

Columbia University in the City of New York | New York, N.Y. 10027

DEPARTMENT OF APPLIED PHYSICS AND APPLIED MATHEMATICS Seeley W. Mudd Building
TEL (212)854-4457, FAX (212)854-8257 500 West 120th Street

14 March 2000

Dr. Robert J. Goldston, Director
Princeton Plasma Physics Laboratory
P. O. Box 451
Princeton, NJ 08543

Subject: Report of the 8th NSTX Program Advisory
Committee Meeting – March 2000

Dear Rob:

The NSTX Program Advisory Committee (PAC) met at the Princeton Plasma Physics Laboratory on 2-3 March 2000 (agenda attached). In addition to receiving a status report on the NSTX Program and NSTX Project Physics, our activities at this eighth meeting of the PAC focused on three areas in response to your charge to the committee (copy attached): (1) the capability of the NSTX research plan to contribute to the completion of the near term FESAC goals; (2) an assessment of the process to strengthen and to plan research by the NSTX National Team; and (3) an assessment of the plans to prepare for the transition from the FY00 to the FY01 research program.

Status of NSTX Project

The NSTX Program has achieved a key milestone of ohmic operation at the 1 MA current level well ahead of schedule. We congratulate the NSTX National Research Team for their success and recognize the hard work and dedication that was required to achieve this important result.

The committee also notes that substantial progress has been made towards the plasma & facility goals for the Inductive Phase of the Research Program

(Phase I). This includes reaching the 1 MA ohmic current goal, producing 130 kA of CHI toroidal current, and delivering 2 MW of HHFW power to the plasma. NSTX is now well positioned to move into the Noninductive Assisted Research Phase (Phase II) which includes the installation of Neutral Beam Injection.

We received reports from the Task Force Leaders describing results of the 1999 experimental run period as well as reports on the physics modeling progress on the few remaining open issues which were raised at our previous meetings. Our comments and/or questions on these are briefly summarized below:

Bakeout and Vacuum Conditioning: The Project reported that heated helium gas could be used to provide 350 °C bake-out temperature to the passive structure and its PFC carbon tiles instead of the Dowtherm fluid which was abandoned due to a flammability concern. This appears to be a good solution and we encourage its implementation by the time NBI experiments are begun on NSTX.

Diagnostic Plans: The committee is pleased to note that the Project is now planning to include a set of saddle loops for locked mode detection on NSTX and an EBW emission diagnostic to provide additional T_e information, as recommended at our previous meeting from among the list of high priority areas for FY00 if additional resources became available.

Neutral Beam Injection and Fast Ion Losses: Addressing a concern raised in several of our previous meetings, the project reported that modeling of bulk ion losses in high beta, $q_0 > 2$ equilibria shows the losses to be quite small. The project also reported that it is continuing to follow up on our concern that there may be serious fast ion losses in $q_0 > 2$ equilibria. Further studies are planned on variation of the NBI angle to optimize hot ion confinement.

HHFW and CHI Insulator Issues: The Project reported BN insulator material has been added to the HHFW antenna and the surfaces on the existing BN insulators on the HHFW antenna have been examined for carbon deposition as recommended in our previous report. Problems were reported with the CHI insulators due to arcing during experimental operation. A new insulating

plate will be installed together with external circuit changes in an attempt to reduce this problem.

MSE Issues: The status and plans for the installation of an MSE diagnostic on NSTX were reported to the committee. Since analysis of the data from the MSE system relies on knowledge of the poloidal plasma flow, we recommend the Project explore the measurement sensitivity expected from the uncertainties in the poloidal flow estimates, and develop contingency plans as needed if this sensitivity is too low.

ECH/EBW Start-up: Because the development of non-inductive start-up techniques is one of the critical issues for development of the ST concept, we have previously encouraged the NSTX Project to explore alternative methods of non-inductive start-up. We were pleased to learn that the Project has decided to explore EBW/ECH as an alternate non-inductive start-up method as recommended at our previous meeting from among the list of high priority areas for FY00 if additional resources became available.

NSTX Research Plan and FESAC Near-Term Goals

In the FESAC Panel Report on Priorities and Balance from the August 1999 Knoxville meeting, four goals for Magnetic Fusion Energy research are established:

- 1) Advance fundamental understanding of plasma...
- 2) Resolve outstanding scientific issues and establish reduced cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic confinement configurations.
- 3) Advance understanding and innovation in high-performance plasmas...
- 4) Develop enabling technologies to advance fusion science...

While the NSTX research program will be able to make important contributions to each of these goals, the primary contribution of NSTX to the Fusion Energy Sciences program is in the area of Goal 2. Under this goal the FESAC/Knoxville report sets out specific 5, 10, and 15 year milestones which

in the near term call for the US fusion program to make a preliminary determination of the attractiveness of the ST in 5 years and assess potential of the ST for sustained long pulse operation in 10 years. Since the NSTX research plan developed over the past several years by the NSTX Program is based on developing the physics base to achieve these goals, the NSTX research program is quite naturally well directed to making a major contribution to achieving the FESAC/Knoxville goals specific to ST development and assessment.

The NSTX Program has taken the present research plan for NSTX and recast it to make very explicit the contributions made by this program to the detailed FESAC/Knoxville milestones which have been established for each of the four MFE goals. Some comments on this recharacterization of the NSTX program are summarized below:

Program Breadth: Because the FESAC/Knoxville goals are quite broad, encompassing the entire Fusion Energy Sciences program in MFE, and since NSTX has the capability to make important contributions supporting all four MFE goals, the recast NSTX program appears to also be quite broad. It is very important that the NSTX Program maintain a clear focus and maintain the highest priority on its primary role in support of goal 2 in establishing the physics basis of the ST concept. The advice of this committee from our earliest meeting in 1996 has strongly and consistently urged that “...the physics program effort be tightly focused on pursuing the physics areas which are unique to the ST [PAC1 Report 11/96].”

Goal 4 - Enabling Technology: NSTX has a very full plate of critical ST enabling technologies to develop including reliable CHI, center post technology, non-inductive start-up, and non-inductive sustainment. Development of these technologies are the primary contribution of NSTX to the FESAC/Knoxville Goal 4 and should be clearly recognized. While a ‘watching brief’ on concept exploration class enabling technologies (*e.g.* liquid lithium plasma facing components) is always appropriate, it is premature to modify present research planning to include tests of these ideas on NSTX.

Activity in Support of the ST PoP Program: In laying out the set of NSTX scientific milestones, it is important to recognize that NSTX is part of a national Proof of Principle program to develop the ST concept. In particular, there are activities on concept exploration class devices, in the Advanced Tokamak program, and in the theory and modeling program which relate directly to important scientific issues in NSTX. Advances made in these other activities can be expected to contribute to reaching the primary NSTX goal of establishing the physics base of the ST concept. In the areas where these other activities have made or are being expected to make a contribution, this should be noted in the detailed NSTX scientific plan.

NSTX National Research Team

You have asked us to provide advice on the process to strengthen the NSTX National Research Team and on the research planning process used by the National Research Team. In addressing this area of the charge, it is important to note that the NSTX National Team has come together last year as an effective research group which successfully integrated the effort of 14 collaborating institutions with scientists from PPPL to formulate a detailed research plan, to execute the initial experiments on NSTX, and to achieve the critical milestone of 1 MA operation well ahead of schedule. In its first full year of activity the NSTX National Research Team has demonstrated through its actions and its success that it is already a highly effective research group. Our suggestions are made to further strengthen the National Team as it moves from completing the task of initial operation the broader challenges of achieving the Phase II goals on Non-Inductive Assisted Operation and high power NBI and HHFW heating.

Process to Strengthen the National Research Team: The initial members of the NSTX National Research Team are typically funded for 3 years by the DOE and that funding will be up for renewal in FY02. While it is essential to maintain the opportunity for new participants to be added to the NSTX National Team, we are concerned that a plan which is based on a single competitive panel review of 100% of the NSTX Team in FY01 would likely be highly disruptive to the research program. We recommend that NSTX and the PPPL Host organization work with the DOE to develop a process of “rolling reviews” with an annual opportunity for new participants to

compete. This process should begin shortly after the start of the fiscal year with the objective of putting funding in place by beginning of the next fiscal year. We endorse the model used in the solicitation of the initial National team members in 1998, and a majority (but not all) of the committee supports continuing the role of the PAC established in that 1998 process by providing advice to the NSTX Project based on a review of the Letters of interest from renewal and new prospective participants in the NSTX National Team.

Research Planning Process: To aid us in providing assessments and recommendations in this area the committee met privately for about 1 hour each with two groups of NSTX National Team members: one group consisting of non-PPPL team members and the other group consisting of PPPL team members. Project and Program Directors, Masa Ono and Martin Peng, voluntarily excused themselves from these meetings to insure maximal “candor” on the part of the team members. The focus of the committee discussions with these two groups of team members was to understand their views on the effectiveness of the NSTX National Team and solicit suggestions for improvements in research planning and execution and team organization.

The information obtained from both groups was highly consistent and verified our impression that the NSTX National Team was working very well as a “team” with no distinctions being made between PPPL and non-PPPL team members in carrying out scientific work or as participants in research planning. It was further reported that it was relatively easy for an on-site team member to integrate into the host institution PPPL “culture” and that being an on-site team member makes you more effective in getting ideas and proposals considered and implemented. Since most on-site team members have off-site colleagues at their home institution who also participate in NSTX research, having an on-site participant is clearly aids the home institution effective overall interaction as part of the NSTX National Team.

Both groups also reported that the Experimental Proposal (XP) review and approval system which was established for the 1999 experimental run worked very well and proved to be relatively efficient and useful in practice. Based on this input we recommend the XP process be continued, and any major changes be considered carefully in light of the success of the present system.

While it was clear that the team members are pleased with the way the National team is working, proud of the success they have enjoyed so far, and enthusiastic for the moving on to the next phase in the research program, there were a few suggestions for improvement which emerged which we wish to pass on for your consideration. These are summarized below:

- When the Team was established, DOE did not fund all equipment required by team member's proposals in an effort to maximize the number of Team members that could be supported. Some Team members may therefore lack essential equipment/diagnostics to accomplish goals set down in their original proposal. The NSTX Project should be aware if this situation occurs. Furthermore, if the Project funds this equipment directly, it is important that the affected team member(s) are fully integrated in the use of that equipment.
- The process for selection of paper submissions to major meetings (*e.g.* APS invited papers, IAEA papers, EPS papers) is not clear to Team members. It is very important for this process to be understood by Team members and perceived to be fair in allocating these key factors in professional development to all NSTX Team members.
- Team effectiveness could be improved with better and/or more efficient communication between Team members and between Team members and NSTX management. Two suggestions in this area are: have a very proactive facilitator as part of the NSTX management who makes sure that each member of the Team is informed of decision making activities that need their input or affect them in an important way (*i.e.*, nobody gets "left out of the loop") and (ii) reduce the number of perceived "management levels" by clear definition of the roles and responsibilities of each management position in the NSTX Project.

On final note is that the NSTX has done a good job in deploying remote collaboration equipment to allow off-site team members to participate in important daily, weekly, and annual meetings to discuss NSTX research results and plan the NSTX research program. We support the effort made so far and encourage the Project to continue to invest in and support this important element in sustaining a highly effective National Research Team.

Plans for Transition from FY00 to FY01

A description of the research plan for the FY01 experimental run was presented to us which was based on a 13 week base budget run plan and a 19 week incremental run plan. A set of scientific goals and milestones for the FY01 run period was presented based on the assumption of 19 weeks of experimental operation.

We support the allocation of run time resources for the 19 week plan presented, which can accomplish the FY01 scientific goals. However, accomplishment of the FY01 scientific goals cannot be achieved on the base budget 13 week run plan.

The Project should consider what scientific goals and milestones can be accomplished is only the base budget 13 weeks of experimental operation is available in FY01. We recommend that the priority for reduction of Ohmic Heating demand (V-sec) via CHI and HHFW should remain high, even under the base budget assumptions of 13 run weeks.

Under either the 13 week or 19 week experimental plan, we continue to support installation of the NBI on the planned schedule.

Next Meeting of the NSTX PAC

The next meeting of the NSTX PAC is expected to be in September 2000.

In closing, we again express our congratulations to the NSTX National Research Team for the excellent progress made in bringing the device to full ohmic operation well ahead of schedule and achieving the design basis current of 1 MA.

Sincerely yours,

Gerald A. Navratil, Chairman
for the NSTX Program
Advisory Committee

National Spherical Torus Experiment
Program Advisory Committee
8th Meeting

Agenda

Princeton Plasma Physics Laboratory
Conference Room LSB-318
March 2 - 3, 2000

Thursday, March 2, 2000

8:30 Coffee & Donuts
9:00 PAC Executive Session
9:30 Goldston Welcome
9:40 Willis/Priester Comments from DOE
9:50 Navratil Agenda
10:00 Peng Actions from PAC-7
10:10 Coffee Break

FY 2001 - 2002

10:20 Peng Proposed Research Program Scientific Milestones
11:00 Synakowski Research Priorities
11:40 Ono Proposed Facility Project Plan
12:20 Lunch

Completing FY-2000 Research

1:20 M. Bell Experiment Status, Plan and Issues
1:50 Sabbagh Ohmic Characterization Data and Interpretations
2:20 Raman CHI Data and Interpretations
2:50 Wilson Data and Plans for HHFW Experimental and Modeling
Studies
3:30 Cookie Break
3:40 Kaye Near-Term Issues for NSTX Physics
4:00 Sabbagh Status and Plans for Remote Scientific Collaboration
Capabilities

4:15 PAC Caucus
5:15 Navratil PAC Comments & Requests
5:30 Adjourn

6:30 PAC Party at the Goldstons'

Friday, March 3, 2000

8:30 Coffee & Donuts

9:00 Peng, Ono et al. NSTX Responses to PAC Comments & Requests

National Team Research Planning

10:00 Peng Process, Research Forum, Possible DOE Solicitation,
National Team

11:00 Coffee Break

11:15 PAC Caucus

12:00 Lunch

1:00 PAC Caucus

2:00 Navratil Briefing for PPPL Director (in Video Conference with
OFES)

3:00 Adjourn

Charge to the Eighth NSTX Program Advisory Committee Meeting, March 2-3, 2000

Recent FESAC Report on Opportunities and Balance has articulated overarching fusion energy science research goals, which include clear statements for the Spherical Torus proof of principle research during the next 5 years as well as over the longer term. The NSTX research and facility teams recently achieved major milestones in plasma current and are well underway in completing the research and facility goals for FY 2000, which aim to establish a fuller capability to address the FESAC goals. The NSTX Research Forum for FY 2000, held during January 31 - February 2, provided an update of research elements for FY 2001-2002, when full HHFW and NBI powers are scheduled to be available. As a major U.S. magnetic Fusion Facility capable of innovative confinement concept research, the national NSTX research and facility teams therefore must determine how the present research plan and projected capabilities of the national research team can effectively contribute to achieving the FESAC goals during the next 5 years.

I therefore ask the PAC to review and advise me on the following issues during the next meeting:

- 1) Are the proposed NSTX scientific (plain English) research milestones for FY 2000-2001 properly directed to contribute effectively to the FESAC 5-year objectives (see the FESAC report at http://www.foe.er.doe.gov/more_html/FESAC/Knoxville.pdf)? Are the necessary research tools and capabilities to achieve these milestones identified? Are the Phase-II research program and facility project plans, both baseline and incremental, optimal for achieving these milestones?
- 2) Is the process to strengthen the NSTX national research team effective in meeting the needs of the proposed research program? Is the process to plan the national team research appropriate?
- 3) To prepare for transition from FY 2000 to FY 2001 research, are the baseline and incremental plans for the following areas appropriate?
 - * Plans in Ohmic plasma and CHI experimental runs for completion of this FY
 - * Plans for HHFW experimental and modeling studies in FY 2000-2002
 - * Plans for NBI availability
 - * Plans for diagnostic enhancements
 - * Status and plans for remote scientific collaboration