensus was not an explicit goal for the forum, the reports from the three breakout groups were remarkably similar. This is a significant outcome of the forum's discussion. Below are bulleted statements that capture key conclusions from the breakout discussions:

- A healthy plasma and fusion science program must have strong university programs that involve experiments, theory, and computation
- Unlike some fields, world-class research programs in fusion and plasma physics can be carried out in small to medium-scale experimental facilities located at universities
- Student training (workforce development) is a strong benefit but not the primary motivation for university research, which is instead frontier science and innovation

- University faculty need local, on-campus research efforts, but this does not always have to be centered on a local facility
- A combination of local and off-site activities is powerful and stimulates useful synergies
- Multilateral collaborations between university-located research and large labs should be pursued
- Scientific leadership opportunities in frontier-class research are essential for the viability and growth of fusion and plasma science faculty hires
- University programs are relatively fragile due to the long time constant for developing and maintaining faculty slots, lab space, and infrastructure
- Our national fusion facilities already involve university researchers but a better model and process is needed to support faculty leadership for off-site-focused research programs
- Models for user facilities used by other communities could be viable but work best if they are in place at the start of large programs, not implemented midstream; we need a better understanding of how other communities deal with this issue
- Funded "missions" or "campaigns" on important science topics that are linked to multiple facilities, theory and computation is one possible approach
- Validation and material science offer possible growth areas, given DoE emphasis on high performance computing and leveraging with BES
- Stewardship of all of plasma and fusion science by a single federal agency is challenging and may be limiting the scope of our research program; we should nurture growth in multiple agencies and learn how this is done in other communities
- The fusion program needs a community-engaged strategic planning process that includes ITER plus a vision for other compelling program components
- Partnership with DoE is key to developing strategic planning and should be mediated through FESAC
- Strategic planning should not be "one off" but rather continual, as done for P5 and HEPAP, for example, allowing the program to adapt to evolving needs in fusion and plasma science
- Strategic planning should engage younger researchers to help develop future leadership
- U.S. contributions to ITER should not be a barrier to progress
- The development of predictive capability is essential to ITER's success
- The U.S. should prepare for modes of participation in ITER research; we should be a leader in developing this common need for the world fusion effort

Suggested follow-on activities

1. Complete a report on the UFA Round Table, documenting the situation in university research and conveying the boundary conditions for the academic environment. This might include additional data, e.g., faculty demographics
2. Immediately establish a working group to develop an approach to addressing the crisis in university fusion research
3. Initiate a dialog with the NRC panel on coordinating UFA and other group-led planning and/or forums that link research strategies to the broad practice of plasma science
4. Initiate a dialog with DoE on strategic planning that is adaptive to changing circumstances
5. Develop a community-wide, systematic approach to strategic planning with a scientific roadmap for fusion and plasma science, i.e., a Snowmass-like process; this could be part of the NRC Decadal Study process

6. Collect information and best practices on strategic planning in various fields of science
7. Collect information on modes of university participation on user facilities in various fields of science

Forum organization

Steering Committee:
Brett Chapman (UW-Madison)
Martin Greenwald (MIT)
Michael Mauel (Columbia U)
Dave Maurer (Auburn U)
John Sarff (UW-Madison), Chair
Uri Shumlak (U Washington)

Breakout Discussion Leaders:
Troy Carter (UCLA), Group 1
François Waelbroeck (U Texas), Group 2
Anne White (MIT), Group 3

Local Organizers (U Maryland):
William Dorland
Adil Hassam
Matthew Landreman

Appendix 1

A Forum on the Future of Fusion Energy and Plasma Science Research in the U.S.
December 14-15, 2015

Sponsored by the University Fusion Association (UFA)
Hosted by the University of Maryland-College Park

Agenda

Monday, Dec 14
Plenary Session (Chair, Uri Shumlak)
8:30 AM Welcome and Introduction, John Sarff, University of Wisconsin-Madison
9:00 AM Overview 1, Gerald Navratil, Columbia University
"Nurturing Research in the Academic Environment: Federal-University Partnership"
10:00 AM Coffee Break
10:15 AM Overview 2, Martin Greenwald, M.I.T.
"Community Planning For Fusion Energy and Plasma Science: The Good, the Bad, and the Ugly"
11:00 AM Overview 3, Michael Knotek, Former Deputy Under Secretary for Science and Energy, US DoE

12:00 – 1:30 PM Lunch

Parallel Breakout Session #1 (see group membership assignments)
1:30 – 3:30 PM (2 Hours)
3:30 – 3:45 PM Coffee Break
3:45 – 6:00 PM (2 1/4 Hours)

Tuesday, Dec. 15
Parallel Breakout Session #2
8:30 – 10:00 AM (1 1/2 Hours)
Opportunity for contributed presentations (2-3 slides, 5 minutes)
10:00 – 10:15 AM Coffee Break
10:15 – 12:00 PM (1 3/4 Hours)

12:00 – 1:30 PM Lunch

Plenary Session (Chair, John Sarff)
1:30 PM Reports from breakout groups
3:00 PM Discussion and organization of follow-on activities

4:00 PM Forum ends

Guidelines for Breakout Group Discussions

Each breakout group will engage the two broad topics and several subtopics listed below:

1. Opportunities and requirements for nurturing the growth of fusion and plasma science research in the academic environment
   A. Role of experiments located on campus
   B. Model(s) for university leadership on shared user facilities for fusion and plasma science
   C. Growing the stewardship of plasma science in the federal complex

2. Means for developing a strategic plan for fusion and plasma science
   A. Developing and nurturing a strategic plan
   B. Impact of delayed ITER

Each group has a Discussion Leader and a Scribe. The Discussion Leaders will manage the Monday afternoon breakout sessions such that equal time is devoted to the two broad topics. Thus, all participants will have an opportunity to share their points of view and engage their colleagues' points of view on both topics.

On Tuesday morning, participants will be able to make short presentations within their breakout groups (2-3 slides, 5 minute). We strongly encourage participants to align their presentations with the discussions that occur Monday afternoon. Hence, the discussions Tuesday morning will be guided by the ideas that evolve within each breakout group separately.

The Discussion Leaders and Scribes will prepare short summaries of their breakout discussions to be presented in the plenary session Tuesday afternoon.

Anticipated outcome: The ultimate goal of the effort being initiated by this forum is the development of a comprehensive vision and plan that strengthens the future of fusion energy and plasma science research with broad support by the community, policy makers, and funding agencies. While complete answers to key questions are beyond the scope of a two-day meeting, the forum will promote discussion on the challenges and future research that is not likely to occur in current and anticipated planning activities. Specifically for this meeting we aim to identify:

a) Areas and issues with broad agreement
b) Issues for which there is a significant divergence in viewpoints
c) Issues where follow-on effort can provide the additional information needed to continue the discussion
d) Ideas for further deliberation, aiming toward consensus on open issues

Questions to Guide Discussion

To help stimulate and focus the dialog, a number of questions related to the topics above are recommended as starting points for discussions. These sets of questions are listed below. Other questions may be raised, but each group should manage the time available such that all of the topics listed above are covered in the Monday sessions.

1. Opportunities and requirements for nurturing the growth of fusion and plasma science research in the academic environment

   A. Role of experiments located on campus
      - ***i. Can experimental plasma physics and fusion sustain their presence at universities without local experiments? i.e. can it generate and maintain faculty positions and significant student engagement?***
      - ***ii. What are the unique advantages of university-based experiments and what has their role been historically?***
      - ***iii. What are the advantages of facilities at the national labs?***
      - ***iv. What is the appropriate scale(s) for each venue?***
      - v. ***What about computational plasma physics? Do similar arguments apply?***

   B. Model(s) for university leadership on shared user facilities for fusion and plasma science
      - ***i. What models for university participation and university leadership in large scientific endeavors are there? (e.g., large telescopes and observatories, space probes, light/particle sources, accelerators …)***
      - ***ii. What governance models are used?***
      - ***iii. How does (or should) research on plasma physics and fusion map onto these models? What is similar and different?***
      - ***iv. Are there models within the Office of Science complex relevant to fusion?***
      - ***v. Will this be feasible for U.S. participation on ITER?***
      - ***vi. Who should we talk to find out more?***

   C. Growing the stewardship of plasma science in the federal complex
      - ***i. What is working or not working about the current model?***
      - ***ii. How can we establish a broader base for plasma science within the U.S. government? Which Agencies are appropriate?***
      - *iii*. ***How would this come about?***

2. Means for developing a strategic plan for fusion and plasma science
   A. Developing and nurturing a strategic plan
      - ***i. What are the essential elements of a strategic plan for a science program?***
      - ***ii. Are there special features or issues particular to plasma and fusion science?***
        - ***Can we employ an "industry-standard" logical and stepwise process for developing such plans?***
        - ***What processes have other science communities used for their plans?***

- *What has worked or been difficult?*

iii. ***What are the strengths and weaknesses of the FESAC plan?***

B. Impact of delayed ITER

i. ***ITER has been the centerpiece of our future planning for more than 20 years***
ii. ***Given the current schedule and uncertainties, how do we maintain the overall health of the program?***
iii. ***What types of new activities should we be pursuing?***
iv. ***In addition to efforts already planned, what can the U.S. community do to hasten ITER's progress?***
v. ***How should we plan for ITER operations?***
vi. ***What should be our contingency plan in case U.S. participation in ITER is terminated?***

Appendix 2

Attendees and Breakout Groups

Group 1	Group 2	Group 3
Troy Carter (UCLA), Discussion Leader	François Waelbroeck (U Texas), Discussion Leader	Anne White (MIT), Discussion Leader
Brett Chapman (U Wisconsin), Scribe	David Maurer (Auburn U), Scribe	Martin Greenwald (MIT), Scribe
Dylan Brennan (Princeton U)	John Canik (ORNL)	Sarah Castro (U Washington)
Michael Brown (Swarthmore)	Julie Groeninger (Princeton U)	Michael Delage (General Fusion)
Richard Buttery (General Atomics)	Richard Hawryluk (PPPL)	David Ennis (Auburn U)
Sean Finnegan (DoE)	David Hill (General Atomics)	Charles Greenfield (General Atomics)
Chris Hansen (U Washington)	Chris Holland (UCSD)	Mark Haynes (Concordia Power)
Adil Hassam (U Maryland)	George McKee (U Wisconsin)	Matthew Landreman (U Maryland)
Thomas Jarboe (U Washington)	Bob Mumgaard (MIT)	Jeffrey Levesque (Columbia U)
Catherine Johnson (U Wisconsin)	Gerald Navratil (Columbia U)	Richard Majeski (PPPL)
Mike Knotek (retired)	Hutch Neilson (PPPL)	Joshua Reusch (U Wisconsin)
Michel Laberge (General Fusion)	Nirmol Podder (DoE)	Ned Sauthoff (ORNL)
Earl Marmar (MIT)	David Ruzic (U Illinois-UC)	Uri Shumlak (U Washington)
Michael Mauel (Columbia U)	John Sarff (U Wisconsin)	Ryan Umstattd (ARPA-E)
Jon Menard (PPPL)	Fred Skiff (U Iowa)	James Van Dam (DoE)
Stewart Prager (PPPL)	Derek Sutherland (U Washington)	Michael Zarnstroff (PPPL)