The PPPL Highlights for the week ending January 22, 2016 are as follows:

FEATURED HIGHLIGHT (P. EFTHIMION):

C. E. Myers, M. Yamada, H. Ji, and the MRX team and NASA collaborators published a letter in the December 24 issue of Nature titled "A dynamic magnetic tension force as the cause of failed solar eruptions." In this letter, the authors use a laboratory magnetic flux rope experiment to identify a new mechanism that causes some solar eruptions to fail and collapse back toward the sun rather than to erupt successfully into the heliosphere. The new mechanism was discovered when the laboratory experiments produced fail events in a parameter regime that was previously thought to be eruptive. Magnetic measurements of the forces acting on the plasma reveal that the underlying cause of the failed events is a dynamic toroidal field tension force generated by self-organization processes within the flux rope. Since the toroidal field tension force has traditionally been neglected in the study of solar eruptions, these results have important implications for the analysis and prediction of solar eruptive events.

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

Steady State Electric Network (SSEN):

On the 6.6kV Switchgear procurement, terms of a contract amendment covering changes to Lots 2, 3, and 4 were negotiated and agreed to with Schneider Electric. These changes were necessitated because of changes to the Tokamak Cooling Water System load requirements that developed after the 6.6kV Switchgear contract was signed.

Activities continued for the remaining three SSEN procurements (Uninterruptible Power Supply (UPS) system, DC Distribution, and Low Voltage (LV) Distribution and Sub-distribution Panels procurements) that will lead to final agreements with respect to a revised procurement strategy. Procurement of some of the items (battery banks associated with UPS and DC distribution, plus the LV Distribution and Sub-distribution Panels) will be transferred to the ITER Organization (IO) for future procurement action to avoid long storage times (battery banks) and to allow more time for the load consumers' designs to evolve (LV panels). PPPL will sign contracts for the other items before the end of FY16. Once the process of cost and schedule estimate revision is completed, a Project Change Request (PCR) will be submitted to US ITER to authorize the revised strategy.

Diagnostics:

Low Field Side Reflectometer (LFSR): A. Zolfaghari visited General Atomics to review progress on Low Field Side Reflectometer (LFSR) system level design and microwave testing of PPPL's Gaussian Telescope. The LFSR front-end antenna layout configuration was discussed with GA/UCLA and ITER IO/CT. He also took part in the implementation of an FPGA (Field Programmable Gate Array) phase data acquisition and processing system developed as R&D for ITER LFSR, on DIII-D plasmas. The FPGA hardware was tested with revised programming at profile measurements rates of 100, 500, and 1000 events per second for a five second duration.

Motional Stark Effect (MSE): Progress is being made with the MSE optical ray traces. The MSE ZEMAX models are being rebuilt to incorporate changes in the port plug design and to make sure that the MSE diagnostic is looking at the right locations within ITER. There have been discussions on how to deal with the machine at operating temperature compared to designing and modeling at room temperature.

Diagnostic RGA (DRGA): Testing was conducted at CEA Cadarache on an Optical Penning Gauge to explore the simultaneous detection of H and He emission at pressures relevant to the interstage port of the ITER DRGA system. It was demonstrated with "makeshift" instrumentation that detection of optical emission from H and He was possible for ~3% He in 97% H2. Confirmation testing was conducted at ORNL using the ITER DRGA prototype and recently developed mixing station. The mixing station was used to prepare H2:He mixtures in the ratios of 50:50, 90:10, and 99:1. In sequential tests, these mixtures were introduced at an orifice at pressures expected in the ITER pumping duct. The concentrations of these species were then simultaneously measured in the proto-DRGA analysis chamber by QMS and ITMS gauges and in the interstage port OPG. Though the gauges are only roughly calibrated, the measurements roughly agreed with the mix concentrations, including 99:1, which is a lower concentration of He ash in D2 than what is expected during Q=5 fusion burn in ITER.

Upper Port 11 and 14 Integration and DSM Engineering: Engineering focus is currently on optimizing the design of the complex water piping system. The piping routes water for cooling and baking to the DFW, DSM, and diagnostic components in Upper Port 14. During the high temperature bake thermal stresses in the piping can be high and pipe stress relief features are needed. Electromagnetic disruptions also cause the pipes to twist. A. Jariwala is working through pipe stress analysis of the Upper Port 14 piping combining loads from pressure, temperature, and electromagnetic transients.

Equatorial Port 9 Integration and DSM Engineering: Two variations of ECE mirror mounting concepts are developing and under evaluation for EP9 port integration. The chosen mirror mount will advance definition of DSM2 structure and mass. This week USDA proposed the possibility of a DSM1 (VisIR) design approach common to EP17 to IO and EUDA. This could lead to EP03, 09 and, 17 common DSM designs for the VisIR system and cost reductions for the USDA in realizing this efficiency.

Toroidal Interferometer and Polarimeter (TIP): At General Atomics, modifications were made to the TIP real-time alignment prototype lab system to allow a larger separation between the incoming and outgoing beams at the retro-reflector, corresponding to the ITER channel 1 configuration. A draft Statement of Work for a copper prototype retro-reflector was completed,

including input from GA concerning optical performance and vacuum compatibility. This retro will be utilized in DIII-D as part of the single channel ITER prototype planned to begin operation later this year.

Core Imaging X-Ray Spectrometer (CIXS): Preparations for magnetic field testing continue, and a magnet was brought online this week. Technicians found that the static magnetic field strength was lower than expected but this will still meet the needs for testing to ITER relevant levels. Transient field testing will need to happen at a later date. Y. Zhai provided static and transient magnetic field data to the CIXS team to show what field levels should be expected on ITER. Zhai uses OPERA to evaluate this data. The maximum static field the CIXS detectors will operate in is 1.7 T.

Equatorial Port 3 Integration and DSM Engineering: Equatorial Port 3 activities are focused on supporting the MSE preliminary design work.

Port Plug Test Facility (PPTF): The PPPL PPTF team met with representatives from ITER and the Russia DA to discuss Electrical Codes and Standards for the PPTF.

NSTX-U (M. ONO):

A FY 2016 NSTX-U plasma operations update: The department has completed 2.33 run weeks and 241 plasma shots. The total operation targets are to be decided.

NSTX-U plasma operations continued this week after completing another vacuum vessel full bottle boronization on January 17. Operations this week utilized neutral beam injection and added the Switching Power Amplifier (SPA) driven Resistive Wall Mode (RWM) coils for the first NSTX-U experiments on error field correction. Also this week, the Gas Injection System (GIS) was configured for a period of neon glow for an off-hours diagnostic calibration. Our daily electrical insulation tests (hi-pots) identified a degradation of the PFIC upper coil insulation (not currently being used for NSTX-U experiments), and that coil has been drained and the power supply disabled to continue experimental operations. Troubleshooting will continue during the two-week maintenance period starting this coming week. Other activities in addition to planned maintenance for this period include lithium system preparations such as the installation of the argon dump system and lithium evaporator (LITER) controls, commissioning of new diagnostics, and gas injection system upgrades.

Magnetics calibration shots under XMP-106 [Magnetics Calibrations, Myers] were conducted for approximately 1.5 hours on January 18. These were followed by operations under XMP-116 [Initial H-mode Development, Battaglia et al] for the remainder of January 18. Routine H-mode access was achieved with beam powers ranging from 1 - 3 MW and the H-mode period was extended up to 700ms (202930). Operations on January 19 continued with XMP-116 where the LH transition was moved earlier to the start of flattop. This effort resulted in achieving the first discharges to exceed 150 kJ of stored energy (202946) and the internal inductance remaining below one for the length of the H-mode flattop (202951).

All of January 20 and much of January 21 were dedicated to troubleshooting an increased leakage resistance during inner vessel hi-pots. The cause was found to be a reduction of the

electrical isolation between the inner vessel and the PF-1cU coil. This coil was not needed for operations during the rest of the week, and so it was put in a safe state and will be inspected during the upcoming maintenance period. The remainder of January 21 was dedicated to running step 3.1 of XMP-121 [6 SPA Checkout, Gerhardt]. The goal of this step was to run the Resistive Wall Mode (RWM) coils via the dedicated Switching Power Amplifiers (SPAs) during plasma shots. After some debugging of related PCS code, this was successfully accomplished.

In the evening of January 21, a short Ne GDC was performed for CHERS calibration under XMP-134. The Ne glow was followed by an hour of He GDC.

The morning of January 22 was dedicated to running additional shots towards XMP-116 with the continued goal of diverting earlier in the discharge in order to enter H-mode at lower values of li and larger elongation. While H-mode was achieved, diverting earlier in a double null (DN) shape made the discharges prone to vertical instabilities. In response, diverting in a lower single null (LSN) shape was pursued, however H-mode access was found to be more difficult in this configuration. This effort will benefit from improvements to the vertical feedback control (see XP-1506 summary below), larger heating power, and ISOFLUX shape control, which is ready for deployment when operations resume.

The afternoon was dedicated to running steps from XP-1506 [L-Mode Error Field Studies, Myers]. The objective was to perform a "compass scan" to identify the mode locking threshold as a function of the applied n=1 error field. An ohmic L-mode scenario was chosen to eliminate the effect of beam-driven rotation on the locking threshold. Numerous discharges were taken, each using the RWM coils to apply a ramping n=1 error field at a particular phase. Mode locking was observed, and the data are now being analyzed to determine if any gross error fields can be detected. During this XP, some adjustments were made to the vertical position control configuration, and these modifications appear to have been beneficial. These will be utilized in future NSTX-U operations, including the H-mode XMP where they may prove quite beneficial.

ITER & TOKAMAKS (R. HAWRYLUK):

R. Hawryluk participated in the ITER External Management Advisory Board meeting. The focus was on the plans for machine assembly.

DIII-D (R. Nazikian):

This week the LGI is being prepared for injection of carbon granules in DIII-D to trigger ELMs. The LGI team worked through some difficulties with the granule dropper in order to overcome EM noise from the tokamak. This was a particular problem for the new photodiode sensors that have replaced the bulky cameras for detecting the lithium ablation and the granule injection. In addition the gate selector that releases carbon granules into the piezo dropper crystal was jammed and would not turn on. It suggests that the carbon granules have jammed the gate actuator. Repairs are underway to inject the carbon granules into plasma.

R. Nazikian visited ASIPP early this week to attend the first EAST research forum. He presented a set of proposals on behalf of NSTX-U, C-MOD and DIII-D for collaboration on EAST in areas of lithium boundary physics, I-mode physics, and RMP and EP physics, respectively.

W. Solomon was beam programmer and assistant session leader for an experiment aimed at expanding the parameter space associated with the recently discovered wide-pedestal QH-mode that exists in balanced double null shapes at beam low torque in DIII-D. Plasmas with considerably higher betaN up to 2.3 were achieved compared with earlier efforts that were limited to ~1.6, and a significant increase in confinement was also found at the higher power and beta levels. This accomplishment is further discussed in the DIII-D program highlights.

C-Mod (L. Delgado-Aparicio):

L. Delgado-Aparicio submitted a paper for publication in Physical Review Letters (PRL). New detailed observations of the formation and dynamics of error-field-induced locked-modes at ITER toroidal fields and without particle and momentum input have recently been carried out on Alcator C-Mod at MIT. A novel suite of spectroscopic imaging diagnostics has facilitated the determination of various plasma parameters with adequate temporal and spatial resolution during the mode onset. In addition, delay of the locked-mode onset and recovery from pre-existing locked-modes has been successfully obtained for the first time using Ion Cyclotron Resonance Heating (ICRH). This simple heating mechanism could provide an important actuator to circumvent error-field-induced locked-mode disruptions in tokamak plasmas.

An article by L. Delgado-Aparicio and colleagues from John Hopkins, MIT, and SULI appeared in the December BPO newsletter on "Multi-energy x-ray cameras for magnetically confined fusion plasmas." Due to important advances in the x-ray detector technology, especially the manufacturing of two dimensional hybrid pixel array x-ray detectors of large areas and high count rate capabilities, it is now possible to record spatially resolved x-ray photons at multiple energy ranges from highly charged ions from tokamak plasmas. Multi-energy x-ray imaging of magnetically confined fusion plasmas provides a unique opportunity for measuring, simultaneously, a variety of important plasma properties. The energy resolved measurements can be used to produce images of impurity concentrations (n_Z and Z_{eff}) from the absolute image intensity at different energy bands and the electron energy distribution function—both thermal (T_e) and non-Maxwellian ($n_{e,nM}$)—from the variation of emissivity with x-ray energy. This novel capability offers also a unique opportunity to monitor high-Z impurities, calculate impurity transport coefficients, and distinguish between contributions from medium-Z (e.g., Ar) to high-Z (e.g., Mo, W) impurities in reactor configurations with metal plasma facing components (PFCs).

ADVANCED PROJECTS (H. NEILSON):

The Office of the Dean of Research of Princeton has named theoretical work done by D. Gates, R. White, and D. Brennan as one of the University's top ten research highlights for 2015. The researchers identified a disruption mechanism that may explain a phenomenon known as the Greenwald density limit. This phenomenon limits the density achievable by tokamak fusion reactors, which in turn can limit the achievable fusion power in such a reactor. The mechanism may also be responsible for many other tokamak disruptions. Gates and colleagues Professor E. Kolemen and Dr. L. Delgado-Aparicio were also awarded the prestigious Torkil Jensen Award, which grants the researchers a day of run time on the DIII-D tokamak to explore their ideas. Currently the experiment is planned run in March at the DIII-D experimental facility in La Jolla, California.

The Laboratory is leading the fabrication of two TDU Scraper Elements for Wendelstein 7-X (W7-X), each consisting of sub-assemblies that will be supplied by commercial fabricators. The Laboratory's Procurement Division issued a request for quotation (RFQ) for fabrication of the base plate sub-assemblies. Raw material for being furnished to the project by IPP, drawing on IPP's inventory of materials already qualified for use in W7-X, arrived at the Laboratory this week.

THEORY (A. BHATTACHARJEE):

A paper entitled "Full-wave modeling of EMIC waves near the He+ gyrofrequency" by E.-H. Kim and J. R. Johnson has been published in Geophysical Research Letters.

On January 21, D. Pfefferlé (PPPL) presented a theory seminar on non-twist map bifurcation of drift-lines and drift-island formation in saturated 3D MHD equilibria: "Based on non-canonical perturbation theory of the field-line action, guiding-centre drift equations are identified as perturbed magnetic field-line equations. In this context, passing-particle orbits are called drift-lines, and their topology is completely determined by the magnetic configuration. In axisymmetric tokamak fields, drift-lines lie on shifted flux-surfaces, i.e. drift-surfaces, the shift being proportional at lowest order to the parallel gyro-radius and the q-profile. Field-lines as well as drift-lines produce island structures at rational surfaces only when a non-axisymmetric magnetic component is added. The picture is different in the case of 3D saturated MHD equilibrium like the helical core associated with a non-resonant internal kink mode. In assuming nested flux-surfaces, such bifurcated states, expected for a reversed q-profile with qmin close yet above unity and conveniently obtained in VMEC, feature integrable field-lines. The helical drift-lines however become resonant with the axisymmetric component in the region of qmin and spontaneously generate drift-islands. Due to the locally reversed sheared q-profile, the drift-island structure follows the bifurcation/reconnection mechanism found in non-twist maps. This result provides a theoretical interpretation of NBI fast ion helical hot-spots in Long-Lived Modes as well as snake-like impurity density accumulation in internal MHD activity."

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