The PPPL Highlights for the week ending April 29, 2016 are as follows:

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

Steady State Electric Network (SSEN):

Uninterruptible Power Supply (UPS) system and DC Distribution: The RFP package for the UPS is still with PNNL for review, after which it will be submitted for DOE PSO review. The DC Distribution procurement value falls below the review threshold so it will not been sent to PNNL/DOE, but has been held back in case comments from the PNNL review seem appropriate for incorporation.

Power Transformers: Lot #3 Release for Shipping (RFS) was resubmitted and is being processed. Target shipping date is now May 17. Factory Acceptance Testing (FAT) of the transformers for Lots #1 and #2 was completed and correction of punch-list items is underway. Target shipping date is June 13.

Diagnostics:

Upper Port Wide Angle View Vis-IR Cameras (UWAVs): The revised version of the UWAVS2 subcontract was approved by PNNL and is now ready for review by DOE PSO.

Motional Stark Effect (MSE): This week, Nova Photonics made a detailed technical and budgetary proposal to PPPL to perform MSE diagnostic first mirror cleaning prototype work. Nova Photonics maintains a large vacuum test chamber used on other projects that can be modified to house the large MSE mirrors. Radio Frequency equipment is already in place from other experiments and there are also magnetic field coils that can be used for critical testing of the sputtering cleaning technique. Currently, the MSE mirror-cleaning prototype is PPPL scope so a subcontract amendment will be needed to transfer the scope and budget to Nova Photonics.

Diagnostic RGA (DRGA): Due to a malfunctioning ion trap mass spectrometer (ITMS), the magnetic field effects testing apparatus at Oak Ridge National Lab (Helmholtz Coil pair) was moved to the laboratory housing the proto-DRGA so that its ITMS could be placed within a magnetic field while still being connected to the DRGA. This will allow the sensitivity to low-level magnetic fields of the ITMS to be measured, which will ultimately define the amount of magnetic shielding required for the deployed system. Data acquisition for this test is expected to be completed this week or next. In DRGA design, the Analysis Chamber concept is being reworked to incorporate commercial Swagelok valves for the gas calibration system. Because these valves are located behind two ITER-approved isolation valves they are not required to be

double-sealed valves. This new concept should result in lower overall fabrication cost as compared to the ITER-designed valves.

Upper Port 11 and 14 Integration and DSM Engineering: One important preliminary design review (PDR) document is the Remote Handling Compatibility Assessment (RHCA). This week the first draft of portions of the UP11 RHCA were sent to IO for review. The locked PDR Upper Port Electromagnetic and Structural analysis model is complete and has been sent to the analysis team. The Disruption Mitigation Pellet Injection System (DMS) integration into Upper Port 14 remains a difficult issue for all parties. The DMS team with support from the PPPL UPP14 integration team had their system feasibility review this week at IO. Various design options (including moving DMS out of UP#14) and constraints have been discussed. IO is going to evaluate all the options/constraints presented in the review and will advise the DMS team.

Equatorial Port 9 Integration and DSM Engineering: DSM2 (ECE) was internally reviewed this week for progress with the DSM structure and integration of a "pushrod" shutter/mirror design. The EP09 team concluded to carry on with the current design path, noting that fabrication questions will be increasingly important to resolve. DSM3 (TIP) design is studying the integration of several radiation heat transfer cooled mirrors as one of three proposed mirror concepts. The DSM integration study will be a key factor in evaluating which concept the TIP team will choose.

Toroidal Interferometer and Polarimeter (TIP): Using a full scale beam relay system, prototyping the full 120 path length needed for the ITER system, interferometer and polarimeter signals were obtained with sufficiently low noise to satisfy ITER measurement requirements with the laboratory prototype created at General Atomics (GA). For the polarimeter, the real-time alignment system needed to be operational to achieve this performance, and further investigation is planned to understand why.

Core Imaging X-Ray Spectrometer (CIXS): Preparations and logistics management for magnetic, nuclear and experimental testing at C-Mod continues this week. The Magnetic Field Testing bracket and cutout drawings were finished, approved and released to manufacturing, bracket manufacturing orders submitted, and ready to start build of parts for testing. Test shots of the dummy load magnetic testing coils planned are underway to check that all systems are working properly and prepared for full power test runs.

NSTX-U (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 new version of the plasma control system (PCS) software was deployed over the maintenance period. This version includes numerous updates, including, but not limited to, improved error field correction algorithms, anti-aliasing filters on the rtEFIT input data, and multi-threaded rtEFIT. The last update allows the vessel currents to be fit in real-time.

Electrical testing of the Massive Gas Injector electronics and power systems continued. These tests were largely successful, with only some SCR triggering issues yet to be resolved.

In order to assess noise levels on the detectors that will be used for the Florida International University Fusion Products Detectors, a test set-up was installed in the NSTX-U test cell. This assembly placed two detectors in proximity to the machine, along with electronics in a Category Four rack at the 119' level. Data will be collected in the upcoming run.

The NSTX-U Granule Injector installation is completed. The stand and platform have been reinforced to prevent deflection of the coupling bellows under vacuum load. The new stand and granule injector chamber have successfully passed a high-pot test and helium leak check and the system is currently under vacuum. The command and control electronics have also been installed and connected to the injector. In addition, local testing of the injector sub-systems (dropper, impeller, cameras, etc.) has also been successfully completed.

The mockup waveguide run for the FIReTIP diagnostic was extended from the level where it enters the NSTX-U vacuum vessel to the floor below. A table located there will hold the components to detect the interference between the probe and reference laser beams for plasma density measurements.

The reinstallation of the 16-channel UCLA reflectometer system at Bay-J is progressing. All AC power, conduit runs, and cable pulls were completed for the UCLA reflectometer at Bay J. A new isolation transformer for additional power to the electronics rack has been installed and power returned to that equipment rack. BNC cables between the equipment rack holding the data acquisition/power supplies and rack holding the source/receiver boxes have been installed. Work is underway on terminating these cables (45 cables in total) with the goal of first plasma data during the upcoming run period.

The NSTX-U maintenance period is drawing to a close. Internal repairs to the neutral beam Cryoplant have been completed, and the refrigerator is now fully operational and liquifying helium. All six of the RF sources are being prepared for operation and conditioning of the HHFW antennas.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

L. Cui and N. Logan have developed a pedestal analysis workflow using OMFIT profiles to constrain the equilibrium boundary based on the zero crossing of the radial electric field in the plasma edge. This new constraint, using the DIII-D CER system, complements the boundary constraint on the electron temperature at the foot of the pedestal measured by the Thompson scattering system. With the new OMFIT workflow, L. Cui and N. Logan were able to form equilibria with well-aligned kinetic profiles in the boundary required for detailed ELM physics studies.

A new workflow in OMFIT has been developed by B. Grierson to produce impurity transport coefficients derived from the TGLF model for arbitrary ion species and charge. These impurity transport coefficients (D and V) are then used directly in the OMFIT STRAHL module for predicting experimental charge-exchange and soft X-ray signals for diagnostic systems. The

workflow is being used to both validate the TGLF transport model with existing data inside a nonlinear optimization loop, as well as feed-forward predict the expected signals for upcoming impurity transport studies (including tungsten) and diagnostic system upgrades. The workflow is general, where any tokamak that is supported by OMFIT equilibrium and profile analysis can use the workflow for validation and experimental planning.

V. Duarte visited DIII-D to work with the energetic particle team to understand the physics of bursting/chirping Alfvén eigenmodes driven by beam ions in DIII-D. V. Duarte has developed a generalization of the Berk-Breizman model for full toroidal geometry to demonstrate the experimentally relevant parameters for the onset of bursting of AEs based on the linear growth rate and fast particle effective collisionality due to turbulent fluctuations. He presented a talk at the FSM showing how turbulence change affects the bursting behavior across the L-H transition.

G. Kramer visited DIII-D to discuss progress in the modeling BAE and BAAE type modes and associated fast ion transport in high qmin plasmas. He visited UC Irvine with B. Tobias and V. Duarte to discuss progress in the GTC modeling of the BAE/BAAE modes.

L. Delgado-Aparicio visited General Atomics (GA) to interact with PPPL and DIII-D scientists and perform the first data analysis on an experiment run with E. Kolemen and D. Gates in early March. L. Delgado-Aparicio and E. Koleman won the 2016 GA Torkil Jensen Award to run an experiment on the stabilization of Radiatively induced Tearing Modes (RiTMs) near the density limit using ECRH. This is a milestone experiment considered in L. Delgado-Aparicio's DOE Early Career Award Research program. Their group has obtained a good data set to study their RiTMs model, its connection with the density limit, and the use of off-axis ECRH for stabilization and safe operation at or above the Greenwald density. A first cut analysis indicates that the 2/1 RiTMs appears at mid-radius when $P_{Ohmic} \sim P_{rad}$, near or at the density limit. In addition, the time evolution of all discharges indicates that high-density MARFEs at the edge are connected but not directly responsible for the density-limit disruption. Actually, in scenarios where ECRH successfully prevents the 2/1 RiTMs the discharges experience MARFEs but without density limit disruptions, possibly offering a safe operating scenario at $n \gtrsim n_G$. Moreover, the results from a comparison between on- and off-axis ECRH heating near the density limit are also supportive of D. Gates' and L. Delgado-Aparicio's RiTM model. Further data analysis is in progress.

C-Mod (L. Delgado-Aparicio):

L. Delgado-Aparicio and J. Maddox visited the MIT Plasma Science and Fusion Center (PSFC) to find port-space for testing two new soft X-ray diagnostics developed by the PPPL X-ray group. This is the last opportunity the X-ray group has for testing new diagnostic concepts at MIT since Alcartor C-Mod will end operations at the end of FY2016. L. Delgado-Aparicio and J. Maddox discussed several installation options with John Rice and Rui Vieira of PSFC and concluded that will use a radially viewing port, which can be optimized for testing the new multi-energy SXR pinhole camera as well as a new impurity profile spectrometer. Both tests will use the newly purchase Pilatus3 X-ray camera which will arrive from Switzerland in mid-May. The new enhanced low-energy sensitivity of the Pilatus3 system will allow diagnosing the strong emission from high-Z impurities (e.g. molybdenum and tungsten). The novel non-paralyzable photon counting technology developed by DECTRIS allows for enhanced count rate correction and improves data quality at high-count rates. Photon rates of more than 10^7 photons per second

in a single pixel can be accurately measured with the new PILATUS3 detectors. L. Delgado-Aparicio will also install two of these X-ray cameras in NSTX-U as part of his DOE Early Career Award Research program.

International (F. Poli):

F. Poli traveled to IPP Garching on April 26-29 to attend the ITPA-IOS meeting. She reported on three topics: (1) A joint activity on the integration of a reduced pedestal model in time-dependent simulations based on EPED1 calculations, (2) modeling of the non-active phase at half-field in ITER, focusing on the access to H-mode, the possible IC heating scheme and the neutral beam fueling; and (3) NTM control on ITER and how integrated modeling can support the optimization of the EC launcher.

ADVANCED PROJECTS (H. NEILSON):

An article by N. Pablant, et al.—"Investigation of ion and electron heat transport of high-Te ECH heated discharges in the Large Helical Device," (Plasma Phys. Control. Fusion 58, 2016, 045004)—appears in the journal's April issue. The authors found predicted electron heat fluxes to be an order of magnitude less than the measured fluxes, indicating that electron transport is largely anomalous, while the neoclassical and measured ion heat fluxes are of the same magnitude. Neoclassical predictions of a strong positive ambipolar electric field in the plasma core are validated through comparisons to perpendicular flow measurements from the U.S. X-ray imaging crystal spectrometer diagnostic that operated on LHD from 2012 to 2014. This provides confidence that the predictions are producing physically meaningful results for the particle fluxes and radial electric field, which are a key component in correctly predicting plasma confinement.

A summary of the working meeting on remote collaboration technology for Wendelstein 7-X (W7-X), held April 6-7 at PPPL, was issued. Requirements for effective remote collaboration in W7-X by U.S. team members, including data access and communication needs, are documented. The report documents solutions that were identified by meeting participants and a joint action plan for implementation over the next several months. The Laboratory and the Max Planck Institute for Plasma Physics, the W7-X host, will work together on the implementation.

H. Neilson made a seminar presentation, "Report on the First Wendelstein VII-X Experimental Campaign," at General Atomics on April 18. The talk was part of a session, organized by GA, of presentations on international activities by members of the DIII-D Program Advisory Committee. Besides W7-X, the session included talks on JET, ASDEX-U, EAST, KSTAR, JT-60SA, and ITER.

THEORY (A. BHATTACHARJEE):

On April 28, E. Kim (PPPL) presented a theory seminar on 2D Full-wave simulations of plasma waves in space and tokamak plasmas: "A 2D full-wave simulation code (so-called FW2D) has been recently developed. This code currently solves the cold plasma wave equations using the finite element method. One advantage of using the finite element method is that the local basis

functions can be readily adapted to boundary shapes and can be packed in such a way as to provide higher resolution in regions where needed. We have constructed a 2D triangular mesh given a specified boundary and a target mesh density function. Moreover, the density of the mesh can be specified based on the expected wavelength obtained from solution of the local dispersion (except close to resonances) so that the most efficient resolution is used. Another advantage of this wave code is short running time. For instance, by using node number of 24,395, the computing time is approximately 300 seconds CPU time to obtain a solution. The wave code has been successfully applied to describe low frequency waves in Earth and Mercury's multi-ion magnetospheres. The results include: (a) mode conversion from the incoming fast to the transverse wave modes at the ion-ion hybrid resonance, (b) mode coupling and polarization reversal between left-handed (i.e., electromagnetic ion cyclotron waves: EMIC waves) and right-handed polarized waves (i.e., fast mode), and (c) refraction and reflection of field-aligned propagating EMIC waves near the heavier ion cyclotron frequency. Very recently FW2D code has been improved to adopt tokamak geometry and examine radio frequency (RF) waves in the scape-off layer (SOL) of tokamaks, which is the region of the plasma between last closed flux surface and tokamak vessel. The SOL region is important for RF wave heating of tokamaks because significant wave power loss can occur in this region. This code is ideal for waves in SOL plasma, because realistic boundary shapes and arbitrary density structures can be easily adopted in the code and the SOL plasma can be approximated as cold plasma."

BUSINESS OPERATIONS (K. FISCHER):

Budget Office:

PPPL received approval from the DOE on its request to increase the Laboratory Directed Research and Development budget for FY2016 from the current level of $3.0 million to a maximum level of $5.5 million.

PPPL submitted the five following proposals in response to a solicitation by the DOE, Office of Fusion Energy Sciences (OFES), and LAB 16-1498 Collaborative Research in Magnetic Fusion Energy Sciences on International Long-Pulse Superconducting Tokamaks. PPPL is the lead on the first proposal listed below and a collaborator on the other four proposals: (1) "Control of the Plasma-Material Interface for Long Pulse Optimization in EAST and KSTAR,"—the PPPL requested budget for the three-year period of performance is $3.318 million and the Project Lead and PPPL Principal Investigator is R. Maingi, (2) "Disruption Prediction and Avoidance in High Beta Long Pulse KSTAR Plasmas,"—the PPPL requested budget for the three-year period of performance is $930 thousand and the PPPL Principal Investigator is S. Scott, (3) "Control and Extension of High Performance Scenarios to Long Pulse,"—the PPPL requested budget for the three-year period of performance is $1.363 million and the PPPL Principal Investigator is R. Nazikian, (4) "Development of Long-Pulse RF Actuators and Divertors Compatible with High Plasma Performance,"—the PPPL requested budget for the three-year period of performance is $1.950 million and the PPPL Principal Investigator is J. Hosea, and (5) "Scrape-off-layer and Divertor Physics with Enhanced Diagnostics at KSTAR,"— the PPPL requested budget for the three-year period of performance is $162 thousand and the PPPL Principal Investigator is R. Goldston.

DIRECTOR'S OFFICE (C. AUSTIN):

On April 17, Dr. Joshua Frieman, Fermilab/University of Chicago, presented a colloquium entitled, "Probing the Accelerating Universe with the Dark Energy Survey."

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