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20 March 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 – February 1998

Dear Rob:

The NSTX Program Advisory Committee (PAC) met at the Princeton Plasma Physics Laboratory on 11-12 February 1998 (agenda attached). Our activities at this fourth meeting of the PAC focused on two areas in response to your charge to the committee (copy attached): (1) comment on the present status of the NSTX Project, including Project physics considerations, and (2) review and advise on the research priorities and balance of the draft NSTX Research Proposal, as the primary focus for the meeting. We also heard summary presentations on the research plans for the MAST device at Culham and Pegasus at the University of Wisconsin, as well as recent results from START.

Status of NSTX Project and Project Physics

We are again pleased to note that the NSTX Project continues to progress on schedule and within its planned budget, and we congratulate the dedicated team of engineers and scientists working on NSTX. One major design change which occurred since the previous meeting of the PAC was the recent decision to procure new 'dome' sections for the NSTX vacuum vessel. The PAC strongly supports this decision, and notes that the new vacuum vessel sections provide improved diagnostic access and a stronger overall design.

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

Free Boundary Shape Effects: It was noted at our previous two meetings that the free boundary calculations of the baseline equilbria 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. We recommended this effect of this deformation on stability be assessed and the Project reported that indeed the predicted ballooning stability limits were significantly reduced from over 40% to 33% volume averaged β. These studies confirm the importance of the outer boundary shape on both high-*n* and low-*n* stability. Several strategies were presented for recovering the original β • 40% baseline performance which included redistributed coil currents in the existing PF coil design, small changes in minor radius, or possible modifications of the PF coil design. We recommend that the Project explore options to optimize the control of the plasma shape and stability, and plan to change the poloidal field coil geometry as required.

Counter Neutral Beam Injection:: Calculations to estimate the prompt orbit losses of counter neutral beam injection in NSTX were carried out by the Project. These studies conclude that prompt losses would exceed 30% of injected neutral beam power for typical 1 MA equilibria in NSTX, and consequently counter neutral beam injection in NSTX would not be practical. Based on these results, the committee concurs in this assessment. The results of these studies suggest several 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?

In addressing these follow-up issues, 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.

Stabilizing Plate Structure: As indicated in our previous report, the committee remains concerned about energetic ion impact on the stabilizing plate edges. A related issue is the magnitude of the flux expansion between mid-plane 5 cm scrape off layer specification and stabilizing plate structure?

Stability at High Elongation:: In response to a question raised during the previous meeting of the committee, the Project examined the ideal stability for n=0 vertical motion in the high elongation equilibria ($\kappa \sim 3$) in NSTX and found it to be ideally unstable.

Modeling CHI Start-up: The effect of 500 kA of CHI on the peak toroidal current duration was modeled using the TSC code and showed that a significant pulse extension would be achieved in this case. A remaining open issue is the calculation of the time scale for transition from "flux conservation" radial equilibrium to an equilibrium maintained by the external poloidal field coils .

Modeling of HHFW Heating: A question was raised at the previous meeting of the committee regarding the stability of HHFW heated plasmas during the rapid beta increase which shows it to near or above the stability limits depending on small variations in the assumed pressure profile, particularly for the n=3 mode. Further analysis has shown this is not expected to be a problem in NSTX.

Breakdown of Plasma: At our previous committee meeting 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 progress by the Project.

Summary of Research Plan for MAST and Pegasus

The committee was presented with summary of the research program plans for the MAST experiment at Culham Laboratory in the UK and the Pegasus experiment at the University of Wisconsin. The committee notes that these other ST experiments which will be carried out in parallel with NSTX are complimentary and we recommend that the Project should continue to follow this planned work on other ST experiments closely.
In the case of the Pegasus experiment which is part of the US program in ST research, we recommend that NSTX continue to work with Pegasus to aid and encourage work which could directly contribute information useful to the NSTX planned research, *e.g.* tests on alternative non-inductive start-up techniques.

NSTX Research Proposal and Program Plan

At our previous meeting in September 1997, the NSTX Program presented a plan by which the NSTX National Research Program and a National Research Team would be formed. In "Step 3" of that plan, the NSTX PAC was called upon to review the preliminary letters of interest submitted in January 1998 by prospective members of the NSTX National Research Team and the draft research proposal by the NSTX Program. As described in our previous report, the PAC's role was at this stage in the process was 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 .

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.

The NSTX Program presented a detailed research plan which divided the science research activities into 5 areas:

I. Slow Mechanisms for Current Formation and Sustainment
II. Fast Mechanisms for Heating and Current Drive
III. Magnetics and Stability Limits
IV. Plasma Transport and Fluctuations
V. Divertor, SOL, Power and particle Handling

In assessing the relative emphasis and priorities among these 5 areas, we can apply our assessment of relative priorities for the first few years of NSTX research from the report of our November 1996 meeting:

> We were asked specifically in our charge to comment on the relative emphasis among the ST physics areas in the first few years of the NSTX research program. The PAC recommends the following priorities:
>
> 1) Studies of Transport, Beta, Heating and sustaining current drive, using inductive start-up
> 2) Non-inductive start-up studies
> 3) Divertor & SOL studies
>
> While we recognize that it is critically important to the development of the ST concept to discover means for non-inductive start-up, obtaining early results on the transport, beta limits, heating and current drive using the inductive start-up capability of NSTX should get somewhat higher priority. The PAC also recommends that the physics program effort be tightly focused on pursuing the physics areas which are unique to the ST.

Application of these priorities to the proposed 5 science areas would rank as highest priority Science Areas II, III, and IV. Second priority would be Science Area I, and third priority would be Science Area V. We find the proposed allocation of FY99 funds by the NSTX Program among these 5 science areas to be consistent with these relative priorities. We recommend that an additional overall technical objective be added "...to achieve 1 MA operation sustained for ~ 1 sec..." at the end of Phase II (see attached Program Plan). Achieving this objective will most likely require a combination of successful non-inductive start-up & current drive together with good confinement at high β. Achieving this objective will also establish the basis for a successful science program during Phase III of the research plan.

The relative balance between PPPL participation and collaborator participation in the NSTX research program has been established as approximately 2 to 1, and the PAC supports that balance. We note that in assessing the proposed relative funding balance between activities of PPPL scientists and collaborators, 25% of the collaborator activity is allocated to the lowest priority area. While this correctly reflects an assessment of relative strength within PPPL in the required scientific areas, it may slow the development of the desired "national" balance among the highest priority science areas of research on NSTX.

The committee also reviewed the detailed Research Program Plan for the Phase I and Phase II periods, and we compliment the NSTX Program on the excellent effort in assembling a coherent research plan among a wide range of research topic areas. Below are listed some general recommendations regarding the plan and attached to this report are our recommendations for revised emphasis among program elements.

- In general we advise the project to more clearly emphasize to prospective participants in NSTX the degree of risk and innovation required to carry out the proposed research plan.

- We recommend that in the presentation of the detailed program plan that the term "research priority" be replaced by "research emphasis" to more correctly indicate that most areas need to make some progress in each phase of the research plan but that the relative emphasis will change in time.

- Using this terminology of High, Medium, or Low research emphasis, the relative emphasis for Phase I and Phase II should both be listed in two adjacent left-hand columns to more clearly indicate the phasing of relative emphasis as the program moves from Phase I to Phase II. The activities in Phase III could be listed separately and are so contingent on the success of specific elements in Phase I and Phase II, that we do not believe it is useful to try to specify emphasis rankings at this time.

- The committee feels that it is does not have sufficient information to assess the need for collaboration effort versus PPPL effort on an area, so we are not able to provide advice on this column. We recommend that this information be provided by PPPL in the public release of this detailed research plan.

- We recommend that the public release of the detailed research plan not show $ figures, but rather list rough % of total effort for each research area.

- We recommend that the titles and institutions submitting letters of interest in NSTX not be listed for each research element in the public release of the detailed research plan.

- We recommend that PPPL establish a uniform process as soon as possible to show that the program of collaboration submitted by Proposers responding to the 98-07 DOE Program Solicitation Notice for collaboration on NSTX has been "...developed through cooperation and discussions with the NSTXresearch team at PPPL..." as required in the 98-07 Program Notice.

- We found that several important enabling diagnostic or control activities were divided in their focus among the several of the 5 research areas, resulting in a loss of priority and visibility. We recommend that a sixth category be created in the detailed plan titled “Enabling Activities” to include (i) current profile measurements; (ii) Multi-point Thomson scattering; and (iii) Plasma control systems. Each of these should receive a “High” research emphasis in Phase I; while the Plasma control system should also receive a “High” research emphasis in Phase II.

Terms of Membership

In order to provide for better continuity during the construction period of NSTX, the terms of membership on the NSTX Program Advisory Committee as described in the NSTX PAC Charter have each been extended by 1 year for the 9 regular members of the committee and the chairman.

Initial terms of office for 4 members were 18 month terms and for the other 5 members were 3 year terms. These have been extended to 2.5 years and 4 years respectively. The revised term of appointment for each member of the PAC is listed below with terms ending on 31 December 1998 for 2.5 year terms and 30 June 2000 for 4 year terms:

Ken Gentle	Univ. of Texas	(4 years)
Ed Lazarus	ORNL	(4 years)
Farrokh Najmabadi	UCSD	(4 years)
Gerald Navratil, Chair	Columbia Univ.	(4 years)
William Nevins	LLNL	(2.5 years)
Stewart Prager	Univ. of Wisconsin	(2.5 years)
Stewart Zweben	PPPL	(2.5 years)
Ron Stambaugh	General Atomics	(2.5 years)
Alan Sykes	UKAEA/Culham	(4 years)
Yuichi Takase	MIT	(4 years)

Sincerely yours,

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

cc: M. Ono
M. Peng
S. Kaye
W. Dove
J. Willis
J. Hoy

Proposed Revisions to NSTX Research Program Element Relative Emphasis

Relative Research Emphasis: **H**igh, **M**edium, and **L**ow

Research Program Element	Phase I	Phase II
I. Slow (MHD) Mechanisms for Current Formation and Sustainment		
• Inductive formation of plasma, EC preionization	H	
• Preliminary CHI plasma formation studies	H	
• Combined CHI start-up, inductive sustainment		H
• Initial study of CHI during current sustainment		M
• Initial assessment of bootstrap current drive		L
• Preliminary studies of configurations for plasma formation		L
• Ramp-up via bootstrap current overdrive		L
II. Fast Mechanisms for Heating and Current Drive		
• Develop HHFW modeling tools, integrate into codes	H	H
• HHFW heating and current drive at moderate power	H	
• HHFW heating and current drive at high power		H
• ECH, EBW noninductive startup planning and prep	L	
• ECH, EBW noninductive startup		M
• Prep for fast ion experiments (RF and NBI)	L	
• NBI heating and current drive (assess fast ion losses)		H
• Understand Heating Profiles		M
• Early HHFW injection to assist current ramp-up		M
• Modeling advanced RF techniques		M
III. Magnetics and Stability Limits		
• Equilibrium reconstruction and post-pulse analysis	H	
• Plasma ramp-up and operation	H	
• MHD operation limits	M	H
• Assessment of ideal MHD stability	M	H
• Preliminary assessment of mode control	L	
• Fast ion driven instabilities		M
• Effects of sheared rotation		M
IV. Plasma Transport and Fluctuations		
• Characterize global confinement	M	
• Global confinement database		M
• Parallel transport and resistivity	L	H
• Preparation for Local Transport Studies	M	
• Local Transport Studies		H
• Design/scoping studies for core fluctuation diagnostics	M	H
• Edge Plasma Studies	M	H

[Combine: High-k, low-k, perturbation studies, transport barriers, and computation, theory into fewer program elements]

V. Divertor, Scrape -Off Layer, Power and Particle Handling		
• Wall conditioning, recycling, impurity control	H	M
• Heat Flux and Power Distribution	H	H
• Edge and SOL characterization	M	M
VI. Enabling Activities		
• Current profile diagnostics	H	
• Multi-pulse, multi-point Thomson scattering	H	
• Plasma Control	H	H

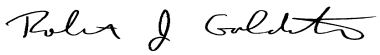
M E M O R A N D U M

TO: NSTX Program Advisory Committee

SUBJECT: Fourth Meeting of NSTX PAC, February 11-12, 1998

DATE: February 2, 1998

FROM: Robert J. Goldston



As NSTX is focusing on fabrication and research program preparation, advice from the NSTX Program Advisory Committee will be very important. We planned the fourth meeting of the Advisory Committee at the Princeton Plasma Physics Laboratory on February 11 and 12 with this in mind.

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

I would like to thank again Gerald Navratil and the Committee members for having conducted an excellent third meeting in September 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: Rich Hawryluk, PPPL
Masa Ono, PPPL
Martin Peng, ORNL
John Schmidt, PPPL
N. Anne Davies, DOE/OFES
John W. Willis, DOE/OFES
Jeffrey C. Hoy, DOE/OFES
William F. Dove, DOE/OFES
Ron McKnight, DOE/OFES
Jerry Wm. Faul, DOE/PG

CHARGE TO THE FOURTH
NSTX PROGRAM ADVISORY COMMITTEE MEETING
FEBRUARY 11-12, 1998

1. Comment on the present status of the NSTX Project, including Project physics considerations.

2. Review and advise on the research priorities and balance of the draft National NSTX Research Proposal, as the primary focus for this meeting.

National Spherical Torus Experiment
Program Advisory Committee

Director's Conference Room (LOB-331)
Princeton Plasma Physics Laboratory

February 11 - 12, 1998

DRAFT AGENDA

Wednesday, February 11, 1998

8:30 AM	*Coffee and Pastries*	
9:00 AM	Welcome and Charge	R. Goldston
9:05 AM	Agenda	G. Navratil
9:10 AM	DOE Update	R. McKnight
9:15 AM	Previous Meeting Action Review	M. Peng
9:30 AM	NSTX Project Status	M. Ono
10:30 AM	*Break/Coffee*	
10:45 AM	NSTX Design Physics Considerations Status	S. Kaye, etc.
12:00 PM	*Lunch*	
1:00 PM	Pegasus Program	R. Fonck
1:25 PM	START/MAST Program	A. Sykes
1:50 PM	*Tour of NSTX*	
2:40 PM	National NSTX Research Proposal Overview	M. Peng
3:30 PM	*Coffee without break*	
3:30 PM	Detail of Topical Areas in Research Proposal	M. Peng, M. Ono, S. Kaye, etc.
5:45 PM	*Adjourn*	
6:30 PM	Program Advisory Committee Party	

Thursday, February 12, 1998

8:30 AM	*Coffee and Pastries*	
9:00 AM	Program Advisory Committee Discussion	G. Navratil
12:00 Noon	*Lunch*	
1:00 PM	Program Advisory Committee Report Preparation	PAC Members
2:30 PM	Briefing to PPPL Director	G. Navratil
3:00 PM	*Adjourn*	