The PPPL Highlights for the week ending May 13, 2016 are as follows:

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

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

Uninterruptible Power Supply (UPS) system and DC Distribution: A revised RFP package, incorporating changes resulting from the PNNL review process, is being prepared for submittal for DOE PSO review. The DC Distribution procurement value falls below the review threshold so the RFP does not require PNNL/DOE review. However, it will be held back and released at the same time as the UPS package in case changes to match the UPS package are deemed appropriate.

Power Transformers: The Lot 3 Release for Shipping (RFS) documentation package was approved, and the 10 dry-type transformer units (6 @ 2.5MVA and 4 @ 1.6MVA) will be shipped on May 17 from the Schneider Electric factory near Istanbul, Turkey. Factory Acceptance Testing (FAT) of the Lot 1 and Lot 2 transformers was completed and correction of punch-list items is underway, subject to inspection on May 30 by PPPL’s subcontract QC inspector. Target date to begin shipping the Lot 1 and Lot 2 oil-filled units (8 @ 35MVA and 4 @ 7MVA) is June 13.

6.6kV Switchgear: The Lot 2 Release for Shipping (RFS) documentation package was accepted by PPPL and will be submitted for review and approval by the ITER Organization. Forecast shipping date for the 48 cubicles in Lot 2 from the Schneider Electric factory in Manisa, Turkey is June 3. Fabrication of the remaining 110 cubicles in Lot 3 and 4 are nearing completion and the FAT will commence on June 1.

**Diagnostics:**

Motional Stark Effect (MSE): PPPL and Nova Photonics has received an important interface definition document from the European DA for hosting the Core Viewing MSE diagnostic in Equatorial Port 1. The interface document is under review and follow up meetings with the EUDA are planned for next week. PPPL is working on a revision to the subcontract with Nova Photonics where scope for the design and operation of a Mirror Cleaning Prototype will be transferred from PPPL to Nova. A test facility with equipment for RF power testing needed for the mirror cleaning is already in operation by Nova Photonics and can be easily upgraded for use with the ITER first mirror cleaning research.
Electron Cyclotron Emission (ECE): University of Texas at Austin is preparing for tests of the ECE hot calibration source using a conductive heat transfer configuration between the silicon carbide emitting surface and the high temperature heating element. Simultaneous effort is under way with the goal of increasing emissivity of the heating element so that radiation heat transfer can be employed in the hot source. There is less risk of mechanical damage to the silicon carbide emitter if the heating element is not in contact.

Diagnostic RGA (DRGA): A replan of the RGA detailed design phase is underway in preparation for submitting a PCR. A revised draft schedule has been provided to PPPL, which shows the proposed activities and duration. A review of the resource requirements is currently in progress. For R&D progress, analysis of the spectrometer data acquired over the past few months has begun. This data will be included in the final R&D report. Issues with an ion trap mass spectrometer (ITMS) being used in the magnetic field effects testing have been resolved, so final testing of that instrument in the Helmholtz Coils will be completed soon.

Upper Port 11 and 14 Integration and DSM Engineering: A working design meeting was held with the China DA (CNDA), the ITER Organization Diagnostic Team (IO), and PPPL Port Integration staff about CNDA’s Glow Discharge (GDC) probe feedthrough design. CNDA’s feedthrough is larger in diameter and requires more space at the port plug closure plate than originally estimated. During the discussion it was recommended to CNDA to use the bolted connection and not a welded as relevant design codes have very strict requirement for lip welds used as first confinement barriers. Also the bolted connection requires less room for maintenance tools. IO-CT (Diagnostic group) is going to check if there is an ITER style flange, which is smaller than DN100. As most of the feed through requires smaller flanges it could be developed as a catalog item. CNDA will modify its feedthrough design and will present it in the next monthly meeting. A working design meeting was also held this week with the Oak Ridge based Disruption Mitigation System (DMS) team. The DMS team has come up with a new flexible pipe concept at the port plug closure plate which does not require huge cantilevered brackets to hold its valves. This design has edge-welded bellows which takes the displacement due to bake out and VDEs. Concerns were raised that this design may not survive accelerations due to seismic and VDE loads. The PPPL based port plug analysis team will provide loads to the DMS team for analysis of the DMS design.

Equatorial Port 9 Integration and DSM Engineering: A meeting was held with the European Domestic Agency (EUDA) to launch a collaboration on developing an electrical vacuum and confinement barrier feedthrough design. The EUDA has proposed designs that look promising for US equatorial port applications. The U.S. will next assess electrical requirements and review designs internally with PPPL experts. TIP diagnostic working meetings were held with General Atomics (GA) to coordinate modeling, analysis planning and integration with the U.S. and IO. Many coordination topics were clarified and several integration topics were identified that will need definition in the coming months to allow GA to progress with the TIP system design.

Toroidal Interferometer and Polarimeter (TIP): D. Johnson spent three days meeting with members of the TIP diagnostic development team at GA in San Diego. He witnessed a demonstration of the laboratory prototype interferometer/polarimeter operating on a 120 meter
beam path, and with resolution sufficient to meet ITER measurement requirements. Recently created models of the five-channel relay system under design for ITER were reviewed. Progress on PPPL TIP scope was presented. The schedule to PDR was discussed along with document deliverable requirements for this review.

NSTX-U (M. ONO):

A FY2016 NSTX-U plasma operations update: The department has completed 8.88 run weeks and 934 plasma shots. The total operation target is 18 run weeks.

The paper “Quasi-linear gyrokinetic predictions of the Coriolis momentum pinch in National Spherical Torus Experiment” by W. Guttenfelder (PPPL) et al., was published in Physics of Plasmas, http://scitation.aip.org/content/aip/journal/pop/23/5/10.1063/1.4948791. Previous perturbative measurements in NSTX H-modes indicated the existence of an inward momentum pinch that was similar to analytic theory predictions based on conventional tokamaks. This paper shows that linear gyrokinetic simulations run for the NSTX discharges in fact predict a momentum pinch that is small or even outward, in contradiction to the experimental results and simpler analytic theory. The small predicted pinch is a consequence of both electromagnetic effects at relatively large beta and low aspect ratio minimizing the allowed symmetry-breaking of the instabilities necessary for a pinch. A stronger inward pinch is predicted either at increasing aspect ratio or in the electrostatic (low beta) limit, the latter of which motivates new NSTX-U experiments.

R. Lunsford (PPPL) presented the outreach talk “Skipping Rocks off the Sun: Taming fusion plasma eruptions through controlled microgranule injection” at the inaugural Princeton Research Day on May 5. The talk was a portion of the “Designing the Future” session and introduced fusion research, challenges in the plasma material interface, and the utilization of granule injection to attempt to mitigate ELM peak heat fluxes through ELM pacing in current and future fusion devices.

Operations on May 9 started with XMP-141 (Loop Voltage Proportional Error Field Correction), with the goal of seeing whether MHD activity in the current ramp could be reduced with additional pre-programmed error field correction. Approximately eight discharges were taken to develop a suitable 900 kA ohmic target, and then two loop-voltage-proportional compass scans at different amplitudes were conducted. The applied fields did have an impact on the plasma, and a slight asymmetry in the ramp-up performance was observed. Analysis is ongoing to determine whether these results should be incorporated into the standard NSTX-U feed-forward error field correction recipe.

When these scans were complete, a few shots were taken from XMP-142 (Reduced MHD H-mode Development). These shots had difficulty achieving reliably H-mode timing during the current ramp, and improving the reliability of H-mode access will be a feature of future development.

At the end of the day on May 9, the MSE-LIF TIV was opened to the vessel, and the gas+RF used for making a beam was fired during a clock cycle. In this first test, the NSTX-U vessel
pressure rise was found to be minimal. Also, the LLNLEUV spectrometers at Bay E all collected initial data. Two of the instruments were found to need improved alignment.

The first shots of May 10 were dedicated to XMP-149 (MSE Diagnostic Neutral Beam Checkout). These showed that the DNB gas load on the torus did not impact the NSTX-U breakdown, and that the DNB did not have a significant impact on the plasma. It also confirmed that operation of the DNB plasma source was unaffected by the NSTX-U fields, and demonstrated injection of the DNB into the torus.

There was then a multiple hour break to troubleshoot some issues with the gas delivery system. This was followed by further shots towards XMP-142, where a pause in the plasma current ramp rate was found to be highly beneficial in achieving reliable H-mode timing.

The morning of May 11 was dedicated to XMP-142 (Reduced MHD H-mode Development). It was observed that a brief pause in the plasma current ramp that reduced the loop voltage below 1V was effective in improving the access to H-mode early in the current ramp. It was also important to divert before or during the pause, however shot-to-shot variations in the neutral beam heating evolution made the transition to a diverting timing difficult to control, especially when near double null. In response to this observation, a discharge under isoflux dnull control with Xpoint R and Z control starting at 135 ms (the time the xpoints enter the vessel) and diverting at about 240 ms was developed and worked well. It is hoped that this technique will be more resilient to minor changes in wall conditioning and NB timing than was the case when controlling the divertor coils in current feedback mode.

During the afternoon of May 11, a second error field correction compass scan was conducted at higher density under XP-1506 (C. Myers, Low-beta error field correction). Several discharges were taken to stabilize the density at $\sim 3e13$ cm$^{-3}$ in a 650 kA, 1 MW L-mode scenario. This density is $\sim 2.5$ times the original, low density compass scan, which was conducted at $\sim 1.2e13$ cm$^{-3}$. Once the density stabilized, a new four shot compass scan was performed. First, this new compass scan confirmed the optimum feed-forward error field correction of 0.088 A/A PF5 and 15 degrees that was obtained from the original low density compass scan. Secondly, it showed a 10\% higher absolute locking threshold than that of the low density compass scan. While it is expected that the locking threshold would go up with increasing density, the modest observed increase in the locking threshold indicates that rotation and other variables are contributing to the locking behavior. Finally, a few attempts were made to vary the density and raise the plasma current. These shots were subject to an $n=2$ rotating mode that impacted the plasma rotation and the locking behavior.

Shots on May 12 were dedicated to XMP-153 (H-mode access and control development in boronized wall conditions). One goal of this XMP is to develop a control strategy that achieves a consistent diverting and L-H transition timing over a range of neutral beam heating evolutions. Most of the development used 600 kA H-mode discharges that achieve poloidal beta above 1.5. The early X-point control strategy demonstrated improved resilience to shot-to-shot variations in NBI heating. However, the results also indicated that this effort would benefit from a new control scheme for the plasma shape when it is limited on the inner wall. In this scheme, the reference flux for the shape control points on the outer boundary of the plasma within the ISOFLUX double null algorithm is the minimum of the flux at each X-point and the inner wall. The afternoon transitioned to XMP-151 (L-mode development), where a higher density, 800 kA
L-mode target was established on the first attempt. However, the discharge ended slightly early due to a locked mode, likely as a consequence of having no current in RWM coil 4. Investigating the problem with SPA #2, sun-unit #1 took the remainder of the day, and the problem was ultimately traced to a loose wire on a relay.

On May 13, the morning was dedicated to H-Mode development. The use of the algorithm in the PCS that allows the minimum of flux at the 2 Xpoints and the inner wall tangency to be used as the reference flux solved the issue of poor control in the double null algorithm when the plasma is in contact with the inner wall. That provided more reproducible plasma when in contact with the inner wall. The difficulty of making a clean transition from inner wall limited to double null with a significant inner gap remained. By the end of the scheduled period incremental progress led to plasmas with an inner gap for about 70 ms, which was achieved by a series of small changes to the requested plasma shape. This process will be continued on Monday. The afternoon again transitioned to XMP-151 (L-mode development) using the 800 kA L-mode target. Using source 1B for consistent shot startup, a transition to each of the six beam sources was successfully tested on a shot-by-shot basis, with excellent beam reliability at ~1 MW.

Changes in rotation and MHD behavior were seen after the source transitions at 500 ms. However, the shots transitioned into H-mode for brief periods due to slightly lower densities caused by inaccurate HFS gas fuelling pressure readings. It has also been noted that all L-mode fiducials run after the last maintenance period have one or more brief L-H transitions which were not evident in the fiducials run prior to the maintenance period.

The reinstallation of the 16-channel UCLA reflectometer system at Bay-J has been completed. Final tasks were BNC data and power cable terminations and debugging of a digitizer connection. First plasma data was obtained and all 16 quadrature channels worked properly. Clear evidence of high frequency coherent mode activity (~1.8 MHz) was observed during neutral beam heating consistent with GAE activity. Some minor noise issues are currently being addressed as well as proper setting of gains. Neal Crocker (UCLA) visited NSTX-U this week working on this system as well as collaborating on data analysis and upcoming experiments.

The vacuum conditioning of high harmonic fast wave (HHFW) antennas is progressing with voltages reaching ~ 20 kV using rf sources 1 - 4. If these voltages hold during a plasma discharge we should be able to apply ~ 2 - 3 MW of the HHFW heating and current drive power to the plasma. We are stopping vacuum conditioning now to allow the new relays to be installed for sources #5 and #6 so that these sources can be conditioned as well in the near future.

A. Diallo (PPPL) visited Physical Science Laboratory in Madison on May 2-6 to continue tests for the integration of the custom power supplies to the laser head for the pulse burst laser system. During this week, the beam laser beam was injected into the amplifier where pulse energy in the range of 1.7 J was successfully measured. In addition, measurements of the beam characteristics in the far field were performed using Phantom camera on loan from NSTX-U. Initial tests at 30 Hz, 1kHz, and 10kHz were successful. The status of the pulse burst system and analysis of the beam characteristics will be presented at the High temperature plasma diagnostics in June 2016. We are now mapping out the operating parameters to finalize the characterization of the laser. Work is in progress to finalize the control software to be delivered to NSTX-U.

Fatigue testing of the NSTX-U lead extensions was completed over the weekend. The most highly loaded extension was tested at the 1.0 Tesla load level and survived 400,000 cycles.
Cyclic testing will be augmented with a Charpy impact test of the CuCrZr base material and e-beam welded joint material. The successful testing of the lead extension supports near term 0.8 T operation and supports the design, analysis and quality assurance programs for the upgraded lead extensions planned for installation in the Fall. Installation of fiber optic strain gauges on the toroidal field coil outer legs is progressing and will provide measurements of the structural integrity of the new and original outer legs also to support 0.8 Tesla operation.

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

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

T. Stoltzfus-Dueck visited DIII-D from May 9-13 to work with the main ion CER group on physical mechanism of intrinsic rotation generation in the plasma edge. An analytic model for edge intrinsic rotation was integrated into OMFIT in preparation for testing of the model on the existing edge main ion shot database. At the Friday science meeting, T. Stoltzfus-Dueck also presented theoretical issues relating to the L-H transition.

A. Nagy and GA staff are in the process of assembling the Super Supply Patch Panel (SSPP), after a year of design, component fabrication and purchases. The cable connection bus and tabs will be installed next week and then the cable routing and connections tasks starts in mid-July. This new patch panel will cross connect the existing SPAs, Audio Amplifiers, C-Supplies and the new Super Supplies being delivered from China. All connection possibilities have been designed into this 72” x 160” panel. All of the connections are slip fit (no bolts), to enable timely set up and changes. The expected commissioning is this fall.

**ADVANCED PROJECTS (H. NEILSON):**

T. Brown attended the First IAEA Technical Meeting on Safety, Design and Technology of Fusion Power Plants held at the IAEA Headquarters in Vienna. T. Brown presented a paper entitled “Engineering advancements in the design of all magnetic fusion options have improved their feasibility.” The paper discussed progress in improving the engineering feasibility of three fusion reactor concept designs, based on the advanced tokamak (AT), spherical tokamak (ST), and quasi-axisymmetric stellarator (QAS), respectively. Special emphasis was given to design attributes that can simplify the device configuration and improve maintenance features. In the QAS case, it was reported that improvements in coil design tools now make it possible to design stellarators to have large inter-coil openings on the outboard side, facilitating sector maintenance of the in-vessel nuclear components. The three-day meeting involved approximately 40 participants from EU, China, S. Korea, India, Russia, and the U.S. The thrust of the meeting centered on issues dealing with safety, design and technology of a fusion power plant. The primary focus was on technical areas associated with ITER, next generation DEMO studies, and safety-related topics.
THEORY (A. BHATTACHARJEE):

R. Maingi gave a Theory Department Research Review Seminar on May 13. The talk was about “Opportunities highlighted by the 2015 FES PMI workshop report.” The 2015 FES PMI Workshop identified five priority research directions (PRDs), updating the community discussions that were held during ReNeW. In shorthand notation, the five PRDs are: (1) identify the present limits on power and particle handling of present candidate PFCs, (2) develop innovative dissipative/detached divertor solutions for power exhaust and particle control, (3) develop innovative boundary plasma solutions for main chamber wall components, (4) understand the science of evolving materials at reactor-relevant plasma conditions, and (5) understand the mechanisms by which boundary solutions and plasma facing materials influence pedestal and core performance.” In addition, four cross-cutting research opportunities, i.e. activities that contributed to each of the PRDs, were identified. This talk discussed the science elements in these PRDs and cross-cutting areas. The goal is to identify the areas appropriate for expanded theory involvement, e.g. liquid metal research as a cross-cutting opportunity.

W. Fox travelled to the University of Rochester Laboratory for Laser Energetics to conduct experiments on magnetic reconnection between colliding laser plasmas at the OMEGA EP laser facility. The experiments were designed by Fox with collaboration from Gennady Fiksel at the University of Michigan, and are supported through a grant from the National Laser User Facility by the DOE National Nuclear Security Agency to Principal Investigator, A. Bhattacharjee, in the Department of Astrophysical Sciences at Princeton.

COMMUNICATIONS & MEDIA RELATIONS (L. BERNARD):

Science magazine and The Verge wrote about NASA’s Magnetospheric Multiscale Mission. The Verge story quoted A. Bhattacharjee and can be viewed here, and the Science story quoted M. Yamada and can be viewed here.

BEST PRACTICES & EXTERNAL AFFAIRS (J. DELOOPER):

Science Education (A. Zwicker):

A. Dominguez gave a talk at California State University San Marcos and discussed collaborations with Professor Michael Burin on May 9. A. Dominguez met with Rick Lee and A. Nagy at GA to discuss outreach collaborations.

A. Dominguez gave a talk at California State University LA on May 10. He also participated as a judge on behalf of the coalition of plasma science at the INTEL ISEF fair on May 12.

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