The PPPL Highlights for the week ending January 15, 2016 are as follows:

NSTX (M. ONO):

A FY 2016 NSTX-U plasma operations update: The department has completed 1.74 run weeks and 170 plasma shots. The total operation targets are to be decided.

J. Menard (PPPL) attended the Fusion Energy Sciences Advisory Committee (FESAC) meeting held in Bethesda, MD on January 13-14 and gave a presentation entitled "Motivation, Status, and Plans for NSTX Upgrade."

A press release has been published this week in the ITER Newsline website on the modeling of non-inductive ramp-up for NSTX-U by F. Poli (PPPL) and can be accessed at the following link: http://www.iter.org/whatsnew. The work highlighted in the release has been published recently in the Nuclear Fusion journal and shows the advantages of using electron cyclotron heating to increase the electron temperature and improve the absorption of High Harmonics Fast Waves (HHFW).

NSTX-U plasma operations resumed this week after replacing a leaking TF water fitting, and then completing a vacuum vessel boronization using the deuterated trimethylboron (dTMB) injection system. A full bottle boronization was performed on January 11, following the repair of the failed TF water fitting. The new dTMB system is also being used for the between shot helium glow discharge cleaning (GDC), which has allowed for better gas control to reduce He loading and pump-out time. Operations this week utilized neutral beam injection, and added coils PF1A, PF3, and PF5 for plasma elongation and gap control. We routinely saw diverted plasmas and successfully transitioned to H-modes. High-field side gas injection was used for both He and D2 discharges. Also this week, OH coil parallel cooling paths were further calibrated, and initial temperature measurements indicate good thermal balance. Another vacuum vessel boronization will be performed over this coming weekend.

XMP128 (Increase the Elongation in L-Mode) was run on January 12 and 13. This XMP targeted the development of diverted L-mode scenarios as a means of moving from the previous inner-wall-limited cases to full H-mode scenarios. NB #1 sources were used with a total injected power up to ~2.5 MW, and the high field side fuelling injectors were used for the first time. These experiments had great success, resulting in both longer pulse, well controlled diverted L-mode scenarios, and the first H-mode discharges in NSTX-U.

XMP116 (Initial H-mode Development) was run on January 14 and 15. The efforts on January 14 were aimed at moving the H-mode timing earlier in the discharge and increasing the early

plasma elongation. Also, the impact of the timing and flow rate of the high field side (HFS) and early low field side (LFS) fueling on the discharge evolution was investigated and nearly the full ohmic precharge was used routinely. While progress was made in achieving H-mode before the start of the plasma current flattop, vertical control in these scenarios remained a challenge. Continued improvement in wall conditions should lower the internal inductance and improve the reliability of these scenarios. Neutral Beam #2 was used for the first time in regular operations on this day. Though operations on January 15 were limited to five plasma shots due to technical issues, the final shot of the day leveraged 3 MW of beam heating from NB source #1 and achieved an ELMy H-mode with the lowest value of the sustained internal inductance yet in NSTX-U. This is a positive result upon which to build experiments in the following week.

ITER & TOKAMAKS (R. HAWRYLUK):

R. Maingi summarized the conclusions of the 2015 Plasma-Materials Interactions community workshop report at the FESAC meeting in Bethesda, MD, on January 13-14. Discussion followed on how best to follow-up on the recommendations from this and other workshops.

DIII-D (R. Nazikian):

During the 2016 DIII-D experimental campaign the main ion CER system has been acquiring data over a wide range of plasma parameters and new tools are being developed to rapidly calculate the impurity and Deuterium rotation, temperature, and density. S. Haskey and B. Grierson are developing OMFIT tools that significantly streamline calculations of the impurity and main ion profiles compared to existing tools.

The upgraded IGI is being prepared for its initial run on DIII-D where carbon spheres will be injected into plasma in piggyback experiment. The new impeller motor drive was successfully tested on DIII-D along with the granule dropper counter. A new capability is now available to calibrate the granule drop rate from the control room between shots. The IGI is scheduled for several operational periods in the present run campaign.

ADVANCED PROJECTS (H. NEILSON):

The Laboratory is leading the fabrication of two TDU Scraper Elements for Wendelstein 7-X (W7-X) in collaboration with Oak Ridge National Laboratory and Germany's Max Planck Institute for Plasma Physics (IPP). Each scraper consists of two sub-assemblies that commercial fabricators will supply. Much of the raw material for these components, including all of the structural steel, is being furnished to the project by IPP, drawing on IPP's inventory of materials already qualified for use in W7-X. Materials satisfying W7-X requirements for low magnetic permeability and low cobalt content can be difficult to obtain, so the use of available qualified material reduces cost and schedule risks for the U.S. effort. This week, all of the IPP-furnished material was shipped by IPP and is due to arrive at PPPL next week.

The journal Physics of Plasmas has published an article online by S. Lazerson, et al., "Verification of the ideal magnetohydrodynamic response at rational surfaces in the VMEC code." The paper compares calculations with the VMEC nonlinear

ideal MHD equilibrium code against analytic linear ideal MHD theory. The aim is to verify the ideal MHD response at magnetic surfaces that are resonant with spectral values of the perturbed boundary harmonics. The code is found to capture the plasma response as predicted by a newly developed analytic theory.

H. Neilson attended the January 13-14 meeting of the Fusion Energy Sciences Advisory Committee. In addition to participating in committee discussions as a member, Neilson made a presentation, "The U.S. Collaboration on the Wendelstein 7-X Stellarator," reporting the status of the collaboration.

THEORY (A. BHATTACHARJEE):

On January 14, Sebastian Meuren (Max Planck Institute for Nuclear Physics, Germany) presented a theory seminar on nonlinear quantum electrodynamics in strong laser fields, from basic concepts to electron-positron photoproduction: "Since the work of Sauter in 1931 it is known that quantum electrodynamics (QED) exhibits a so-called 'critical' electromagnetic field scale, at which the quantum interaction between photons and macroscopic electromagnetic fields becomes nonlinear. One prominent example is the importance of light-light interactions in vacuum at this scale, which violates the superposition principle of classical electrodynamics. Furthermore, an electromagnetic field becomes unstable in this regime, as electron-positron pairs can be spontaneously created from the vacuum at the expenses of electromagnetic-field energy (Schwinger mechanism). Unfortunately, the QED critical field scale is so high that experimental investigations are challenging. One promising pathway to explore QED in the nonlinear domain with existing technology consists in the combination of modern (multi) Petawatt optical laser systems with highly energetic particles. The suitability of this approach was first demonstrated in the mid-1990s at the seminal SLAC E-144 experiment. Since then laser technology continuously developed, implying the dawn of a new era of strong-field QED experiments. For instance, the basic processes nonlinear Compton scattering and Breit-Wheeler pair production are expected to influence laser-matter interactions and in particular plasma physics at soon available laser intensities. Therefore, a considerable effort is being undertaken to include these processes into particle-in-cell (PIC) codes used for numerical simulations. In the first part of the talk the most prominent nonlinear QED phenomena are presented and discussed on a qualitative level. Afterwards, the mathematical formalism needed for calculations with strong plane-wave background fields is introduced with an emphasize on fundamental concepts. Finally, the nonlinear Breit-Wheeler process is considered more in depth. In particular, the semiclassical approximation is elaborated, which serves as a starting point for the implementation of quantum processes into PIC codes."

PLASMA SCIENCE AND TECHNOLOGY (P. EFTHIMION):

This week there were two Plasma Science and Technology seminars.

On January 11, Shurik Yatom from the University of Minnesota in Minneapolis, MN presented a seminar on electric fields in plasmas generated in nanosecond discharges. The abstract reads: "Discharges generated on a timescale of single nanoseconds in gases under pressures equal or greater than 1 atm have attracted a considerable amount of attention both due to wide

array of application and interesting physical phenomena involved. The investigation of plasma parameters have been especially difficult, mainly due to a short timescale of the processes involved. Until recently these plasmas were mainly studied via the time-averaged emission of Balmer-alpha and Balmer-beta lines. A study of the emission lines of neutral He atoms have suggested that the plasma channels hide significant electric fields with magnitudes of ~10 kV/cm. To validate this suggestion a direct measurement was then carried out, using a Coherent anti-Stokes Raman Scattering (CARS) technique, which allows a high temporal and spatial resolution. This talk elaborates the journey from the first hints to the direct measurement of the electric fields in the nanosecond discharge plasma channels."

On January 14, Jeff Parker presented a seminar on zonal flow and a phase transition of turbulence. The abstract reads: "Zonal flows appear in a diverse array of physical systems, including magnetically confined plasmas and planetary atmospheres. These zonal flows, which arise from turbulence, are a spectacular example of self-organization and order out of chaos. In magnetically confined plasmas, it is believed that zonal flows can play a crucial role in regulating the overall strength of turbulence driven by the ion temperature gradient. A better understanding of zonal flow behavior may therefore offer ways to reduce plasma heat loss. Detailed understanding has been hampered by the inability so far to come up with a self-consistent analytical description of the nonlinear zonal flow-turbulence interaction, given the complexity and nonlinearity of turbulence itself. Here, I report discoveries of fundamental properties of the zonal flow-turbulence interaction in an approach that sweeps away most of the details of turbulence. In a quasilinear approximation to the Hasegawa-Mima equation in slab geometry with periodic boundary conditions, I show analytically that zonal flows arise from turbulence in a phase transition mathematically analogous to the emergence of convection rolls in Rayleigh-Benard convection. Directly from the equations of motion, I derive a reduced equation that describes the phase transition. These results are derived in a statistical formalism that uses the turbulence two-point, one-time covariance function, in a statistical approach essentially equivalent to the Wigner-Moyal formalism. Physically, zonal flows appear in a zonostrophic instability in which zonal flows shear turbulent eddies in such a way that the eddies act to reinforce the zonal flow through a net Reynolds stress. I also solve the nonlinear statistical equations numerically to find self-consistent zonal flow equilibria, both stable and unstable. Additionally, I use this statistical formalism to show that the instability that drives zonal flow is a generalization of the so-called modulational or secondary instability discussed in the literature. These results offer a new way to understand and explore how zonal flows and turbulence behave, and with greater development, this approach could be adapted to specifics of tokamaks. Although the phase transition was discovered in a quasilinear approximation of the Hasegawa--Mima equation, basic symmetry arguments, numerical evidence, and preliminary analytic work indicate the transition survives in more complicated systems such as Hasegawa-Wakatani or gyrokinetics. Thus, it appears that this phase transition is a universal effect, relating to many forms of turbulence."

BEST PRACTICES & EXTERNAL AFFAIRS (J. DELOOPER):

Science Education (A. Zwicker):

On January 9, Alan Hirshfeld, University of Massachusetts Dartmouth, gave the first Science on Saturday Lecture to more than 368 individuals. The lecture was entitled "Starlight Detectives: How Astronomers, Inventors, and Eccentrics Discovered the Modern Universe."

On January 16, Shirley Tilghman, Princeton University (former President), gave the Science on Saturday Lecture to more than 484 individuals. The lecture was entitled "The Wild and Wacky World of Epigenetics."

DIRECTOR'S OFFICE (C. AUSTIN):

On January 13, Dr. Bruce A. Remington, Lawrence Livermore National Laboratory, presented a colloquium entitled "Frontiers in Plasma Science: A High Energy Density Perspective."

On January 13, S. Prager attended the National Laboratory Director's Council meeting, held at DOE Forrestal headquarters in Washington, D.C.

A Fusion Energy Sciences Advisory Committee meeting was held on January 13-14 in North Bethesda, Maryland. S. Prager, M. Zarnstorff, and R. Hawryluk attended the meeting; J. Menard, R. Maingi, and H. Neilson presented talks at the meeting.

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