The PPPL Highlights for the week ending May 25, 2019, are as follows:

**NSTX-U RECOVERY (R. HAWRYLUK) AND RESEARCH (S. KAYE)**

Recovery (R. Hawryluk):

The NSTX-U recovery project held a team meeting this week to update the progress toward baseline. The meeting covered the project’s commitment to safety, went over recent accomplishments, and focused on critical path, near-term priorities.

**Director’s Review** — A complete panel has been recruited for the director’s review scheduled for July 16-18. The panel has been split into four committees that cover 1) technical issues, 2) ES&H, ASO, and Ops, 3) cost and schedule, and 4) management. The recovery project team has a complete charge and agenda. Speakers have been provided detailed templates for their talks and are preparing the talks under that guidance. The goal of this review is to assess the project’s readiness for the upcoming CDE-2/3a independent project review (IPR).

**TF Bundle** — Fabrication continues on samples for the material testing that will be performed at PPPL. The process of vacuum pressure impregnation (VPI) and multiple cure cycles has begun, with the first cure cycle occurring over Memorial Day weekend. After completion, the impregnated glass layers will be removed from the plates to form flat laminates, and test samples will be cut from the laminates. Sample preparation for tensile tests at the vendor (CTD) experienced a setback in that the first set of six samples were damaged while being removed from the mold; a second set of six samples whose processing had already been initiated exhibited similar failures. A revised sample design has been developed to prevent recurrence, and the remaining sample parts are being shipped back for modification. A new stainless steel VPI mold is also being fabricated to replace the previous aluminum mold. PPPL engineers have visited CTD to further investigate and explore ways to recover the schedule. Modulus and coefficient of thermal expansion (CTE) tests at CTD are underway with no issues. PPPL's delamination model has now been aligned with another high-fidelity model that evaluates the bundle stresses with greater resolution. The aim is to have the models all working and in alignment using estimated property data so that preliminary findings can be presented at the director’s review. Then, once the material test data becomes available, the results will be finalized prior to the Stage 2 review.

**Center Stack Casing** — Oak Ridge Technologies and PPPL teams continue to review fabrication and inspection procedures. Procurement contracts of the raw materials have been awarded.
**Inner PF Coils** — The DOE has reviewed the red book for the coil contract award and provided comments. PPPL is in the process of responding to those comments.

**Machine Core Structures** — Sling prototyping has been initiated. Load cases for the upper MCS components are being analyzed in support of the FDR.

**Test Cell Shielding** — Polyethylene sheets and neutron putty materials for the shielding work were delivered this week.

**ASO Implementation** — A revision to the ASO implementation plan was signed and submitted to the DOE Princeton Site Office (PSO). PSO subsequently accepted the plan as satisfying the PEMP Notable for Goal 5 related to the development of the implementation plan.

**Research (S. Kaye):**

S. Kaye traveled to the U.K. to participate in the CCFE Program Advisory Meeting May 21-23. The advisory committee listened to presentations and discussed all aspects of CCFE work, ranging from fusion experiments to their development of robotic, material and tritium technology, which can be directed not only to fusion applications but also to fission and other applications.

**U.S. ITER FABRICATION (H. Neilson)**

Finalizing the mechanical interfaces with its enclosing diagnostic shield module (DSM) and with remote handling equipment has been a focus of the Low Field Side Reflectometer (LFSR) engineering team for several weeks. This week those efforts came to fruition. The locations and dimensions of the trunnion attachment feature for the front-end support block have been optimized to achieve several simultaneous constraints. They are strong enough to support the antenna assembly during electromagnetic transients such as plasma vertical displacement events (VDEs). The center of gravity is below the trunnions for stability during delicate installation operations by remote handling. Cooling to offset the nuclear heating of the trunnions and clamps is found to be adequate. Based on the size and location of the trunnions and clamps, a model for the geometry of the close-fitting opening in the DSM has been developed.

Completion of these interface details has advanced the LFSR toward two final design goals, namely freezing of the mechanical interfaces with the DSM and with the planned remote handling equipment and processes. The designs will be reviewed and evaluated next week by responsible parties for these systems, namely the Russian Federation’s
ITER team and the ITER remote handling consultants RACE (United Kingdom), respectively.

ITER & TOKAMAKS (R. Nazikian)

DIII-D (B. Grierson)

Operations:

E. Gilson and R. Lunsford travelled to DIII-D this week to assist in assembly and run planning for upcoming impurity powder dropper (IPD) and impurity granule injector (IGI) experiments on DIII-D, KSTAR, and LHD. With the help of A. Bortolon and other on-site PPPL personnel, they assisted in assembly of the dropper, hi-pot testing and development of the remote dropper control system. The new computer control system will allow better reliability and flexibility for dropper operation. The system will allow both local control for testing and integrated control within the DIII-D PCS system. In addition, it is being adapted to allow multiple drops and multiple powders per discharge, substantially expanding the available research avenues.

International PMI (R. Maingi):

R. Maingi, A. Diallo, Z. Sun, and K. Tritz (Johns Hopkins) ran experiments on the EAST device, using the impurity powder dropper and impurity granule injector for ELM control, in collaboration with the wall conditioning group led by J.S. Hu (ASIPP). Full ELM suppression was realized while injecting boron powder into discharges over a broad range of auxiliary heating power (2.8-7.1 MW), density (3.8e19 – 6e19), and mix of RF and NBI heating. Stored energy increased slightly as compared to the ELMy H-mode reference at constant density. There is no apparent wall hysteresis: termination of boron injection caused resumption of ELMs in ~ 0.5 sec. Low frequency edge oscillations with harmonics were observed in the radiated power from AXUV diodes near the upper X-point, and magnetic probes on the high-field side and low-field side. Comparisons were made between boron and lithium powder injection. In addition, lithium granule injection was used to pace the ELM frequency in the ELM-suppressed discharges between 5 Hz and 100 Hz, to assess the impact on ELM size. Finally, carbon granules were injected into EAST for the first time, with signs of ELM triggering at low injection speeds.
International Long Pulse (F. Poli):

W. Choi and F. Poli visited the Experimental Advanced Superconducting Tokamak (EAST) in China during the week of May 20 (US-China week) to participate in a joint experimental campaign. PPPL ran experiments with lower hybrid current drive (LHCD) and electron cyclotron (EC) heating to assess the lower hybrid (LH) physics models, including the synergy between the two-frequency LH sources and the EC heating. The experiments were motivated by previous time-dependent simulations that suggested large uncertainties in the evolution of the launched LH spectrum. These plasma discharges had good diagnostic coverage for both core and edge profiles to allow validation of the LH models and of the spectrum evolution from the antenna to the confined plasma. The EAST team is helping analyze the results.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

On May 17, C. Fall, the nominee for the Director of the Office of Science in the Department of Energy (DOE), came to the Institute for Plasma Physics in Greifswald, Germany. He toured the W7-X experiment and IPP, and later met with 13 members of the DOE-supported U.S. research team, including senior scientists, post-docs, and graduate students. PPPL scientists S. Lazerson, N. Pablant, and D. Gates were present. The researchers were participating in a workshop that was reviewing progress on understanding the results from the most recent W7-X run. The meeting lasted about an hour. Fall was very interested in the collaboration and asked many questions about how the collaboration was functioning and what the DOE could do to help make the collaboration more effective.

Fusion Energy System Studies (H. Neilson)

The Laboratory is participating in the current Fusion Energy System Study (FESS) examination of high-field magnet options for fusion nuclear devices. At a recent meeting, P. Titus reported detailed investigations of a structural solution for the toroidal field (TF) coils introduced at a previous meeting, based on combined bucking and wedging of the inner nose of the coils. Y. Zhai reviewed the TF winding pack designs from recent studies, including the U.S. FNSF study, based on low-temperature superconductors. He then introduced winding pack designs based on high-temperature superconductors, showing the potential for achieving higher magnetic fields. Both speakers addressed some of the key issues for the application of high-temperature superconductors to tokamak designs, such as very long ramp-up times and long delays in quench detection.
D. Garg attended the April APS meeting in Denver and presented a poster entitled, “Gravitational ponderomotive forces and linear gravitational waves in matter.”

M. Churchill attended the machine learning workshop in France and gave a presentation titled, “Priority research opportunities.” This workshop will determine future funding proposal topics for machine learning in fusion. PPPL can benefit by having researchers involved in setting future priorities and receiving funding. Churchill also presented an invited talk titled, “Deep convolutional neural networks for long time series classification,” at ICDDPS. His participation benefitted the lab by highlighting the work he has done with deep convolutional neural networks for fusion diagnostic analysis, which will be important for federated analysis in the future.

F. Ebrahimi was a panelist for the Innovation Showcase of 3D Printing, Machine Learning Algorithms, and Robotics, held May 16 at Siemens in Princeton. She and other panelists — C. Arnold (Princeton University), N. Bouaynaya (Rowan University), and D. Rapaport (Siemens) — discussed the future of research in the coming decade. Ebrahimi in particular discussed the critical role of public-private partnerships for the advancement of fusion energy and other related technologies. She outlined four areas where plasma physics could foster significant advancements: 1) fusion energy, 2) space propulsion, 3) medical technology and 4) cosmology, space, and astrophysics.

COMMUNICATIONS & PUBLIC OUTREACH (A. Zwicker)

Communications (L. Bernard):

The Office of Communications posted two press releases to the PPPL website. One highlighted a recent video produced by the San Diego Supercomputing Center of B. Tang explaining how artificial intelligence could help advance the development of fusion energy. Another noted that four PPPL scientists — R. Maingi, C. Dong, M-G Yoo, and Y.-M. Huang — have won national and international awards. The stories were also posted to the Newswise and EurekAlert press release distribution services.
DIRECTOR’S OFFICE (S. COWLEY)

J. Menard visited Lawrence Livermore National Laboratory on May 22 to discuss collaboration opportunities and to tour the National Ignition Facility (NIF). He also visited General Atomics on May 23 and 24 to discuss upcoming community workshops and initiatives and to meet with PPPL staff working on the DIII-D National Facility.

This report is also available on the following web site:

http://www.pppl.gov/publication-type/weekly-highlights