The PPPL Highlights for the week ending April 8, 2016 are as follows:

**U.S. ITER FABRICATION (C. NEUMEYER):**

**Steady State Electric Network (SSEN):**

Uninterruptible Power Supply (UPS) system and DC Distribution: Preparation of the RFPs is underway. Sample contracts have completed review by U.S. ITER/ORNL procurement group with respect to ITER-specific requirements. Package will be submitted next to PNNL for review prior to submittal for DOE review.

6.6 Switchgear: Factory Acceptance Testing (FAT) of Lot 2 was completed at the factory of Schneider Electric in Manisa, Turkey.

Power Transformers: The Lot 3 packing inspection has been competed at the factory of Schneider Electric in Çayirova-Kocaeli, Turkey (near Istanbul). The pro forma invoices have been completed and approved. The Release for Shipping (RFS) document package is still a work in progress. The shipping date is April 19 but will probably be postponed due to late submittal of the RFS package. There is still ample float with respect to the milestone. Note that the delivery of this shipment (by June 15) is an important ITER Council and PEMP milestone, and progress is well ahead of schedule. FAT of Lot 1 and Lot 2 will take place this coming week.

**Diagnostics:**

Upper Port Wide Angle View Vis-IR Cameras (UWAVs): The UWAVs team at General Atomic and TNO is focused on wrapping up some details for the optical-mechanical and system level design. Bullnose and front-end mirror cooling channels are being optimized. System level optical performance, measurement error, impact of optical element temperatures, and light transmission are also being evaluated. The in-vacuum preliminary design will be complete by the end of April.

Diagnostic RGA (DRGA): DRGA prototype testing continues at ORNL. Testing has commenced on a gate-able gas “puff” valve to allow millisecond control of gas flow into the DRGA analysis chamber. A valve has been identified within ORNL stocks, matched to a power supply, and successfully controlled to deliver a range of gas flows from 1 to 250 SCCM. This capability is needed to ensure and demonstrate the “1 second” time response measurement requirement of the full system.
Upper Port 11 and 14 Integration and Diagnostic Shield Module (DSM) Engineering: Added additional longer spiral bends to the DSM pipe to let it flex during the bakeout and operation. More analysis is needed to confirm that bellows and additional pipe bends would not be needed on this pipe manifold to gain flexibility. This change in DSM piping design requires adjustment to the UP#14 and UP#11 installation scheme. Closure plate integration and remote handling assessment has started. The department met with analysis team to discuss the status of UP#14 analysis for the Load Spec. UP#14 tenants are moving towards their PDR design and requesting loads from the port integrator to design their system. The analysis team is going to evaluate the workload and give feedback.

Equatorial Port 9 Integration and DSM Engineering: This week, U.S. ITER approved the Project Change Request (PCR) for an updated EP09 integration schedule and budget plan covering the PDR phase. This will significantly improve work planning and tracking metrics through better alignment with current work. DSM design has received further analysis guidance for optimizing internal coolant paths. Temperature distributions for cooling and baking are very favorable. The EP09 team is committed to re-evaluate port plug structural design to meet ITER weight requirements. A new iteration for optimizing the challenging balance of weight and neutron shielding, a primary concern for the project, commences next week.

Toroidal Interferometer and Polarimeter (TIP): We received a draft Interface Sheet (IS) covering the vacuum windows, supplied by the ITER Organization, for the U.S. toroidal interferometer/polarimeter (TIP) diagnostic. Barium Fluoride (BaF2) is the baseline window material, with CVD diamond proposed as an alternative, should development of the BaF2 windows prove impractical. The U.S. team will review the details of the optical specifications for these windows, with a goal to finalize the IS in the next few months.

Core Imaging X-Ray Spectrometer (CIXS): A peer review for the CIXS detector magnetic testing has been set up for next week to review the test method, bracket designs, procedure, and more. The aim is to prepare and verify that tests are ready to be performed during the upcoming NSTX maintenance week. Preliminary data has been received on initial C-MOD runs for our Xenon crystal testing. The reactor is not yet running at high enough power for Xenon, so initial results looked at the Calcium spectral line to verify crystal was working properly. Results are promising, refracting expected Ca line and showing the crystal is ready for high power testing with Xenon.

NSTX (M. ONO):

A FY2016 NSTX-U plasma operations update: The department has completed 7.23 run weeks and 748 plasma shots. The total operation target is 18 run weeks.

A research highlight on the Materials Analysis Particle Probe (MAPP) appeared in the March 31 Monthly Newsletter of the U.S. Burning Plasma Organization (USBPO). Understanding plasma-wall interactions is critical to the development of controlled thermonuclear fusion. The MAPP diagnostic provides unique data toward this goal through exposing first-wall materials to tokamak discharges, and analyzing them without compromising any time-sensitive chemistry-dependent surface information. This is accomplished by withdrawing samples into a separate chamber under vacuum, where their surfaces can be probed with X-rays and low energy ions to
characterize them. The MAPP system was installed on NSTX-U as a collaborative effort by the University of Illinois at Urbana-Champaign (UIUC) and PPPL, and has already been used to study the effects of surface conditioning techniques on plasma-facing components.

NSTX-U researchers and collaborators attended the US Transport Task Force meeting on March 28–April 1 in Denver, Colorado (http://www-internal.psfc.mit.edu/TTF2016/index2016.html). Talks were presented by J. Canik (ORNL), T. Gray (ORNL), W. Guttenfelder, M. Podesta, Y. Ren, and J. Ruiz Ruiz (MIT). Posters were presented by A. Diallo, S. Kubota (UCLA), D. Ogata (U. Alaska-Fairbanks), and S. Zweben. F. Poli led a Working Group discussion on modeling the so-called No Man’s Land (the transitional region between core and top of the H-mode pedestal).

V. Soukhanovskii (LLNL) attended the International Conference on Atomic Processes in Plasmas (ICAPiP) in Paris, France, where he presented an invited talk titled “Near-infrared spectroscopy of tokamak divertor plasmas.” In the talk, experimental results from NSTX, DIII-D, and recent calculations from the non-LTE code Cretin were used to demonstrate how extending conventional spectroscopic methods to the near-infrared region can augment plasma-surface interaction studies and temperature and density measurements from Stark-broadened Paschen series deuterium lines in recombining divertor plasmas. Discussions were held with atomic physics data community scientists on the status and availability of state-of-the-art atomic structure and transition rate data for low and high-Z impurities in support of planned NSTX-U radiative divertor experiments and molybdenum spectroscopy for divertor erosion and core transport measurements.

R. Kaita gave a seminar entitled “The Dusty Road to Fusion: Addressing First Wall Erosion in the National Spherical Torus Experiment-Upgrade” at Baylor University in Waco, Texas on April 5. The topics included results from the Materials Analysis and Particle Probe (MAPP), which allows samples of plasma-facing components (PFCs) to be exposed to plasmas and withdrawn into a surface analysis chamber without breaking vacuum. Experiments conducted to study lithium coatings on PFCs in the Magnum-PSI linear plasma device were also summarized. They showed a significant reduction in lithium erosion compared to expectations from temperature-dependent thermal sputtering and evaporation, and the mechanism has been explained by first-principles molecular dynamics calculations that model the mixed material formed by the lithium and the incident deuterium. Problems common to effects of plasmas on PFC on NSTX-U and studies of plasma-surface interactions in complex (“dusty”) plasmas were also discussed with students and faculty at the Center for Astrophysics, Space Physics, and Engineering Research (CASPER) at Baylor University.

The first ideal MHD stability computations run for NSTX-U H-Mode plasmas using DCON were performed on kinetic equilibrium reconstructions of shots 204112 and 204118, which reached normalized beta above four. For each discharge, the plasma is shown to move above the $n = 1$ no-wall limit during the discharge evolution. A composite no-wall beta limit model by J.W. Berkery (Columbia University), et al. (Nucl. Fusion 55 (2015) 123007), which includes internal inductance, pressure peaking, and plasma aspect ratio as parameters is shown to well-represent the no-wall beta limit. The model will be further tested against NSTX-U plasmas and DCON calculations as the first component of a simplified model for kinetic RWM evaluation, to be used for disruption forecasting.
The first four shots of April 4, were dedicated to XMP-143, degassing the walls from the boronization on the previous evening. These shots also tested various phases of the n=1 correction, scanning over about 60 degrees toroidal (from the optimal phase inferred in the XMP-140 to the optimal phase inferred from XP-1506). The rotation from the rtVphi diagnostic was used as the metric. There were no immediate conclusions regarding the optimum n=1 phase, but the phase inferred from to be optimal from the XP-1506 compass scan at least did no harm.

This activity was followed by XMP-142 (Establish H-mode with reduced MHD over a range of I_p and B_t). These shots were successful in developing long H-mode scenarios at 900 kA and 1 MA. The 1 MA scenario (204118), which was the first 1 MA H-mode in NSTX-U, set an NSTX-U record stored energy of 330 kJ. This shot also demonstrated the longest period yet of low internal inductance (l_i=0.65 for about a 0.9 second duration). The best discharge at 900kA (204112) maintained a normalized beta near four and minimal MHD activity for 0.5s. Key features enabling these advances were use of the new n=1 EFC phase established in XP-1506, higher beam power (5.4MW from four beams: 1B, 1C, 2A, 2C) and higher plasma current, both of which helped maintain ELMs at high density (60-90% of the Greenwald density limit). The increased power also provided more consistent entry to H-mode as the oxygen content increased after many shots following the boronization.

A new boronization sequence was started on the evening of April 4, and continued each evening through April 7. A ~¼ bottle boronization was performed each night, followed by a half hour helium GDC session. An additional half hour of He GDC was also done on the mornings of April 6, April 7, and April 8.

April 5 was dedicated to additional shots towards XMP-142, following an extended delay to remedy problems in FCPC. These shots were unable to replicate the excellent results on April 4, due to an inability to achieve and/or sustain H-mode plasmas. This observation motivated the additional morning He GDC on following days, as noted above.

The morning of April 6 was dedicated to running XMP-147 (Improve L-mode Fiducial). This activity involved moving the start of the ISOFLUX X-point control phase earlier so that the X-point feedback control could be used to determine the time of diverting and the early evolution of the inner gap. The approach was successful in reducing and sometimes eliminating vertical oscillations at the time of diverting that had been observed in earlier shots. The improved control transitions will make the scenario easier to use in future L-mode XMPs and XPs, and will be applied to H-mode scenario development. The shots in XMP-147 were also used to tune aspects of the controlled ramp-down of the plasma current (beam modulation, plasma current ramp rate, vertical control, etc.), resulting in a successful disruption free ramp-down (204155). Finally, the flattop of the XMP-147 shots was used to try aspects of XMP-146 (n=2,3 error field correction) in piggyback. Changes to the plasma rotation and density were observed as n=2 fields were applied, and analysis is ongoing. Operations were terminated at ~12:00 due to a leak in a cooling water flow switch for a vacuum ruffing pump in the NSTX-U Test Cell.

Operations resumed at ~1:30 on April 7, following final recovery from the water leak. The first shots of the day finished the present XMP-147 activities using a 1 MW L-mode plasma, demonstrating both upper and lower biasing of the plasma, from the time of diverting through the entire flat-top. Shots were then taken towards XMP-142. These shots used the H-mode gas fueling, beam power, and shape evolution recipe developed on April 4, and combined them with
the improved shape control developed under XMP-147. These resulted in a 1 second, 900 kA H-mode plasma (shot 204172) with performance largely comparable to discharges on April 4, but with improved shape control capabilities.

Most of the run day on April 8 was dedicated to XMP-142. Some progress was made in improving the vertical position control in these H-mode plasmas, but difficult in achieving and sustaining H-mode hindered progress. The final two hours of the day were dedicated to XMP-148 (BEAST Validation, S. Kaye and R. Bell). These shots used only beamline #1, and were able to collect good data for the CHERS diagnostic and for validation TRANSP calculations.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

N. Logan, in collaboration with J.K. Park, is now maintaining official releases of the Generalized Perturbed Equilibrium Code (GPEC) at PPPL. Initial releases contain the Ideal Perturbed Equilibrium Code (IPEC) with new tools for identifying multi-modal plasma responses using the plasma reluctance eigenmodes and v0.4.0 will be the first release containing the kinetic MHD eigenfunctions necessary for self-consistent calculations of neoclassical non-ambipolar transport. With the advent of public releases and documentation, Logan and the GPEC team will now support a number of non-developer users who can fully utilize the power of the computational modeling for 3D plasma response analysis and database formation. The GPEC developer team is also expanding, and welcomes Princeton University graduate student, A. Glasser, who will be working to parallelize the new kinetic pressure tensor calculations.

R. Nazikian visited IPP in Garching to participate with Andy Kirk (CCFE) and Wolfgang Suttrop (IPP) in RMP ELM suppression experiments on ASDEX-U. The experiments explored ELM suppression with n=2, 3, and 4 fields and useful information was obtained on the conditions required for ELM suppression in terms of the amplitude of the applied field and the rotation in the plasma.

The lithium granule injector was used in experiments extending the high poloidal beta scenario to higher current in a joint experiment between DIII-D and EAST. Six plasma discharges had LGI with frequencies between 10-90 Hz.

International (F. Poli):

F. Poli attended the EC-19, a joint workshop on Electron Cyclotron Heating and ECE in Ahmedabad, India, April 4-7. Poli presented an invited talk entitled “Electron Cyclotron power management in ITER, from the commissioning phase to the demonstration baseline.” The focus of the paper was on EC power requirements for NTM stabilization in plasma scenarios at half-field and full field, both in the pre-DT and DT phase.
ADVANCED PROJECTS (H. NEILSON):

C. Kessel led the Fusion Energy System Studies project meeting in Denver, April 5-7, in which the national team discussed progress on the current study of mission and R&D needs for a fusion nuclear science facility (FNSF). Kessel presented the core plasma physics progress, and led discussions on three topics—PFC/PMI, thermo-mechanics analysis, and FNSF program and testing. Y. Zhai (PPPL) presented progress in the magnet winding pack design. Presentations were given by team members covering maintenance, CAD layout, nuclear analysis, liquid metal breeder, accident strategies, disruptions and transients, blanket and divertor thermo-mechanics, magnets progress, tritium issues, materials, SOL/divertor plasma, and tungsten progress. The project is in its final year, focused on completing detailed analysis, parametrics sensitivities, program and testing strategies, and pre-FNSF R&D identification. Some highlights included the MHD simulations showing low pressure drops in the LiPb breeder with SiC-c flow channel inserts for the DCLL design, the use of irradiated material properties in thermo-mechanie analysis of the blanket, simulations showing a continuous transition between the partially and fully detached divertor regimes as the slot geometry is changed, updates on examination of the VM-tungsten alloy (used in lightbulbs), and time-dependent plasma evolution with both LFS and HFS lower hybrid current drive.

S. Lazerson presented a poster entitled “The QUASAR experiment as a facility to test ITG turbulence” at the 2016 Sherwood Fusion Theory Conference held in Madison Wisconsin. In this work, the QUASAR device was used as a basis for a set of numerical simulations to experimentally test the response of ITG turbulence. Free boundary ideal MHD equilibria were generated for the device holding the edge iota fixed and leveraging the toroidal field coil set of the device. Assuming ohmic discharge conditions and 2% beta, the equilibria were evaluated using proxies functions, linear, and non-linear gyro-kinetic flux tube simulations (GENE). The results showed a consistent reduction of electrostatic ITG turbulence at all radii for a case with tokamak-like shear. This work demonstrated some of the unique physics, which could be explored in the QUASAR experiment.

The Laboratory hosted a working meeting on remote collaboration technology for Wendelstein 7-X (W7-X), the purpose of which was to identify solutions for improving capabilities for remote participation by U.S. scientists in W7-X research. Attending the meeting were Drs. Stephan Bosch and Andreas Werner from the Max Planck Institute for Plasma Physics and members of the Laboratory’s research and information technology departments. Drs. Glen Wurden (Los Alamos National Laboratory) and Oliver Schmitz (University of Wisconsin) participated remotely. Attendees identified gaps between existing and desired capabilities for accessing W7-X data and for communicating during experimental sessions and physics meetings. Practical solutions for narrowing or closing these gaps were identified. A joint implementation plan consistent with resource availability and IT security constraints at each institution will be developed.

D. Gates served on the international selection committee for the International Atomic Energy Agency's (IAEA) Fusion Energy Conference (FEC). The committee is tasked with selecting which of the more than 800 submitted of papers will be oral presentations at the upcoming FEC, which will be held in Kyoto Japan in October. The meeting was held from April 4-8 in Vienna, Austria at the headquarters of the IAEA. The committee consisted of 28 individuals representing
On April 4-6, members of the Theory Department attended the Sherwood Theory Conference in Madison, Wisconsin. Poster presentations were given by the following researchers: D. Brennan—“A reduced model of differential flow effects on stability and penetration of coupled toroidal modes”, N. Ferraro—“M3D-C1 Modeling of Disruptive Instabilities,” S. Janhunen—“Mixed finite-element/finite difference method for toroidal field-aligned elliptic electromagnetic equation” and S. Jardin—“Progress on Nonlinear Resistive MHD Code Verification Problems with M3D-C1.” Two Theory Department graduate students also presented posters, J. Lestz—“Hybrid MHD/particle simulation study of sub-cyclotron Alfvén Eigenmodes in NSTX” and Y. Zhou—“Topologically constrained equilibration of the ideal coalescence instability.”

In addition, there were four invited talks by researchers associated with the PPPL Theory department. V. Duarte presented an invited talk entitled “First realistic characterization of chirping instabilities in tokamaks.” The abstract reads: “In order to properly characterize Alfvénic modes observed in the experiment, the theory of driven kinetic instabilities in the presence of dissipation was extended to account for multiple resonance surfaces and realistic mode structures. A criterion for chirping modes existence was derived and shown to be in accordance with observations in different tokamaks. Microturbulence was introduced for the first time in the model and was shown to be an important diffusive mechanism responsible for particle decorrelation from the coherent structures that support chirping modes.”

F. Ebrahimi presented an invited talk entitled “Physics of plasmoid-mediated reconnection and flux closure in simulations of Coaxial Helicity Injection.” The talk was about “…the process of forced and spontaneous magnetic reconnection during coaxial helicity injection (CHI) in NSTX/NSTX-U. Two major findings were reported: (1) first documentation of plasmoid formation in a laboratory (NSTX) predicted by realistic MHD simulations (http://dx.doi.org/10.1103/PhysRevLett.114.205003), and (2) large-volume flux closure and maximum CHI-generated closed-flux current (http://dx.doi.org/10.1088/0029-5515/56/4/044002) during simulations of CHI in NSTX-U.”

S. Hudson gave an invited talk entitled “Penetration and amplification of resonant perturbations in 3D ideal-MHD equilibria.” The abstract reads: “Recently, and for the first time, we computed the 1/x and delta-function current-densities predicted in 3D solutions to \( \nabla \rho = j \times B \) with nested surfaces, and we realized that self-consistent solutions demand locally-infinite shear at the resonant surfaces. We introduced a new class of solutions that admit additional delta-function current-densities that produce a discontinuity in the rotational-transform, and we show that resonant perturbations penetrate past the rational surface and into the core of the plasma; and the perturbation is magnified by pressure inside the resonant surface, increasingly so as stability limits are approached.”

C. Liu presented an invited talk entitled “Adjoint method and runaway electron dynamics in momentum space.” The abstract reads: “In this work, the adjoint Fokker-Planck equation is applied to study the momentum space structure of relativistic runaway electrons. Two important
results are obtained from the method, the runaway probability function, and the expected slowing-down time. The runaway probability has a smooth transition across the runaway separatrix, which can be attributed to the pitch angle scattering. The expected slowing-down time gives a novel method to estimate the decay rate of runaway current in experiments, and reveals the existence of a potential barrier in momentum space in the marginal case (E is close to critical field).

In the last week of February, Liu and Brennan visited DIII-D to collaborate on runaway electron experiments that tested some of the theories described in this work. Liu also recently published a paper on the subject—Phys. Plasmas Letters 23, 010702, 2016.

**DIRECTOR’S OFFICE (C. AUSTIN):**

On April 8, Mitchell Silber from FTI Consulting, presented a colloquium entitled, “The Evolving Terrorist Threat.”

This report is also available on the following web site:
[http://www.pppl.gov/publication-type/weekly-highlights](http://www.pppl.gov/publication-type/weekly-highlights)