Theory Participation in ST Research

NSTX, Pegasus, HIT-II, and CDX-U Programs
July 2001

This input to FESAC provides a brief account of the theory participation in the present ST research in the U.S. Section I covers the participation by the PPPL Theory Department in the ST research sited at PPPL (NSTX and CDX-U). Section II covers the theory participation of other fusion research institutions (universities, national laboratories, and private companies) in this research. This includes OFES direct-funded NSTX collaboration in important topics of theory application, selected by OFES through a competitive peer-review process. Section III covers the theory participation in the Pegasus, HIT-II, and CDX-U programs.

The latest results from these and other ST experiments (such as MAST in U.K., Globus-M in R.F., and TST-2, TS-3, and HIST in Japan) have been encouraging and indicative of new opportunities for theory development. This input therefore also covers in Section IV the goals and preparation of an ST Theory Development Meeting scheduled for September 21, 2001, aimed at engaging the plasma theory community in the development of new theories of importance to the progress of ST plasma physics.

While the recent growth in ST theory activities has been driven by individual ST experiments, the expertise developed so far has formed a solid basis for a broadened and coordinated theory participation in the growing ST experimental research in the U.S. and abroad. While the information provided here is telegraphic due to its limited length, the theory scientists identified here will be pleased to provide detail upon request.

I. Participation by PPPL Theory Department

A major component of the PPPL Theory Department participation in ST research is the application of PPPL theoretical and computational expertise to the NSTX physics analysis effort (headed by Stan Kaye), which began in 1997 as part of the NSTX Science activities at PPPL. This participation will benefit from the longer-term development of more powerful and sophisticated analytic and computational capabilities at PPPL that address the overarching scientific issues of magnetic fusion energy sciences. The following provides a brief summary of these two components of theory participation.

A. NSTX Science funded participation

High-leverage application of PPPL theoretical and computational expertise has been led by J. Manickam and is currently at the level of 1.9 FTE per year. Ten scientists[1] have contributed in topics covering MHD including Resistive Wall Mode and Neoclassical Tearing Mode, Turbulence and Transport, Energetic Particle-Plasma Interactions, and Edge Physics. A growing computational participation has been led by Doug McCune and

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[1] Guo-Yong Fu, Nikolai Gorelenkov, Zinhong Lin, Janardhan Manickam, Wonchull Park, Neil Pomphrey, Martha Redi, Gregory Rewoldt, Daren Stotler, Roscoe White

is currently at the level of 2.3 FTE. Four scientists[2] have contributed in updates and modifications of the computational tools for the analysis of NSTX plasmas.

While each scientist has made substantial contributions, notable examples include:

(1) A broad spectrum of magnetic oscillations with sub-ion cyclotron harmonic frequencies were recently observed in neutral beam heated plasmas on NSTX for the first time. These oscillations were often concurrent with anomalously high rate of ion heating. Calculations by Gorelenkov of the Alfven instabilities driven by the strongly supra-Alfven neutral beam ions in NSTX helped identify these oscillations most likely to be Compressional Alfven Eigenmodes (CAE).

(2) White identified the similarities between this apparently anomalous ion heating in NSTX and the unexplained ion heating in solar corona. The theoretical possibility of such a CAE spectrum to heat the thermal ions stochastically was then suggested by an NSTX researcher. The theoretical progress on this topic drew considerable interest in the fusion research and space plasma physics communities. Three invited papers on the key elements of this scientific progress will be presented at the upcoming DPP APS meeting in Long Beach, CA.

(3) Manickam recently contributed to the calculations of the B-normal structure of MHD mode in NSTX, in collaboration with the Columbia University members of the NSTX research team. This is part of an effort to prepare for the upcoming investigation of resistive wall modes on NSTX.

(4) Rewoldt carried out initial calculations of linear micro-instabilities (collisionless trapped electron ion temperature gradient and kinetic ballooning modes) that indicated the possibility of mode stabilization in ST plasmas. He also contributed to more recent calculations of the linear growth rates of the ion temperature and electron temperature gradient (ITG and ETG) modes in NBI heated high toroidal beta NSTX plasmas, which indicated the likelihood of strong suppression of ITG instabilities by the large flow shear.

(5) Pomphrey, jointly with Columbia University researcher on the NSTX research team, carried out the initial calculations of the halo current distribution on the center stack of an ST device, and showed the theoretical tendency for a much-reduced toroidal asymmetry. This tendency was later confirmed by measurements in MAST and NSTX.

(6) Substantial modifications and improvements to the TRANSP analysis code are being carried out by McCune et al to enable more appropriate analysis the high temperature plasmas. This effort is expected to continue and cover a large number of code modules ranging from ST geometry, MHD equilibrium, neoclassical transport, energetic ion transport, to HHFW heating and current drive, etc.

[2] Robert Andre, Chris Ludescher, Doug McCune, Alex Pletzer

B. Longer-term theory development of high relevance to ST research

The preceding theory participation by PPPL Theory Department, while driven by the immediate needs of NSTX research, has also contributed to the development of the longer-term PPPL theory program plan. The part of this plan that is directly relevant to the future ST research at PPPL and elsewhere covers the following topical areas:

(1) Micro-instability and transport[3]

The gyro-kinetic GTC code presently treats electron as being adiabatic. An effort is underway to include the non-adiabatic response of electrons. Several computational models are being tested. When implemented and benchmarked the code will have the capability of treating finite-beta effects and self-consistent non-linear saturation on a more global plasma scale in the low-aspect ratio geometry. It will also properly treat the electromagnetic and differential plasma rotation effects. The code will be applied to analyze the turbulence and transport properties of ST and other very high beta plasmas.

(2) MHD and extended-MHD[4]

The M3D code is being extended to include many important physics mechanisms such as the kinetic effects, free-boundary plasma conditions, and resistive walls, using unstructured meshes and a high degree of parallel computation. This work is proceeding in a phased approach to enable applications to ST plasmas at each stage. Some specific plans include the study of the non-linear behaviors of resistive wall modes and fast-ion driven modes.

Refinements of the Tokamak Simulation Code (TSC) code will play an important role in MHD and magnetic reconnection studies by simulating axisymmetric plasma behaviors produced by Coaxial Helicity Injection (CHI) in NSTX, HIT-II and other CHI experiments. Recently the TSC code was used to simulate solenoid-induced and CHI-produced NSTX plasma operation scenarios and provided information helpful to the interpretation of data.

A universal mapper is under development to permit the treatment of identical plasma equilibrium by many advanced codes, e.g. FULL, PEST, ORBIT, and M3D. This will facilitate comprehensive studies of specific plasma discharges in NSTX and other ST experiments.

(3) Energetic Ion-Plasma Interactions[5]

[3] W. W. Lee, Z. Lin and G. Rewoldt
[4] J. Breslau, G. Fu, S. Jardin, J. Manickam, W. Park and A. Pletzer
[5] R. White, F. Cheng, N. Gorelenkov

The theory of energetic ion driven MHD modes, such as Toroidal Alfven Eigenmodes (TAEs), Resonant type Toroidal Alfven Eigenmodes (RTAEs), Kinetic Ballooning Instability (KBI) and Compressional Alfven Eigenmodes (CAE) will continue to be improved to account for the full toroidal effects, which is of high interest to ST. Major computational tools: NOVA-K (low n, perturbation code), NOVA-2 (low n, finite amplitude code), and HINST (high n, finite amplitude code), will be advanced toward application to ST and tokamak configurations in the next few years.

The full Lorenz gyro motion of the energetic particles will be coupled to the MHD codes to ensure realistic modeling of the driver of these instabilities. The results will be compared with the analytic approaches using the guiding center approximation.

(4) Plasma-Surface Interactions[6]

Tools are under development to enable DEGAS-2 to analyze 3-D effects in ST and other experiments. Important upgrades include tools for specifying the 3-D geometry and recoding to remove all assumptions of axisymmetry. Example applications include the simulation of the effects of localized gas puff used for imaging plasma edge turbulences on NSTX and C-Mod, and data analysis for the proposed comprehensive neutral pressure system for various toroidal asymmetries.

II. Participation by Other Fusion Institutions

NSTX Research Forums have been held annually since FY 1997, to which prospective NSTX collaboration scientists are invited to present and discuss research ideas of importance to the NSTX proof-of-principle experiment. Results from the Forums, together with Letters of Interest from prospective NSTX collaborators, formed a basis for the proposed NSTX research program plan, which included research priorities and collaboration emphasis.

The NSTX PAC advised on the research priorities and collaboration emphasis of the plan. Based on the PAC advice, the PPPL Director submitted a NSTX Program Letter to OFES as input to describe the desirable NSTX national research program. A competitive peer-review of NSTX collaboration proposals during 1998 led to the formation of the NSTX National Research Team, which included the following theory participation.

A. National Theory participation as part of NSTX research team

This is the more prevalent arrangement (see Table I) of theory participation, which began in March 1999 as part of the present NSTX National Research Team. This theory

[6] D. Stotler, E. Valeo

participation currently involves 17 scientists[7] from four universities, two national laboratories and three private companies with direct funding from the NSTX Science at OFES. This activity covers a broad range of theory and computation topics: MHD equilibrium and stability, coaxial helicity injection, edge physics, electron-cyclotron and electron-Bernstein waves, high harmonic fast waves, and transport simulation. This participation has since become an indispensable integral part of the NSTX team research. Examples include:

(1) The Columbia group carried out high-quality implementation and application of between-shot EFIT calculations, with continued improvements to profile modeling of the ST plasma equilibria based on direct measurement of plasma temperature and density profiles. This has become a major tool for between-shot assessment and after-run plasma analysis of the experiment. The Columbia group, jointly with PPPL researchers, also began calculations of Resistive Wall Mode structure using realistic vessel configurations in preparation for mode identification and mode control studies on NSTX.

(2) GA and Washington groups utilized the MFIT code (GA) to model CHI-produced plasma current and field distributions, as a key part of analysis to estimate whether closure of poloidal flux surface has been achieved.

(3) The LLNL group produced initial modeling of NSTX plasma edge fluxes and profiles by using the UEDGE code. The analysis will continue as new data of plasma edge and flux conditions are beginning to become available.

(4) The LLNL group (BOUT code) and the Lodestar group (BAL code) carried out simulations of SOL plasma (resistive fluid) turbulence behavior for comparison with NSTX edge fluctuation measurements using visible light imaging of fast edge gas puff.

(5) The MIT group introduced and continued improvements of the theory for heating and current drive via conversion of electron cyclotron wave to electron Bernstein wave (EBW) in over-dense ST plasmas. This work has led to the initial successful EBW emission measurements on CDX-U, NSTX, and MAST, which confirmed part of the theory. These results have strongly influenced the latest proposals and plans of EBW research on NSTX, Pegasus, MAST U.K.), TST-2 (Japan) ST experiments, as well as the MST reversed field pinch experiment at University of Wisconsin.

(6) The CompX group improved an EBW ray tracing code to interpret recent EBW emission measurements on CDX-U and NSTX, and a Quasi-linear 3-D

[7] Steve Sabbagh, Franco Paoletti (Columbia University), Bob Harvey (CompX), Mike Schaffer, Lan Lao (GA), Gary Porter, Xueqiao Xu (LLNL), Jim Myra (Lodestar), Abe Bers, Abhay Ram, Paul Bonoli (MIT), David Swain, Mark Carter, Wayne Houlberg (ORNL), Roger Raman, Aaron Redd (University of Washington), T. K. Mau (UCSD)

Fokker-Plank velocity distribution function code to enable relatively realistic estimates of EWB heating and current drive efficiencies in ST plasmas.

(7) The MIT, ORNL, and UCSD groups, jointly with PPPL researchers, carried out code improvements to model high harmonic fast wave (HHFW) launching and heating and current drive of NSTX plasmas. More recent efforts by these researchers have focused on improvements to the computational tools and modeling to account for the full-wave and kinetic properties of HHFW to begin interpretation of the exciting new electron heating results obtained so far (central T_e to as high as 3.7 keV measured by Thomson laser scattering). Research at PPPL also began to improve the modeling of HHFW interactions with fast ions and hot thermal ions introduced by NBI heating.

(8) The ORNL group recently updated the NCLASS neoclassical transport model by to account for smooth transitions of velocity-dependent viscosities to very low aspect ratio. This update is provided for integration into TRANSP calculations of NSTX plasmas profiles.

Onsite research contacts (Table I) work closely with these mostly off-site scientists to enhance the effectiveness of collaborative team on NSTX research. OFES has recently started the process of merit review for renewal of these activities to determine future theory participation in NSTX research, which is to begin in March 2002.

B. Cooperation with Theory community funded by OFES Theory Program

A substantial and growing cooperative arrangement with the fusion theory scientists (see Table II) has begun more recently, responding to a rising interest in the community and encouragement by the OFES managers of the Theory Program and the NSTX Science Program. This theory cooperation currently involves eight scientists[8] from five universities and two national laboratories, who have or could have separate funding from the OFES Theory Program. Three scientists from foreign fusion institutions are also involved. Recent results from this cooperation include:

(1) The LANL group improved the MHD stability code DCON, in cooperation with the Columbia group and PPPL researchers, for rapid stability analysis of the EFIT equilibria between shots. It is further improved to calculate plasma edge eigenfunctions for comparison with the experimental observations and for use in Resistive Wall Mode control analysis. The LANL group also contribute in fast computational models and tools of fast ion orbits in ST plasmas.

(2) The University of Maryland group assisted in carrying out linear and nonlinear gyrokinetic simulations of plasma fluctuations of NSTX plasmas to help clarify the relative magnitudes of electron and ion channels of turbulence transport

[8] Barrett Rogers (Dartmouth University), Jean-Pierre Matte (INRS, Canada), Klaus Hallaschek (IPP, Garching), Viktor Yarvoskij (Ukraine), Alan Glasser (LANL), Jan Egedal (MIT), C. S. Cheng (NYU), Fred Jaeger, Steve Hirshman (ORNL), Bill Dorland (University of Maryland), Alexander Pigarov (UCSD).

observed in NSTX. The results suggest possible suppression of the ion-temperature-gradient-driven electrostatic fluctuations by NBI induced plasma flow shear at moderately high toroidal betas (>15%). The results also suggest a relatively strong inverse magnetic field dependence of electron-temperature-gradient-driven electromagnetic fluctuations, which may dominate the ST plasma loss mechanisms.

Onsite research contacts have supported the cooperative research proposals to DOE by producing a joint record of discussion to clarify the importance and timeliness of the proposed work to the NSTX research program, and the NSTX support needed for this cooperation to be effective. We anticipate that the number of theory scientists interested in cooperation with NSTX research will continue to increase as the ST experiments make additional advances into the new plasma physics regimes of very high beta and strong toroidicity.

III. Theory Participation in Pegasus, HIT-II, and CDX-U Programs

The Pegasus, HIT-II, and CDX-U experiments would benefit greatly from increased theory participation in support of their research missions. Areas of activity of interest to Pegasus include ideal and resistive MHD stability and mode structure at near-unity aspect ratio, discharge evolution simulation, RF heating and current drive using HHFW or EBW, and examination of mode coupling and possible relaxation phenomena in the tokamak/spheromak overlap regime. Areas of interest to HIT-II include magnetic reconnection and plasma relaxation associated with the Coaxial Helicity Injection in ST plasma configuration, and the plasma turbulence and transport in plasmas dominated by helicity transport. Areas of interest to CDX-U include edge and core confinement physics associated increased control of particle recycling due to the use of Lithium limiters.

A. Pegasus Program (University of Wisconsin)

Pegasus has benefited from a small amount of theoretical support of its program. Most notably, Dr. Alan Glasser visited Madison for about a week and ported his DCON ideal MHD stability code to local computers. He enabled the coupling of output from the local magnetics equilibrium code to allow stability analysis of model or experimental equilibria. There has been a small amount of activity by C. Forest and A. Ram in support of proposed EBW heating and current drive experiments in Pegasus.

B. HIT-II Program (University of Washington)

The primary focus of the University of Washington theory effort is the understanding of relaxation in CHI current drive. Earlier work by Orvis showed that a hollow current profile plus a narrow vacuum region by the wall leads to the n=1 instability which seems to be a key player in relaxation. We are developing an analytic model of relaxation. So far Karsten McCollam have shown that when the n=1 mode is anti-symmetric a single mode causes MHD dynamo relaxation of the current profile. This effect is electrode polarity sensitive and consistent with the HIT-II data using different polarities. Further work is continuing with this model. We are running the Nimrod code to simulate current startup and relaxation in the HIT-SI experiment. Within a year or so we will be doing equilibrium and stability analyzes of profiles obtained from HIT-SI.

C. CDX-U Program (PPPL)

T. Rognlien and M. Rensink of the LLNL are modeling the CDX-U edge plasma with the UEDGE, a multi-fluid transport code that uses classical transport along magnetic field lines and anomalous transport perpendicular to them. The code performs 2-D calculations of the neutrals, plasma, impurities, and radiation, using models that have been benchmarked with hydrogen and carbon impurity transport data from the DIII-D tokamak. The UEDGE simulations will be particularly important for the interpretation of the liquid lithium limiter experiments on CDX-U, since lithium is expected to have a significant effect on particle recycling.

IV. ST Theory Development Meeting (September 21, 2001, PPPL)

While the preceding theory participation tends to apply largely existing theoretical understanding, models and tools, the ST experimental results so far have indicated several likely new opportunities for theory development. An ST Theory Panel is being formed of senior theory leaders to review the latest advances in ST-related theory research, identify new opportunities for development of ST theories and computational tools, hold the broadly attended theory development meeting, and report their findings and recommendations on ST Theory Development Opportunities to the NSTX Program Advisory Committee. The information so introduced will provide an updated basis for engaging the magnetic fusion theory community in the development of new theories of importance to the progress of ST plasma physics, and enhancing community Theory research and cooperation on ST.

The Panel members will be invited to participate in the first NSTX Research Results Review scheduled for September 19-20, 2001 at PPPL. Experimental seminars from Pegasus (University of Wisconsin) and the Mega Ampere Spherical Tokamak (MAST, U.K.) are also scheduled for September 17-18, 2001 at PPPL to bring the latest ST data into focus. Results from HIT-II (University of Washington) and CDX-U (PPPL) will be presented jointly with the NSTX results review. The Panel is scheduled to meet on September 21, 2001 at PPPL.

Example scientific topics of interest, as suggested by new experimental results, could include:

(1) Magnetic reconnection and plasma relaxation during CHI
(2) MHD equilibrium with large plasma flow and/or extreme low A, and its stability
(3) Wave-plasma interactions in over-dense plasmas
(4) Supra-Alfven energetic particle, plasma, and wave/oscillation interactions

(5) High-beta turbulence and transport in strongly toroidal plasmas
(6) Stability, turbulence, and transport in open flux surfaces with strong mirror ratios

We are very pleased to report that Professor Jim Callen (University of Wisconsin) has agreed to serve as the Panel Chairperson. The ST research programs will support him and the NSTX PAC Chairperson Bill Nevins (LLNL) in carrying out this very important assessment of the ST theory development opportunities, as new discoveries emerge from the ST research programs.

For more information on this input to FESAC, please contact

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Pegasus: Ray Fonck, fonck@engr.wisc.edu
HIT-II: Tom Jarboe, jarboe@aa.washington.edu
CDX-U: Dick Majeski, rmajeski@pppl.gov; Bob Kaita, rkaita@pppl.gov

Table I. NSTX Theory Collaboration Funded by OFES NSTX Science

Updated July, 2001

Institution	Home-Site Lead	Current Research Topic	Collaboration Lead	Onsite Contact
Columbia U	Jerry Navratil Navratil@columbia.edu	MHD Studies	Steve Sabbagh ssabbagh@pppl.gov	Stan Kaye skaye@pppl.gov
CompX	Bob Harvey bobh@compxco.com	Kinetic Modeling of RF Heating and Current Drive (PPPL subcontract)	Bob Harvey bobh@compxco.com	Gary Taylor gtaylor@pppl.,gov
General Atomics	John Ferron ferron@gav.gat.com	Coaxial Helicity Injection (CHI) Equilibrium Reconstruction	Mike Schaffer schaffer@gav.gat.com	Stan Kaye skaye@pppl.gov
LLNL	Gary Porter Porter2@llnl.gov	Edge, Scrape-Off Layer Modeling	Gary Porter Porter2@llnl.gov	Daren Stotler dstotler@pppl.gov
		Boundary Plasma Stability & Turbulence	Xueqiao Xu xxu@llnl.gov	Greg Rewoldt grewoldt@pppl.gov
Lodestar	Dan D'Ippolito dasd@lodestar.com	Boundary Plasma Stability & Turbulence (new proposal submitted to OFES NSTX Science)	Jim Myra myra@lodestar.com	Stewart Zweben szweben@pppl.gov
MIT	Miklos Porkolab Porkolab@psfc.mit.edu	Electron Cyclotron Heating-Electron Bernstein Wave Modeling	Abe Bers bers@mit.edu Abhay Ram Abhay@psfc.mit.edu	Gary Taylor gtaylor@pppl.gov
		Ion Cyclotron Radio Frequency Modeling	Paul Bonoli Bonoli@psfc.mit.edu	Cynthia Phillips ckphillips@pppl.gov
ORNL	Peter Mioduszewski mioduszewspk@ornl.gov	Transport Simulation	Wayne Houlberg houlbergwa@ornl.gov	Stan Kaye skaye@pppl.gov
	David Rasmussen rasmussenda@ornl.gov	Radio Frequency Launcher Design & Experiments (currently VLT funded in part)	David Swain swaindw@ornl.gov Mark Carter cartermd@ornl.gov	Randy Wilson jwilson@pppl.gov
U Washington	Tom Jarboe Jarboe@aa.washington.edu	Coaxial Helicity Injection	Roger Raman raman@aa.washington.edu	Dennis Mueller dmueller@pppl.gov
UCSD	Charlie Baker cbaker@iter.ucsd.edu	High Harmonic Fast Wave Modeling	T K Mau mau@fusion.ucsd.edu	Jon Menard jmenard@pppl.gov

Table II. NSTX Theory Cooperation Funded by Other OFES Programs

Updated July, 2001

Institution	Home-Site Lead	Research Topic	Collaboration Lead	Onsite Contact
Dartmouth U	Barrett Rogers rogers@erie.umd.edu	Simulation of NSTX Edge Turbulence due to Local Drift Ballooning Modes (currently funded by OFES Theory)	Barrett Rogers rogers@erie.umd.edu	Stewart Zweben szweben@pppl.gov
INRS Quebec, Canada	Jean-Pierre Matte matte@inrs-ener.uquebec.ca	Improved Analysis of non-local electron heat transport (proposed to OFES Theory Program)	Jean-Pierre Matte matte@inrs-ener.uquebec.ca	Daren Stotler dstotler@pppl.gov
IPP, Garching FDR	Klaus Hallaschek ksh@ipp.mpg.de	Simulation of NSTX Edge Turbulence due to Non-local Drift Ballooning Modes	Klaus Hallaschek ksh@ipp.mpg.de	Stewart Zweben szweben@pppl.gov
Ukrainian Institute for Nuclear Research	Viktor Yavorskij	Effects of Non-Adiabatic Fast Ions in NSTX (proposal to be submitted)	Viktor Yavorskij	Doug Darrow ddarrow@pppl.gov
LANL	Alan Glasser ahg@nimrod.lanl.gov	Fast Macroscopic Stability and Particle Orbit Modeling (currently funded by OFES Theory)	Alan Glasser ahg@nimrod.lanl.gov	Steve Sabbagh ssabbagh@pppl.gov
MIT	Miklos Porkolab Porkolab@psfc.mit.edu	Phase Space Boundaries of Fast Ions in NSTX (currently funded by OFES Theory, proposal to be submitted)	Jan Egedal jegedal@psfc.mit.edu	Doug Darrow ddarrow@pppl.gov
NYU	C S Chang cschang@pppl.gov	X-Point Transport Effects on H-Mode Transition, and Gyrokinetic Simulation of RF-Driven Plasma Spinup (currently funded by OFES Theory)	C S Chang cschang@pppl.gov	Martin Peng mpeng@pppl.gov
ORNL	Don Batchelor batchelordb@ornl.gov	Neoclassical corrections to electron-ion energy transfer (currently funded by OFES Theory)	Steve Hirshman hirshmansp@pppl.gov	Stan Kaye skaye@pppl.gov
		Coupling AORSA-2D full wave HHFW computation with EFIT equilibrium modeling	Fred Jaeger jaegeref@ornl.gov	Cynthia Phillops ckphillips@pppl.gov
U Maryland	Jim Drake drake@plasma.umd.edu	Gyrokinetic simulation of electrostatic and electromagnetic turbulence (currently funded by OFES Theory)	Bill Dorland bdorland@ipr.umd.edu	Clarisse Bourdelle cbourdelle@pppl.gov
UCSD	Sergei Krasheninnikov skrash@mae.ucsd.edu	Far SOL Turbulence & Transport (currently Funded by OFES Theory)	Alexander Pigarov apigarov@fusion.ucsd.edu	Rajesh Maingi rmaingi@pppl.gov