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6 October 1998

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

Subject: Report of the NSTX Program Advisory Committee – September 1998

Dear Rob:

The NSTX Program Advisory Committee (PAC) met at the Princeton Plasma Physics Laboratory on 24-25 September 1998 (agenda attached). In addition to receiving a status report on the NSTX Project and Project Physics, our activities at this fifth meeting of the PAC focused on three areas in response to your charge to the committee (copy attached): (1) the steps and anticipated products of the Research Program preparation activities planned by the NSTX program prior to our next meeting; (2) to review and advise on the status and plans for the use of HHFW on NSTX; and (3) to review and advise on the status and plans for the NSTX Plasma Control System. We also heard status reports on ST activities abroad (MAST and Globus-M) plans for US-Japan collaboration on NSTX.

Status of NSTX Project and Project Physics

The construction of NSTX has made considerable progress since our last meeting in February 1998 with the delivery of the vacuum vessel and its final machining being carried out now, the completion of the OH/TF centerstack, the near completion of the NSTX test cell, and the preparations for the new control room and supporting data collection annex. This is a very exciting phase for NSTX as it nears the point of initial experimental

operation. We congratulate the NSTX Project for maintaining its schedule and being in a position to advance the date of first plasma to as early as February of next year.

Significant progress was reported on all of the few unresolved issues raised at our previous meetings. These are briefly summarized below:

Free Boundary Shape Effects: Last year we noted that the free boundary calculations of the baseline equilibria in NSTX have a characteristic feature of a mid-plane 'bulge' or more correctly, an off-axis 'dimple' which deviates from the initial fixed boundary shape parameterization used in the baseline stability analyses. In response to our concern, the Project reported that indeed the predicted ballooning stability limits were significantly reduced from over 40% to 33% volume averaged β as a consequence of these equilibrium distortions. We were very pleased to learn that in response to our recommendation that the Project explore options to optimize the control of the plasma shape and stability, the Project has added an additional poloidal field coil set (PF5) nearer the midplane and at somewhat larger radius and repositioned the PF4 coil set. This change restores the expected beta limit to greater than 40% and also provides enhanced capability for plasma boundary shape control in NSTX.

Neutral Beam Injection and Fast Ion Losses: At our previous meeting we raised some additional questions related to the use of neutral beams in NSTX:

(i) For the voltages planned for NBI in NSTX, what are the minimum toroidal current requirements necessary for good confinement of the planned co-injection neutral beam ions?

(ii) Based on the large levels of counter-injection losses for the high-β, $q_o > 2$ equilibria, what is the level of bulk ion losses at the highest ion temperature expected in NSTX?

We were also concerned about that the effects of the anticipated radial electric field should be included as well as an assessment of the fast ion losses to the RF antenna structures and the stabilizing plate edges.

Relative to our second question, the Project reported the results of ion orbit calculations which showed that 6 keV ions for a wide range of pitch angles are well confined and do not strike the stabilizing plates or RF antennas in a $q_o > 2.5$, 1 MA plasmas. This addresses our concern on this point.

Relative to our first and third questions, TRANSP calculations were done to assess the losses of 80 keV beam ions for a range of plasma currents showing loss levels of about 10% of NBI power which would be acceptable if distributed sufficiently over the PFC surfaces. However, there remain some unresolved systematic scaling issues of loss power with plasma current in the TRANSP calculations and assessment of the expected power loss in NSTX low-l_i equilibria. A more important question to resolve is the toroidal and poloidal distribution of the fast ion losses (including finite Larmor radius effects), particularly to the RF antenna Faraday shields and Boron Nitride insulators.

Plasma Scrape-Off Layer near Stabilizing Plates: The passive stabilizing plate design has been modified to insure that the flux surface 5 cm outside the plasma edge on the outer midplane does not strike the passive stabilizing plates for a wide range of equilibria. This addresses a concern raised at our last meeting.

Modeling CHI Start-up: At our previous meeting we identified as a remaining open issue the calculation of the time scale for transition from "flux conservation" radial equilibrium to an equilibrium maintained by the external poloidal field coils. The Project reported the results of 2D model calculations using the "soak-thru" code adapted for use on NSTX by the University of Washington collaborators. CHI start-up simulations have been carried out for 10 ms which show the formation of a 600 kA plasma with the currents on the PF coils set within operating limits. However, this calculation was carried out with a fixed current profile with a varying

magnitude in time, and needs to be extended to cases with variable current profiles consistent with the low-li CHI start-up plasmas.

CHI System Design Change: The Project reported a change from a 15 kV/2 MJ capacitor bank to a 2 kV/24 kA rectifier system to power the CHI System. The benefits include greater safety, control, and pulse length. We support this design change. In addition, the CHI biasing scheme was changed to allow the outer vacuum vessel to float above ground, requiring an increase in voltage isolation requirements for diagnostics mounted on the vessel to 5 kV. The Project should thoroughly survey all diagnostic, bake-out, and control systems to insure that no unexpected problems result from operation with an ungrounded outer vacuum vessel.

Breakdown of Plasma: At our previous committee meetings an issue regarding the effect of the radial magnetic field generated by non-axisymmetric eddy currents in the vacuum vessel and stabilizing plate structure on magnetic field null during the breakdown phase of the discharge was identified. Analysis of this effect is in still in progress by the Project.

Research Program Preparation

Several critical events in the formation of the NSTX National Team are imminent. It is expected that next month the DOE will announce the proposals to be funded in FY99 which were submitted in response to DOE Program Solicitation Notice 98-07 in April 1998. This initial group of funded collaborators together with the NSTX scientists at PPPL will comprise the initial membership in the NSTX National Research Team for the start of operation of NSTX next year. An experimental management approach must be developed which organizes this newly formed team to be able to execute experiments on NSTX.

In addition the Program must prepare for the second round of proposals for additional collaborators to be funded in FY00. Following the plan developed last year by the NSTX Program, the PAC, and the DOE, this process begins with the NSTX Research Forum in December, followed by

the submission of letters of interest in January, and a review and comment by the PAC in February the letters of interest by prospective members of the NSTX National Research Team and the draft research proposal by the NSTX Program. The PAC's role was at this stage in the process is to provide review and comment on two areas:

1. The proposed NSTX National Research Program and its priorities.

2. Coverage by prospective participants on the proposed NSTX National Research Program .

As was the case last year, in providing this review and comment, no evaluation of the relative merits of any prospective participant in the NSTX Program will be made by the PAC.

In reviewing the plans for the Research Program, we feel that the December Research Forum should focus on its primary goal of informing members of the community who are prospective participants in NSTX of the NSTX scientific program and opportunities for collaboration in the FY00 round of proposals for collaboration. This meeting will also serve as the first public presentation of the selected members of the NSTX National Research Team and it would be appropriate to describe the funded activities of each collaborator. The development of a detailed experimental run plan by the team at the December Research Forum seems to us premature.

The formation of the NSTX National Research Team will require time and considerable discussion among the team members as an experimental management structure is adopted by NSTX, and the newly formed team begins to work together to formulate detailed experimental run plans. By the time of our next meeting it would be appropriate for the Program to report to the PAC its ideas for experimental management, its initial actions in bringing the team members together, and the process by which the NSTX National Team will formulate detailed experimental run plans.

In adopting a process for the NSTX Team to develop detailed experimental plans, we note that for the next few years, NSTX will be at a very early

stage of its operation. This requires a relatively ‘nimble’ and flexible approach to planning experiments as compared with the experiment planning process implemented on a mature, large national facility such as DIII-D.

Another issue is the timetable of scientific goals for the NSTX Research Program in Phase-I as described to us. We endorse these goals and recommend that this list emphasize the sequence of scientific issues being investigated which is important for planning the program of research, but that precise numerical targets not be associated with this initial sequence of experiments.

HHFW System

The Project reported to us on the design and installation plans for the High Harmonic Fast Wave System on NSTX. The view of the committee is that this appears to be a sound design and plan for installation employing a conservative approach to the use of the high power RF amplifiers. In addition there is good provision for local density diagnostics, which will allow measurement of the density profile in front of the antenna which is critical for good coupling to the plasma.

Two issues we would like the Project to address are: (1) to assess how long BN insulators could act as limiters with expected heat flux in normal and off-normal operation with and without NBI; and (2) to consider the effect of carbon deposition on the BN insulator surfaces which might result in shorting to the vacuum vessel.

Plasma Control System

The PAC strongly concurs in the decision to proceed with a ‘Day 1’ plasma control system achieving gap control based on flux projection to be followed by a ‘Day 2’ control system using more advanced techniques.

We also note that the RF heating will require outer gap control based on antenna loading quite early in the experimental program.

As ideas mature for the 'Day 2' system, we would expect to receive a report at a future meeting of the PAC.

International Collaboration on NSTX

We support exploration of possible collaboration by Japan on NSTX which may involve the contribution of new hardware systems for NSTX.

As part of this exploration we recommend:

- The collaboration should be fully integrated into the NSTX Team.
- A design approach for a new center stack, or other major hardware system, should remain flexible until more scientific understanding of ST physics at the 1 MA level is obtained.
- Plans for the collaboration should take fully into account the impact on the NSTX device and its prospective upgrade paths.

Sincerely yours,

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

M E M O R A N D U M

TO: NSTX Program Advisory Committee
SUBJECT: Fifth Meeting of NSTX PAC, September 24-25, 1998
DATE: September 18, 1998
FROM: Robert J. Goldston

As the preparation for the NSTX facility reaches its peak level of activity, the PAC has the opportunity to look at "auxiliary" systems of high priority. These include the High-Harmonic Fast Wave (HHFW) and Plasma Control systems. In particular, I would like the PAC to review and advise on the status and plans for

1) The HHFW system design and implementation, which has been a strong collaboration of PPPL and ORNL, bringing expertise in physics and enabling technology to bear on this new subject of magnetic fusion energy science, and

2) The Plasma Control system covering the first plasma, the commencement of experimentation in beginning May 1999, and the Phase-I research.

As the NSTX Research Program approaches the start of experimentation planned for May 1999, a number of important activities are being planned to effect the formation of the initial national research team and the formulation of the Phase-I experiment plan. In particular I would like the PAC to review and advise on

3) The steps and anticipated products of Research Program preparation through the PAC6 meeting, which is anticipated to take place in February 1999.

I look forward to seeing you at the PAC5 meeting at PPPL, September 24-25.

Attachments (2)

cc:
N. Anne Davies, DOE/OFES
John W. Willis, DOE/OFES
William F. Dove, DOE/OFES
Ron McKnight, DOE/OFES
Jerry Wm. Faul, DOE/PG
Rich Hawryluk, PPPL
Masa Ono, PPPL
Martin Peng, PPPL
John Schmidt, PPPL

NSTX PAC5 Meeting
September 24-25, 1998

Agenda

Thursday, September 24, 1998

8:30	Coffee & Donuts	
9:00	Welcome	R. Goldston
9:10	Meeting Plan	G. Navratil
9:20	Actions from PAC4	M. Peng
9:30	Research Program Preparation	M. Peng
10:15	Project Overview	M. Ono
11:00	Break	
11:10	HHFW	R. Majeski, D.Swain
12:40	Lunch	
1:40	Physics Issues and Plasma Control	S.Kaye, D.Gates
3:10	Break	
3:20	PAC Caucus	
4:10	Tour of NSTX facility	A.VonHalle
5:00	Adjourn	

Friday, September 25, 1998

9:00	World STs and Collaboration	
	- MAST Status and Plan (40 min)	A.Sykes
	- Globus-M (20 min)	M.Peng
	- US-Japan collaboration (30 min)	M.Peng, M.Ono
10:30	Break	
10:40	PAC Caucus	
12:00	Lunch	
1:00	Briefing	G. Navratil
2:00	Adjourn	