The PPPL Highlights for the week ending April 1, 2016 are as follows:

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

Tokamak Cooling Water System (TCWS) Electrical Engineering Support:

As part of an existing agreement between Princeton Plasma Physics Laboratory (PPPL), U.S. ITER, and ORNL, PPPL provides review and consultation on electrical engineering matters related to the TCWS. The TCWS design scope, including electrical engineering and other disciplines, has been transferred to the IO by way of an arrangement. PPPL was asked to review the status of the IO TCWS electrical engineering work and has identified some significant issues.

A videoconference was held to develop an overall U.S. ITER strategy to address the issues and a recommended course of action was agreed upon. PPPL will continue to serve in a consulting role (reviewing documents and attending design reviews) but will not provide supervision of the IO design team. That responsibility falls on the ORNL TCWS team.

Steady State Electric Network (SSEN):

Uninterruptible Power Supply (UPS) system and DC Distribution: Preparation of the RFP's is underway.

Power Transformers: PPPL's subcontract QC inspector visited the factory to confirm that the punch list items have been correctly remedied and to inspect the final packaged units. The Release for Shipping (RFS) document package is still a work in progress. The shipping date is April 19, and there is still ample float with respect to the milestone. The delivery of this shipment—by June 15—is an important ITER Council and PEMP milestone, and progress is well ahead of schedule.

Diagnostics:

Upper Port Wide Angle View Vis-IR Cameras (UWAVs): UWAVs preliminary design continues under a subcontract with General Atomics (GA) and TNO. Engineering work is focused on the optimization of the in-vacuum optical mechanical design. There are five UWAVs systems to be integrated into five different Upper Port Plugs managed by three different Domestic Agencies (DA's). Management of these complex integration relationships is a big part of the UWAVs project. This month, a negotiation started with the European DA over the integration of UWAVs into Upper Port 17 (UPP17). Currently, the UPP17 shield module is not compatible with the UWAVs design. The UWAVs space claim and detailed models were available in the ITER CAD

system and both sides are now investigating why this CAD data was not used for the UPP17 shield module design.

Electron Cyclotron Emission (ECE): The ECE team at the University of Texas, Austin, and PPPL have decided to hold a focused Peer Review of the ECE Hot Calibration Source preliminary design at ITER in November. The full ECE PDR will not be until 2017 but the UT engineers need a thorough technical review of the Hot Source design in order to validate the design and continue into a final design phase.

Toroidal Interferometer and Polarimeter (TIP): The TIP engineering team is working with ITER Blanket Shield Module (BSM) engineers and nuclear analysis experts at the University of Wisconsin (UW) on a detailed thermal model of the TIP Corner Cube Reflector (CCRs) components. The UW team is under contract with ITER to perform neutronics analysis of certain BSMs. Some of these BSMs also contain embedded TIP CCRs. PPPL will provide updated CCR models to UW and UW will furnish detailed nuclear heating data for the BSMs and TIP CCRs. This data will then be used by the IO BSM team to calculate temperatures in the CCRs based on a fully detailed BSM thermal-hydraulic model.

Diagnostic I&C Integration Engineering (ORNL, B. DeVan):

Through a productive partnership between ORNL, U.S. ITER, and PPPL, the development of critical I&C Integration documents is proceeding well. B. DeVan has been spearheading the effort to create preliminary design level Piping and Instrumentation Diagrams (P&ID), Single Line Diagrams (SLDs), and a Cable Collection spreadsheet for all of the U.S. ITER diagnostics and port plugs. ITER has asked for these drawings as part of the ITER building process. I&C diagrams for the Basement level B1 were due first, followed by Level L1 equatorial port diagrams. Development of these drawings and diagrams has also helped to organize the various systems and provides a way to present the complex scope in one drawing view.

NSTX-U (M. ONO):

FY2016 NSTX-U plasma operations update: The department has completed 6.45 run weeks and 664 plasma shots. The total operation targets are to be decided.

Graduate student Y. Yoshida from the University of Tokyo completed his visited to PPPL under the Princeton University/University of Tokyo Student Exchange Program (February 26 to March 29). Yusuke worked with S. Kubota (UCLA) on adapting ray tracing and beam tracing codes to determine the propagation characteristics of millimeter-wave beams launched for the UCLA Doppler backscattering diagnostic on NSTX-U. Target plasmas used current and previous shots from NSTX and NSTX-U. This work will aid in the qualitative analysis of the experimental data (once the diagnostic is in place), and his future participation in this project is also anticipated.

On March 28, four shots were taken at the beginning of the day under XMP-143 (Assess Machine Conditions). The 1MW L-mode shots were used to recover from the boronization on March 26. The discharges for the remainder of the day were dedicated to XMP-142 (reduced MHD H-mode development) toward developing a reproducible H-mode scenario that achieves low li and high elongation via an H-mode transition during the I_p ramp up. This scenario can

result in long periods of reduced MHD activity during the H-mode flattop that enables future transport studies. The first discharges to put power on the inner divertor following boronization achieved H-mode flattop with frequent small ELMs (203957-203963). Later discharges transitioned to larger, infrequent type-I ELMs (203971). It was observed that 3.5 MW heating resulted in ELM-free operation, 4.0 MW generated ELMy discharges, while greater than 4.5 MW prior to the start of ELMs led to a disruption at I_p = 800kA, B_t = 0.63T. The timing of diverting and H-mode was moved earlier in the discharge enabling the lowest sustained l_i value (~ 0.6 on 203980) and the highest instantaneous stored energy yet in NSTX-U (~250 kJ on 203981). Some progress was made on implementing X-point and drsep control in the H-mode scenario. Discharge repeatability was hindered by evolving beam availability and wall conditions.

On Tuesday, the first six shots continued XMP-142 to investigate the impact of drsep on the ELM character and continue developing ISOFLUX control in H-mode. The power threshold for ELMs was higher as the impurity content had steadily risen from the previous day. The remainder of the day was dedicated to XMP-145 (Development of Scenarios with Flat-Top H-mode). These shots suffered from some beam timing issues, as well as radial control problems and an elevated L->H threshold, prevented significant progress. However, the final shot of the day produced the highest value of betaN yet achieved (~4.8) in NSTX-U.

On Wednesday, eight shots were taken in the morning under XMP-110 (FIDA/ssNPA/sFLIP checkout). Isolated short pulses (20ms, 1MW power) of four neutral beams at different tangential radii were injected into L-mode plasmas to assess fast ion confinement and check/optimize FIDA and ssNPA diagnostics. Data was collected from the neutron detectors, MPTS, FIDA, and ssNPA diagnostics. The neutron rise and decay rate during beam modulations will be used to compare the confinement of fast ions form NB line #1 and new NB line #2. Clear active and passive responses have been observed on FIDA and ssNPA diagnostics. Some shots, however, suffered from the neutral beams failing to fully produce the requested modulation patterns. The dataset is a good starting point for XP-1522 (beam ion confinement) and will enable initial estimation of fast ion confinement time. The second half of the day was spent on the ninth vacuum vessel boronization.

Eighteen shots were taken toward XMP-142 aimed at establishing low-li, highly shaped ELMy H-mode with about 4.4 MW from three neutral beams. Variations in the early density (before 200ms) established a narrow range for the present scenario, presumably due to the dependence of the neutral beam absorption with density. At low density the power absorption is reduced and the L-H transition is delayed or missed entirely. At high density the power absorption is improved leading to increased normalized beta and MHD mode activity during the ramp-up. A number of good shots (204047, 204049, 204051, 204056) with heating variations in the flattop established a normalized beta limit near 3.5 (~ 5 l_i at kappa ~ 2.2) for the present scenario. As was observed on Monday, the first few H-mode shots following boronization had small, frequent ELMs, while the later shots had regular type-I ELMs. Oxygen levels rose through the day, leading to less reproducible L-H entry and longer ELM-free periods at the end of the day. Continued progress was made in establishing X-point control in highly-shaped H-mode discharges. The final shot of the day was a 1.8 second 700 kA L-mode, demonstrating that elevated oxygen levels are benign for L-mode discharges. In addition, implementation of “slow-ramp-down” that executes a soft-landing of the discharge was integrated into the morning fiducial.

On Friday, an *n*=1 compass scan was conducted under XP-1506 (low-beta *n*=1 error field correction). The target plasma for this scan was the 1 MW beam-heated, sawtoothing L-mode fiducial discharge. After the onset of sawtoothing, the applied *n*=1 fields were ramped in amplitude at selected phases to induce locking. Clear mode locking and disruptive behavior was observed throughout the compass scan and a good circular error field correction pattern was obtained. The optimal correction, as indicated by the compass scan, shifted slightly from the results of XMP-140 (PF5 proportional error field correction), which was conducted in ohmic rather than beam-heated plasmas. After the completion of the XP-1506 compass scan, three shots toward XMP-146 (initial *n*=2,3 error field correction) were taken. In these two second discharges, the amplitude and phase of *n*=2,3 fields were modulated in 250 ms increments to assess whether the discharge was impacted by these higher order applied fields. Preliminary analysis from the rtVphi diagnostic indicates that core and edge rotation were impacted, especially with certain phases of *n*=2 applied fields. These results motivate further studies of *n*=2,3 error field correction.

Later in the afternoon, eight shots continued XMP 110 (FIDA/ssNPA/sFLIP checkout) to measure the stationary fast ion slowing-down distribution function with FIDA and ssNPA diagnostics. Instead of short beam blips, ~100ms (> slowing-down time) pulses were injected to center-stack limited L-mode plasmas. Three good shots (204090-204092) were obtained with the most tangential neutral beam 2A and the most perpendicular beam 1C respectively. The neutron generation rate shows a clear difference between these two beams. The dataset is complementary to that obtained on Wednesday morning. More detailed data analysis is underway to check fast ion distribution and to compare with classical theory.

NSTX-U plasma operations continued this past week after a weekend vessel boronization. Neutral beam injection and the Switching Power Amplifier (SPA) driven Resistive Wall Mode coils were used in support of experiments on H-mode development, error field correction, and long pulse L-mode plasmas. All six neutral beam ion sources are operational and are being actively conditioned in the 60 to 90kV range. Vessel boronizations have proved to be highly effective in controlling oxygen levels during discharges, and procedures/training are being updated to allow for limited, shorter boronizations that could be performed during the latter parts of weekday second shifts.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

R. Nazikian led an experiment with C. Paz-Soldan and C. Petty (GA) to explore ELM suppression by 3D fields in hybrid plasmas with high fraction of noninductive current. The focus of the experiment was to extend previous results on ELM suppression to low rotation by use of counter beam injection. Progress was made on these objectives and a full report of results will be presented in an upcoming science meeting.

B. Grierson attended the TTF meeting in Denver, CO and delivered a plenary talk on the effects of electron heating in the DIII-D ITER baseline scenario. TGLF simulations matched experimental profiles and revealed that intermediate-k TEMs produce an inward particle pinch that causes an increase in density gradient at the location of ECH heating. Future work will apply

a new TGLF model that includes turbulence spreading in wavenumber space, based on multi-scale gyrokinetic simulations. S. Haskey also attended the TTF meeting and presented a poster on the recent development and analysis of the main ion CER system under Grierson's Early Career Award.

The IGI was successfully examined this week and is ready for experiments in the next week.

A. Nagy has taken the lead on the new off axis beam project on DIII-D. A key concept developed by Nagy is a sliding seal that will be used to connect the beam to the vessel without a bellows. If successful, the beam rotation will take only two days instead of one week with the bellows design.

Two new student interns have been identified to replace the two present student interns who have supported Nagy for the past year. The two departing interns have gained practical experience on a range of projects and have made valuable contributions to these projects, such as the impurity granule injector and the neutral beam controller.

International (F. Poli):

F. Poli attended the U.S. TTF workshop in Denver, Colorado. She presented work on the implementation of a reduced model for the pedestal in TRANSP, based on a lookup table of calculations from the EPED1 model. Poli also chaired a working group focusing on the modeling of the region between the pedestal and core.

ADVANCED PROJECTS (H. NEILSON):

D. Gates attended the Coordinated Working Group meeting held March 21-23 at the Max Planck Institute for Plasma Physics in Greifswald, Germany. Presentations were given by members of the international stellarator community on various topics of stellarator physics, including a presentation by S. Lazerson, "Error field measurements in Wendelstein7-X (W7-X)." The agenda for the meeting is available at http://www.ipp.mpg.de/cwgm. Afterward, Gates met with the directors of IPP to discuss follow up activities for the recently completed W7-X OP 1.1 campaign.

The Laboratory is preparing a sample tile assembly that will be used by the Max Plank Institute for Plasma Physics (IPP) for testing in their GLADIS high heat flux facility. The sample design, which includes a graphite tile and Langmuir probe mounted on a steel backplate, is prototypical of the TDU scraper element, now being fabricated by PPPL for installation in Wendelstein 7-X next year. An inspection of the graphite tile and Langmuir probe, which were manufactured by MWI Inc. of Rochester, New York, found the parts to be built exactly as specified and passed receipt inspection. Next, the tile will be test fitted to the backplate, in preparation for shipment to IPP.

THEORY (A. BHATTACHARJEE):

On March 31, V. Duarte (PPPL) presented a theory seminar on realistic characterizations of chirping instabilities in tokamaks: "In tokamak plasmas, the dynamics of phase-space structures with their associated frequency chirping is a topic of major interest in connection with mechanisms for fast ion losses. The onset of phase-space holes and clumps, which produce chirping phenomena, has been theoretically shown to be related to the emergence of an explosive solution of an integro-differential, nonlocal cubic equation that governs the early mode amplitude evolution in the nonlinear regime near marginal stability. We have extended the analysis of the model to quantitatively account for multiple resonance surfaces of a given mode in the presence of drag and diffusion (due to collisions and microturbulence) operators. Then a more realistic criterion is found, that takes into account the details of the mode structure and the variation of transport coefficients in phase space, to determine whether steady state solutions can or cannot exist. Stable steady state solutions indicate that chirping oscillations do not arise, while the lack of steady solutions due to the predominance of drag, is indicative that a frequency chirping response is likely in a plasma. Waves measured in experiments have been analyzed using NOVA and NOVA-K codes, with which we can realistically account for the mode structure and varying resonance responses spread over phase space. In the experiments presently analyzed, compatibility has been found between the theoretical predictions for whether chirping should or should not arise and the experimental observation or lack of observation of toroidicity-induced Alfvén eigenmodes in NSTX, DIII-D and TFTR. We have found that stochastic diffusion due to wave microturbulence is the dominant energetic particle transport mechanism in many plasma experiments, and its strength is the key as to whether chirping solutions are likely to arise."

On March 28, a paper by F. Ebrahimi and Eric Blackman entitled "Radially Dependent Large Scale Dynamos in Global Cylindrical Shear Flows and the Local Cartesian Limit" was published online in Monthly Notices of the Royal Astronomical Society, MNRAS (http://mnras.oxfordjournals.org/content/early/2016/03/28/mnras.stw724). In this paper "minimum conditions needed for large scale field growth" have been identified. We calculate the complete form of fluctuation-induced EMF for both global cylindrical and Cartesian geometries. Through both quasilinear analytical calculations and numerical simulations, we show that the combination of imposed non-axisymmetric fluctuations, even if not helical, and differential rotation (or linear shear in the Cartesian approximation) of the fluctuating field, is sufficient to source the electromotive force and generate a large scale magnetic field in the cylindrical geometry, a seemingly previously unidentified distinction. The standard Omega effect (shear of the mean field by differential rotation) is here shown to be unimportant. For the MRI case, we express the large-scale dynamo field as a function of differential rotation, and show that the global non-axisymmetric instability itself sources the EMF and the large-scale field grows on the time scale of the modal growth.

BUSINESS OPERATIONS (K. FISCHER):

Budget Office:

PPPL was included as a participant in a Small Business Innovative Research Phase II proposal submitted to DOE by Ultramet, Inc. titled "Innovative Surfaces for Controlled Flow of Liquid Metal Phase II." The Principal Investigator for the PPPL work scope is R. Majeski; the PPPL budget is $150,000.

An amendment to the Strategic Partnership Project agreement with Princeton University for the project titled "Fundamental Studies of Reactive Processes at Plasma-Surface Interfaces" was executed to add third year funding in the amount of $70,000 and extend the period of performance by one year. The PPPL Principal Investigator for the project is Y. Raitses.

INFORMATION TECHNOLOGY (S. ZELICK):

The NSTX-U Gap Tile temperature checkpoint software is complete. The package will prevent further plasma shots if selected vessel tiles get too hot. This software package was efficiently developed by using standardized features of the NSTX-U software environment, including MDSplus, EPICS, and IDL.

COMMUNICATIONS & MEDIA RELATIONS (L. BERNARD):

Media:

Princeton Alumni Weekly (PAW) posted online at http://paw.princeton.edu/, the April 6 edition with the cover story on NSTX-U, "A Star on Earth." EnergyWire ran a March 29 story on fusion quoting several PPPL sources, including M. Zarnstorff, A. Bhattacharjee, C. Gentile, and H. Neilson. L. Bernard arranged interviews with C. Neumeyer and M. Donohue for Professional Engineer, the magazine of the National Society of Professional Engineers, for the May/June edition.

OFFICE OF ACADEMIC AFFAIRS (N. FISCH):

Physics, education and warm-hearted humor were all on display last week during a three-day symposium in honor of physicist N. Fisch's 65-year birthday. Attended by some 200 leading scientists from around the world, the event focused on "Solved and Unsolved Problems in Plasma Physics" and celebrated the myriad achievements of Fisch, who is associate director for Academic Affairs at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory, director of the graduate Program in Plasma Physics and professor and associate chair of the Department of Astrophysical Sciences at Princeton University.

More than 35 invited speakers, plus some dozen recent alumni, discussed key developments in plasma physics and looked ahead to issues to be worked on over the next decade. Subjects ranged from magnetic and inertial confinement fusion to solar coronal heating, next generation

laser and accelerator technology, philanthropic giving, and the future of U.S. science. Highlights included a banquet at which speakers praised and poked fun at Fisch and recalled incidents and stories about him.

DIRECTOR'S OFFICE (C. AUSTIN):

On March 30, Professor Joseph Mazur, Marlboro College presented a colloquium entitled, "Fluke: The Math and Myth of Coincidence."

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