FINAL DRAFT

30 May 1997

Dr. John Schmidt, Director
Princeton Plasma Physics Laboratory
P. O. Box 451
Princeton, NJ 08543

Subject: Report of the NSTX Program Advisory Committee – May 1997

Dear John:

The NSTX Program Advisory Committee met at the Princeton Plasma Physics Laboratory on 15-16 May 1997 (agenda attached). Our activities at this meeting focused on three areas in response to your charge to the committee (copy attached): (1) a discussion of the NSTX design requirements; (2) a proposal for the process of forming of the NSTX national research team; and (3) an examination of the plan for NSTX diagnostics as the first part of the committee's plan to review specific areas of the NSTX design requirements. This report summarizes issues raised during discussion and our recommendations in these three areas.

NSTX Design Requirements

The Project described to us considerable progress in addressing the issues and following up on suggestions from the committee as summarized in the report of our previous meeting in November 1996. The committee was pleased to learn that the location of NSTX in the D-site hot cell has been approved, that the entire D-site hot cell will be available for the NSTX experimental facility, and that the design of the OH Center Stack has successfully completed its final design review.

The committee was updated by the Project on the current status of the NSTX Project. We discussed the design requirements as described in the General Requirements Document (GRD) and Physics Requirements

Document (PRD). One of the most important charges to our committee during the design and construction phase of NSTX is to review the adequacy of the design requirements of NSTX to support its physics mission, and we plan to carry out that charge by focusing on specific areas of the NSTX design at each of our meetings. The timing of our discussion of these design areas will be coordinated with the finalization of the design to meet the construction schedule. As described in the report of our previous November 1996 meeting, we had planned to provide the Project with detailed comments on the NSTX design requirements based on our review of the GRD and PRD. However, since the NSTX design is still being refined, these documents have not yet been revised to include the most recent design changes and only a general discussion of elements of the GRD and PRD was carried out at this meeting. In beginning our review of the NSTX design requirements, we have identified one area of general concern which is the lack of an easily accessed source of information which reflects the present status of the NSTX design basis. As the number of collaborators grows through the activities of the NSTX Working Groups it will become even more important that groups outside the NSTX Project have access to up-to-date design basis specifications. To address this concern, we recommend that the project establish a web site which contains easily accessed (*e.g.* in HTML language), up-to-date information on the NSTX basic design parameters, coil locations, allowed coil currents, design basis equilibria, *etc.*

In the course of a broad discussion of the NSTX design requirements with the Project, a number of technical issues were raised which are summarized below together with our recommendations for further action by the Project on some of these issues.

Neutral Beam Injection: As we reported at our previous meeting, the committee strongly supports the installation of neutral beam injection (NBI) on NSTX as rapidly as the available budget will allow after completion of the baseline facility. One area where the NBI system design requirements could be improved is to incorporate a beam power modulation system similar to that presently used on DIII-D. Such a system would allow greater flexibility for heating power control as well as provide background light measurements during machine operation for beam driven diagnostics. We recommend the Project investigate the cost of adding this capability, and if modest, that it be added to the design.

Machine Baking Design Specifications: The committee strongly supports the baseline design requirement that all internal carbon surfaces be capable of bakeout to 350 °C. However, we have a concern that the present specification of a lower baking temperature of the outer metal vacuum vessel wall in NSTX to only 150 °C may cause problems during operation due to the retention of water on these surfaces. The baseline design of NSTX presently has sufficient power and the necessary thermal insulation to permit this outer metal vacuum vessel wall to be baked to 350 °C, however, the observation windows taken over from TFTR are limited to 150 °C. If the costs are modest, the Project should include an increased baking temperature of the outer metal vacuum vessel wall in the baseline NSTX design which should be established by obtaining additional input from experts on wall conditioning in the fusion community.

He Glow Capability: The design of NSTX presently plans a capability for helium glow for vacuum system conditioning. Since it has been found on other experiments to be very important to apply helium glow between plasma discharges, we recommend that the Project should modify the baseline design to support the application of He glow between shots on NSTX.

Breakdown of Plasma The loop voltage induced by the OH coil while it is being "biased" prior to breakdown with a field null in the vessel may present a problem in timing the gas injection with regard to generating an unwanted, early reverse-current discharge. We recommend that the Project analyze this issue more thoroughly and, if necessary, develop an approach to suppress a possible early reverse current discharge.

Capability for High Elongation: In response the our request at the November 1996 PAC meeting that the Project investigate the capability of NSTX to support a $\kappa \sim 3$ equilibrium, a high elongation equilibrium has been modeled by the Project using the NSTX coil set. Since the distance of the plasma outer boundary to the passive stabilizing plates is relatively large for this high elongation case, we recommend that the rigid-body vertical stability against an n=0 mode be investigated.

Baseline κ=2 Equilibria: It was noted that many of the baseline equilibria presented to the committee have a characteristic feature of a 'bulge' in the outer flux surfaces at the outer mid-plane. This appears to be due to the requirement that the plasma boundary be maintained at least 5 cm from the passive stabilizer at all locations. We recommend the Project explore the

possibility of relocating the PF coils or the passive stabilizer plates to minimize this distortion in the equilibrium for the design basis plasmas.

HHFW Heating: Results of time dependent modeling of HHFW heating in NSTX were presented which show a very rapid increase in the electron temperature from a few hundred eV to 4 keV. This implies a very rapid increase in β_p and we recommend that the Project investigate the MHD stability of these plasmas.

Location of HHFW Antennas: There would be advantages for control of the RF spectrum if the HHFW antennas were located side-by-side rather than divided into two groups on opposite sides of the machine. During our meeting the decision was made by the Project to finalize the location of the antennas to a single side-by-side location. The committee supports this decision.

Modeling of CHI Start-up: Equilibrium modeling of CHI start-up has been carried out for NSTX assuming zero current in the OH solenoid. Since a likely scenario for high current operation is to use CHI to ramp the current to the 500 kA range followed by an inductively driven increase in the current to the 1 MA level, we recommend that the CHI start-up modeling studies should also investigate cases where CHI is applied with full bias current in the OH solenoid. In each of these cases, it is also important to insure that the NSTX PF system can maintain radial and vertical stability during the plasma start-up.

Alternative Non-inductive Start-up Techniques: Progress has been made in modeling the CHI non-inductive start-up of NSTX. The committee continues to believe that alternative techniques for non-inductive start-up should be identified and modeled for application to NSTX as recommended in the report of our previous meeting.

<u>NSTX Research Team Formation</u>

A proposal by the NSTX Program to establish a process for the formation of the NSTX national research program and research team participation was presented to the committee. The committee endorses the general objectives and the process proposed and we strongly recommend that <u>all</u> participants in NSTX should follow it. From our discussion of the details of the proposal, the committee offers three suggestions for improvement:

(1) Coordinate the timing of the "Research Forum" with other major research planning activities in the fusion program.

(2) Start the process 1 or 2 months earlier to accommodate internal institutional review requirements.

(3) Plan on staggering terms of Grant participants (2, 3, 4 years initially) so that the annual process will not need to re-evaluate the entire grant funded NSTX team in any year after the initial team formation.

NSTX Diagnostics Plan

The Project presented a detailed report on its plans for both the baseline (part of the TPC) and upgrade/advanced diagnostics (outside the scope of the TPC). We recognize that the baseline diagnostic set is still in the conceptual design phase and therefore the committee plans to revisit this area of NSTX design again as the design details of the baseline and advanced diagnostic sets are closer to finalization. The NSTX Project has done a good job in applying a modest diagnostic budget ($1.2 million) to cover a large number of important diagnostics by taking advantage of the availability of TFTR diagnostic equipment. In our discussion of the present diagnostic plan, a number of issues and recommendations were identified by the committee which are summarized below.

Magnetic Diagnostics: The specification of the baseline set of magnetic diagnostics is a high priority due to the need to finalize the vacuum vessel and plasma facing component design. We recommend that the Project carry out a more quantitative study of the magnetic diagnostics needed to control the design basis equilibria as specified in the GRD. The Project should also consider the installation of redundant flux loops needed for critical measurements which are located in relatively 'inaccessible' locations.

Passive Plate Saddle Loops: Several of the techniques being proposed for control of the resistive wall mode in high beta, wall stabilized plasmas, are most effective if a close fitting array of saddle loops are installed near the passive stabilizing plates to monitor the soak through of low frequency radial magnetic fields. The Project should consider the installation of a set of such saddle loops behind the passive stabilizer in the baseline magnetic diagnostics design.

Passive Plate Viewing Access: The baseline design should allow for viewing access locally through the passive plate structures at the location of all of the upper and lower access ports.

Langmuir Probes: The Langmuir probes located in the divertor tiles should have a spatial resolution much smaller than the scrape off layer width.

CHI Diagnostics: We recommend the project explore what diagnostics are needed to study the instabilities expected during CHI and consider their inclusion in the diagnostic set (*e.g.* high speed video imaging was found to be essential for studies on START and ultra-soft x-ray measurements were important in studies on CDX-U).

Multi-pulse Thomson Scattering: Because of the critical need for the capability to obtain time dependent profile information as early as possible in the NSTX research program, the committee strongly recommends that the Project investigate possible ways to accelerate the installation of multi-pulse Thomson scattering even if this entails delay in some other important baseline diagnostics (*e.g*. PHA, neutral particle analysis, and CHERS).

Current Profile Diagnostic for NSTX: We strongly endorse the Project view that the development of a diagnostic to measure the local current profile in NSTX is one of the highest priority upgrade diagnostics needed on NSTX and support the Project's plan to carry out a broad based community forum this summer to assess the options available for such a diagnostic.

General Comment

The committee notes that insight on many issues related to HHFW heating and current drive and ST diagnostics can be obtained by using CDX-U as a test bed for NSTX. We recommend that PPPL take full advantage of this facility.

Next Meeting of the NSTX PAC

We expect that the next meeting of the committee will take place in late September or early October with part of this meeting focusing on the elements of the machine affected by the finalization of the vacuum vessel which is scheduled to begin construction in early FY98. We expect this would include the design of the magnetic diagnostic set and the options identified for current profile measurements in NSTX.

In conclusion, please convey our thanks and appreciation to the NSTX Project and Program personnel for their efforts in providing us comprehensive presentations on the design specifications and physics modeling and analyses needed to inform our discussions and carry out our charge.

Sincerely yours,

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

Princeton University
Princeton Plasma Physics Laboratory
Office of the Director
Post Office Box 451
Princeton, New Jersey 08543

M E M O R A N D U M

TO: NSTX Program Advisory Committee

FROM: John A. Schmidt

SUBJECT: Second Meeting of NSTX PAC, May 15-16, 1997

DATE: April 30, 1997

As NSTX moves forward into the phase of fabrication and research program preparation, advice from the NSTX Program Advisory Committee will be very timely. We planned the second meeting of the Advisory Committee at the Princeton Plasma Physics Laboratory on May 15 and 16 with this in mind.

Attached for your consideration is the charge to the committee, which I hope you can address at your second meeting. Also enclosed is local travel information.

I would like to thank again Gerald Navratil and the Committee members for having conducted an excellent first meeting in November last year, and I look forward to having this committee continue a critical role in establishing research priorities on NSTX and in helping to determine the research program.

Attachments (2)

cc: Robert J. Goldston, PPPL
Dale M. Meade, PPPL
Masa Ono, PPPL
Martin Peng, ORNL
N. Anne Davies, DOE/OFES
John W. Willis, DOE/OFES
Jeffrey C. Hoy, DOE/OFES
William F. Dove, DOE/OFES
Jerry Wm. Faul, DOE/PG

CHARGE TO THE SECOND NSTX PROGRAM ADVISORY COMMITTEE MEETING MAY 15-16, 1997

1. Physics Requirements for the NSTX Design

The NSTX physics design requirements are driven by a set of operational objectives, which in turn are defined by the NSTX physics mission. On a continuing basis, we request that the PAC address the following questions: Are the operational objectives appropriate for the NSTX physics mission? Do the design requirements support the operational objectives?

2. NSTX Diagnostics Plan

Recent NSTX Working Group Discussions at the NSTX Research Forum highlighted the need to have early multi-pulse, profile measurements of the plasma. This has influenced the baseline as well as the planning for the advanced diagnostic capabilities of NSTX. Are the NSTX diagnostic plans reasonable in supporting the initial priorities of the NSTX research program?

3. NSTX Research Preparation

Recent discussions with the NSTX Working Groups, at the Research Forum, and with the managers at the Department of Energy have resulted in a proposed process for the development of the national NSTX research program. A plan for research preparation during FY 1998 consistent with this process is also proposed. Are the envisioned process, its major components, and the FY 1998 plan appropriate with which to proceed?