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

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

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

Power Transformers: Lot #1 and Lot #2 oil-filled units (eight @ 35MVA and four @ 7MVA) are ready for shipment from the Schneider Electric factory near Istanbul, Turkey. The Release for Shipping documentation package is in final review, and a delivery planning meeting was held on July 1. Shipping is now scheduled for July 26.

6.6kV Switchgear: The 48 cubicles in Lot #2 were shipped from the Schneider Electric factory in Manisa, Turkey and are due to arrive on July 4 at a factory in Barcelona, Spain, where the EU team will install them in modular substation containers. A delivery planning meeting was held for the remaining 110 cubicles in Lot #3 and #4 and the shipping date has been set to July 29.

**Diagnostics:**

This week R. Feder visited ITER to work with various members of PBS.55 (Diagnostic) and to attend portions of the First Plasma Configuration Workshops. An important goal for the week was to finalize the U.S. ITER First Plasma scope for diagnostic and port plugs. It is now clear that the only diagnostic equipment that will be First Plasma scope is the in-vacuum front end portion of the Low Field Side Reflectometer (LFSR) which is a tenant in the Russia DA Equatorial Port 11. Since EQ11 is a FP port plug the RFDA has asked for all tenants to provide the in-vacuum components to enable full port plug assembly.

Low Field Side Reflectometer (LFSR): The LFSR team is focused on providing the in-vacuum transmission line components to the RFDA to support EP11 First Plasma delivery. A. Zolfaghari, M. Gomez, and M. Messineo are developing drawings and other material to gather detailed vendor quotes for the fabrication of the LFSR equipment. The team is also working on CATIA modeling updates so the RFDA has the latest design data. This is particularly important for the Diagnostic First Wall (DFW) interface because the RFDA is getting ready to evaluate nuclear heating and shielding. Modifications to the DFW blocks for diagnostics has a major impact on the nuclear performance of the port plugs.

Electron Cyclotron Emission (ECE): In a major step forward in the preliminary design of the ECE Hot Calibration Sources, the University of Texas-based group performed emissivity testing of the inconel samples with special new surface modifications. The emissivity of the grooved Inconel heater was shown to be about .7, which is better than the original flat Inconel heater at .5.
This may allow creating a hot source, which will satisfy the requirements, using the Inconel heater. The PPPL group continues preparation for the testing of the piezo-motor, which is scheduled to arrive on July 15. Piezo actuation is considered as one of the technologies for shutter mirror actuation, which IO intends to develop jointly by several groups. This was discussed during the teleconference on piezo actuation between PPPL and IO.

Equatorial Port 9 Integration and DSM Engineering: An ITER visit by A. Basile is resolving numerous integration items including SIC1 window status, temperature data for Interspace and Closure Plate and Bioshield interfaces. Design of Interspace Structure will be able to commence with this added information. A more detailed discussion and understanding of the new IO generic DSM took place at ITER with Julio Guirao. USDA now begins to evaluate the merits of incorporating the new design.

Toroidal Interferometer and Polarimeter (TIP): R. Wood completed a draft of an analysis report that considers the thermal distortion of a mirror designed to be suitable for the TIP channels sampling the outermost parts of the ITER plasma. These mirrors are subjected to volumetric heating in the range of 1W/cc. The Mo mirror is cooled through conduction by clamping to a water-cooled stainless steel base plate. Orthogonal tilt adjustments are achieved via a “rotating wedge” approach, which will be utilized upon installation and then locked in place. The thermal analysis indicates that the mirrors can maintain the needed optical performance even in steady state DT discharges. Response to disruption-induced vibration will be analyzed next.

NSTX-U (M. ONO):

A FY2016 NSTX-U plasma operations update: The department has completed 10.06 run weeks and 1066 plasma shots. The total operation target is 18 run weeks.

The paper “Phase coherence of parametric-decay modes during high-harmonic fast-wave heating in the National Spherical Torus Experiment” by J.A. Carlsson (Crow Radio and Plasma Science) et al., in Physics of Plasmas 23, 062519, 2016 is available online at http://scitation.aip.org/content/aip/journal/pop/23/6/10.1063/1.4954825). The paper demonstrates that higher-order spectral analysis can be a valuable complement to power-spectrum analysis for studying parametric-decay instability (PDI) during HHFW heating. The auto bicoherence of probe signals was computed and used to show quantitatively to which degree the suspected PDI modes are related. The bicoherence-analysis software tool is expected to help extract more information from probe data and facilitate a more detailed comparison with theory.

Several NSTX-U researchers attended the International Congress on Plasma Physics (ICPP 2016) held June 27 to July 2 at the Kaohsiung Exhibition Center in Kaohsiung, Taiwan. Four invited talks were given: J. Menard (PPPL) presented “Key physics issues and opportunities for next-step spherical torus devices,” J. Berkery (Columbia University) presented “Kinetic resistive wall mode stabilization physics in tokamaks,” Y. Ren (PPPL) presented, “Recent progress in understanding electron thermal transport in NSTX and NSTX-U,” and A. Diallo (PPPL) presented “Development of medium and fast burst laser systems for laboratory and fusion plasmas.”
M. Podesta (NSTX-U/PPPL) participated in the ITPA Energetic Particle Topical Group meeting, held at the ITER Headquarters (France) on June 27-30. The meeting included a one-day workshop on diagnostics for alpha particle measurements in ITER, aimed at defining the physics requirements for fast particle measurements. Status and plans for potential diagnostics that would fulfill those requirements were discussed. The status of ongoing ITPA-EP joint experiments was discussed, including an experiment on “validation of Neutral Beam current drive and projections to ITER” coordinated by M. Podesta. NSTX-U is expected to provide data for the experimental database, and PPPL is actively involved in developing and validating improved tools to account for “non-classical” effects in the computation and prediction of NB-CD (e.g. using TRANSP).

M. Podesta also presented a summary of recent work by V. Duarte and N. Gorelenkov (PPPL) on the formulation of a new criterion for the emergence of so-called “chirping” Alfvenic modes. The proposed criterion, which improves previous models and reproduces trends observed in experiments (NSTX, DIII-D, TFTR), was well received and the possibility of extending its validation to other devices was discussed. Engagement of NSTX-U and PPPL theory in other EP-related activities was discussed. In particular, NSTX-U/PPPL can contribute to the interpretation and modeling of Ion Cyclotron Emission associated with energetic particles, which is foreseen as a possible fast ion diagnostic tool for ITER.

NSTX-U plasma operations continued this past week with experiments on H-mode access and inner gap control, error field correction, and initial checkouts of the Fast Ion Diagnostics, (SSNPA/FIDA) and new Granule Injector. All utilized neutral beam injection, successfully using fast beam modulation when needed. On Monday, we recorded 30 plasmas in 30 attempts, a high point for NSTX-U.

On June 27-28, a number of steps were taken to try to improve the H-mode scenarios. First, an attempt was made at optimizing the shot without any PF-2 coil currents at the time X-point control is turned on at 158 ms. Similar to the last shot of the previous Friday, this prevented the discharge from drifting to a large LSN bias. The feed-forward PF1A (before 158 ms) was increased faster before 100 ms in order to have the shape very close to diverting at 158 ms. Changing the feed-forward PF1A required some retuning to prevent diverting early, and it required some retuning of the outer gap and PF3/5 gains. It did succeed in having the shape close to diverting around 150 ms, but then the shape would drift farther from diverting by 200 ms (shots 205034-9).

Next, a small optimization of the early error field correction (EFC) was attempted, and basically found a result similar to what had been seen in L-mode scenarios, that the best early correction toroidal phase was meaningfully different than that for the best later correction (shots 205040-3). This early correction was used for some subsequent shots.

Following this small EFC study, attention was turned back to control optimization by requesting X-points closer to the mid-plane using the ISOFLUX targets. This was making good progress in establishing and maintaining an inner gap, but was starting to divert USN and going vertically unstable. Note that this change in X-point requests led to PF1A currents similar to those achieved in the feed-forward shots, but using X-point/inner gap control. In the future, the vertical instability would be addressed by adjusting the outer gap and continuing to reduce the plasma height at the diverting time if need be (205047-50).
Next, in order to properly assess machine conditions, time was spent trying to recreate a shot that only used feed forward divertor currents and no feedback on drsep (204118). After adjusting the HFS pressure, early H-modes were achieved. Eventually, an HFS pressure 50% larger than the target shots from April was found to be optimal, suggesting there may have been a shift in the HFS gas pressure calibrations. The last shot (205062) was very close to an overlay of 204118, though without the transition, potentially due to poor wall conditions after 29 plasma shots. These scenarios will be revisited after a full boronization in the near future.

Following these H-mode studies, operations switched to XMP-110 (FIDA/ssNPA/sFLIP checkout). After taking three shots to get the target plasma right, four good shots were taken with beam modulations at an injection energy of 85 keV. Short (20 ms) pulses from neutral beam line #1 and #2 were alternatively injected into center-stack limited L-mode plasmas. Together with the data from March 31, this set of data will enable the initial assessment of fast ion confinement on NSTX-U and checkout of FIDA and SSNPA diagnostics. The next steps in this activity are some shots with longer beam on-times to obtain stationary fast ion slowing-down distribution function and to check the fast ion spatial profile.

The probe drives for the Lithium Evaporators (LITERs) were tested using location motion control, and it was determined that the remote control software was able to indicate the correct positions. The probe drives were then successfully operated using remote position control. The final set of limit switches and cables were installed for remote control of the probe drive for the Materials Analysis and Particle Probe (MAPP). The interface box for the permissive signals that allow remote MAPP torus interface valve was also mounted.

PLC based gas control logic software that allows the Massive Gas Injection (MGI) gas valves to be filled to the required pressure was fully implemented. The system allows the primary and secondary plenums on the lower and mid-plane MGI gas injectors to be evacuated and then filled to the needed pressure. Other needed hardware for the MGI system, such as pressure transducers were also installed and calibrated. The pre-operational test procedure for operation of the MGI power supplies was nearly completed. During these tests, the mid-plane and lower MGI valve power supplies were operated at voltages up to 1000V. The system is now very close to being able to inject gas into NSTX-U.

**ITER & TOKAMAKS (R. HAWRYLUK):**

**DIII-D (R. Nazikian):**

N. Logan visited PPPL this week to work with J. Park and Z. Wang in order to merge the new Resistive DCON (RDCON) code with the Generalized Perturbed Equilibrium Code (GPEC). A collaborative git repository has been established, the interfaces have been created, and initial calculations of the plasma permeability have been performed using the resistive eigenmodes. The combination of these two codes will allow the computation of 3D perturbed equilibria with finite resistive shielding currents at the rational surfaces. This will be a significant step forward for the multi-modal perturbed equilibrium calculations, with immediate applications in studying and optimizing the resonant and non-resonant torques in the presence of resonant field penetration.
The TRANSP submission through OMFIT has been upgraded to enable inclusion of time-dependent mirror steering of gyrotrons for DIII-D. Feed-forward and real-time feedback gyrotron aiming has been used in DIII-D for optimization of NTM control as well as catch-and-subdue NTM suppression studies. Previously, TRANSP preparation utilities only allowed time-static mirror angles. The upgraded TRANSP module fetches all gyrotron power history and mirror aiming and prepares the UFILE inputs and TORAY namelist for power balance and auxiliary current drive.

A CDR on the 210 off axis beam source housing door opening/holding mechanism was presented by S. Gibson (PPPL student intern since June 1, mechanical engineering senior) to the engineering group at DIII-D. The OANB source doors are ion source magnetic shields. With the OANB being positioned 20.8 degrees off horizontal, opening these 300lb doors safely requires additional hardware. Gibson developed five approaches, each with their own limitations. The winning concept was a balanced force model using a high point arm cantilevered off the source housing with a cable attached to one door, run through a pulley on the arm to the other door. This is a simple, effective, and inexpensive solution.

R. Nguyen (PPPL student intern, since December 2015) is leaving this week to take up a job with General Atomicas (GA) as a starting engineer. Nguyen will become part of the 210 off axis beam project led by A. Nagy on DIII-D.

International (R. Hawryluk):

PPPL hosted the US-PRC Magnetic Fusion Collaboration Workshop onsite on June 28-30. There were approximately 80 registered participants representing nine institutions from the PRC and sixteen from the U.S. This was a very productive meeting to discuss existing collaborations and form new ones.

PPPL staff gave the following oral presentations. S. Prager gave an overview talk on collaboration opportunities at PPPL. M. Ono gave an NSTX overview talk. R. Maingi presented a talk entitled “Comparing helium glow discharge cleaning with Li evaporation in NSTX.” In addition, results and future plans from PPPL-ASIPP collaborations on lithium research were described. J. Yoo presented a talk on “Status of FLARE reconnection experiment.” H. Neilson presented a talk on “Collaboration in fusion reactor engineering science.” A. Bhattacharjee gave a talk on “PRC-PPPL theory collaborations in fusion and plasma science.”

PPPL staff also gave the following poster presentations. W. Guttenfelder and Y. Ren presented “Research opportunities in transport and turbulence on NSTX-U.” S. Kaye presented “TRANSP: status and planning.” L. Cui presented “Transport modeling RMP ELM suppressed plasmas.” J. Hosea presented “RF power deposition exploration in NSTX and EAST with visible cameras and Langmuir probes.” L. Cui and R. Nazikian visited PPPL this week. L. Cui presented a poster titled “Energy confinement recovery of RMP ELM controlled plasmas in the DIII-D tokamak.”

ADVANCED PROJECTS (H. NEILSON):

Laboratory staff gathered this week to congratulate the Costa Rica Institute of Technology (Tecnológico de Costa Rica, or TEC) on the achievement of first plasma in their SCR-1.
stellarator. PPPL scientists and engineers attended the celebration marking this achievement, held in Costa Rica on June 29, participating remotely from PPPL. The event featured recorded messages from PPPL and other stellarator researchers congratulating TEC. The SCR-1 stellarator is designed to explore high-temperature plasma physics in an optimized stellarator configuration. The project director, Dr. Iván Vargas, is currently at PPPL collaborating on both spherical tokamak and stellarator research topics. Following by a few months the startup of Germany’s large Wendelstein 7-X facility, the start of a smaller-scale stellarator program in Costa Rica is the newest entry into this rapidly growing field of fusion physics research and the first stellarator experiment in Latin America.

The Laboratory this week hosted visits by Dr. Joris Fellinger of the Max Planck Institute for Plasma Physics, and by Drs. Jeffrey Harris, J. Lore, and Arnold Lumsdaine of Oak Ridge National Laboratory in connection with the Divertor Scraper project for Wendelstein 7-X (W7-X). Fellinger, the project’s responsible officer, reviewed the status of the fabrication project. Sub-assembly of the base plate has been completed. The prototype first wall back plate was received from the supplier and was successfully trial fit onto the base plate sub-assembly, verifying proof of concept of the design. In addition, Fellinger accompanied PPPL engineers D. Loesser and I. Zatz on a visit to the supplier MWI, Inc. of Rochester, New York, to witness the first assembly of tiles onto the backing plate. Finally a series of meetings was held to discuss progress in the formulation of the research program, led by Dr. Lore, that will be carried out on W7-X during the next campaign, to investigate the interactions between the scraper and the edge plasma and the performance of its intended protective function.

**THEORY (A. BHATTACHARJEE):**

Herb Berk (University of Texas at Austin) presented a theory seminar on explosive solution of a time delayed nonlinear cubic equation derived for fluids (Hickernell) and plasmas (Berk-Breizman): “This presentation described new explosive attractor solutions to the universal cubic delay equation found in both the fluid [F. J. Hickernell, Jour. Fluid Mechanics, 142, 431 (1984)] and (for a kinetic system) in the plasma literature [B. N. Breizman, et. al. Phys. Plas. 4.1559 (1997)]. The cubic delay equation describes a system governed by a control parameter $\phi$ (in plasmas its value is determined by the linear properties of the kinetic response). The simulation of the temporal evolution reveals the development of an explosive mode, i.e. a mode growing without bound in a finite time. The two main features of the response are: (1) a well-known explosive envelope $(t_0-t)^{-5/2}$, with $t_0$ the blow-up time of the amplitude; (2) a spectrum with ever-increasing oscillation frequencies whose values depend on the parameter $\phi$. Analytic modeling explains the results and quantitatively nearly replicates the attractor solutions found in the simulations. These analytic attractor solutions are linearly stable except in some cases where the nonlinear solution needs to be corrected to include higher harmonics. Our analysis explains almost all of the rather complicated numerical attractor solutions for the cubic delay equation.”

A paper by Dr. A. Reiman titled “Pressure Driven Currents Near Magnetic Islands in 3D MHD Equilibria: Effects of Pressure Variation Within Flux Surfaces and of Symmetry” has been accepted for publication in the journal Physics of Plasmas. The abstract reads, “In toroidal, magnetically confined plasmas, the heat and particle transport is strongly anisotropic, with transport along the field lines sufficiently strong relative to cross-field transport that the
equilibrium pressure can generally be regarded as constant on the flux surfaces in much of the plasma. The regions near small magnetic islands, and those near the X-lines of larger islands, are exceptions, having a significant variation of the pressure within the flux surfaces. It is shown in the paper that the variation of the equilibrium pressure within the flux surfaces in those regions has significant consequences for the pressure driven currents. It is further shown that the consequences are strongly affected by the symmetry of the magnetic field if the field is invariant under combined reflection in the poloidal and toroidal angles. (This symmetry property is called “stellarator symmetry”). In non-stellarator-symmetric equilibria, the pressure-driven currents have logarithmic singularities at the X-lines. In stellarator-symmetric MHD equilibria, the singular components of the pressure-driven currents vanish. These equilibria are to be contrasted with equilibria having constant pressure along the field lines, where the singular components of the pressure-driven currents vanish regardless of the symmetry. They are also to be contrasted with 3D MHD equilibrium solutions that are constrained to have simply nested flux surfaces, where the pressure-driven current goes like $1/x$ near rational surfaces, where $x$ is the distance from the rational surface (except in the case of quasi-symmetric flux surfaces). For the purpose of calculating the pressure-driven currents near magnetic islands, the work described in the paper uses a closed subset of the MHD equilibrium equations that involves only perpendicular force balance, and is decoupled from parallel force balance. It is not correct to use the parallel component of the conventional MHD force balance equation near magnetic islands. A small but nonzero variation of the pressure along the field lines is important in this region, and small non-MHD contributions to the parallel force balance equation cannot be neglected there. Two approaches are pursued to solve the equations for the pressure driven currents. First, the equilibrium equations are applied to an analytically tractable magnetic field with an island, obtaining explicit expressions for the rotational transform and magnetic coordinates, and for the pressure-driven current and its limiting behavior near the X-line. The second approach utilizes an expansion about the X-line to provide a more general calculation of the pressure-driven current near an X-line and of the rotational transform near a separatrix. The study presented in the paper was motivated, in part, by tokamak experiments with nonaxisymmetric magnetic perturbations, where significant differences are observed between the behavior of stellarator-symmetric and non-stellarator-symmetric configurations with regard to stabilization of edge localized modes (ELMs) by resonant magnetic perturbations (RMPs). Implications for the coupling between neoclassical tearing modes (NTMs), and for magnetic island stability calculations, are also discussed.

PLASMA SCIENCE & TECHNOLOGY (P. EFTHIMION):

Y. Raitses attended the Symposium on Plasma Physics and Technology in Prague, Czech Republic on June 20–23. He gave an invited talk titled “Controlling of rotating plasma structures in E cross B discharges.” This symposium is one of the major low temperature plasma physics and technology forums in Europe. Y. Raitses also visited Charles University and the Institute of Physics of the Academy of Sciences of Czech Republic where he discussed collaboration on physics of plasma sources of nanostructured films and coatings with leading experts in the field, Professor Milan Tichy, Dr. Zdenek Hubicka, and Dr. Martin Cada.
BUSINESS OPERATIONS (K. FISCHER):

Budget Office:

A new Strategic Partnership Project Agreement was executed with NASA for the work scope titled “Fusion-Enabled Pluto Orbiter and Lander.” PPPL was included as a collaborator on a proposal submitted by Princeton Satellite Systems in response to a NASA Innovative Advanced Concepts (NAIC) solicitation. The funding provided to PPPL for its participation in the project is $20,000 for the one-year period of performance. The PPPL Principal Investigator is S. Cohen.

Second year funding of $130,100 was received from NASA for the Strategic Partnership Project titled “An Investigation of Electron Acceleration and Energy Transport by Alfven Waves in the Jovian Magnetosphere.” The Principal Investigator for this research effort is P. Damiano.

A Field Work Proposal was submitted for the PPPL work scope to be performed for the collaborative proposal titled "Simulation Center for Runaway Electron Avoidance and Mitigation (SCREAM)" which has been selected for funding by the Office of Fusion Energy Sciences. Princeton University is the lead institution for this two-year research effort; the Principal Investigator for the PPPL work scope is A. Bhattacharjee. The total funding to be provided to PPPL is $231,000.

DIRECTOR’S OFFICE (C. AUSTIN):

On June 29, Professor Duncan Brown, Syracuse University, presented a colloquium entitled, “The Observation of Gravitational Waves from a Binary Black Hole Merger.”

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