Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending December 7, 2019, are as follows:

NSTX-U RECOVERY (J. GALAYDA) AND RESEARCH (S. KAYE)

Recovery (J. Galayda):

Earned Value Management System (EVMS) Surveillance (Dec. 4-5) — A committee chaired by C. Lavelle performed a surveillance of the PPPL EVMS. The committee focused on the system's application to NSTX-U and IOI. The committee concluded that it would recommend that DOE certify the system upon implementing five corrective actions. Implementation will be verified earned value reports in the coming months, clearing the way for certification in March 2020.

PF Coil Fabrication — The Project continues to monitor this work closely and participate in teleconferences with manufacturer Sigmaphi. Another NSTX-U/PPPL staff member arrived in Vannes, France, and visited a Sigmaphi subcontractor to observe fabrication of mandrel components. As a result of this visit, the subcontractor took additional steps to expedite fabrication. Another mandrel has been shipped by air freight from China to Vannes. This is encouraging evidence that Sigmaphi is responding constructively to discussions with NSTX-U and PPPL management; however, continued focus on this procurement is necessary. Project management is preparing to visit Sigmaphi in mid-December. Logistics of travel in France have become difficult due to labor strikes underway in France.

CS Bellows Fabrication — Project and procurement personnel held teleconferences with Holtec and its suppliers to verify that work there was proceeding on schedule. NSTX-U is sending a member of the project team to visit the vendor in the coming weeks.

Machine Core Structure Ceramic Break System Peer Review — A peer review was held on Dec. 5 for the machine core structure ceramic break system assembly modification. The review addressed the design modification of the upper flange sub-assembly, including changes made to address field technician concerns since the Aug. 2019 final design review (FDR) about assembling the upper flanges onto port flanges.

Real-Time Control & Protection — Preliminary tests of the shorted turn protection (STP) voltage measurement design were conducted in FCPC this week. This work will prove components of the final design that will be reviewed in January.

NSTX-U Test Cell — The BOA subcontractor completed installation of the formwork for the test cell labyrinth walls. Concrete placement is scheduled for the week of Dec. 9.

Research (S. Kaye):

J. Carling, CEO of Tokamak Energy Ltd, UK, visited PPPL on Dec. 5. He met with the multi-institutional group of ST40 Collaboration researchers located at PPPL to discuss the status of ST40 and HTS magnet development (to the extent that he could, given the proprietary nature of the technical development), approach to collaboration, and the present state of the collaboration. This collaboration is the most important and largest one that ST40 has. Carling reiterated the sentiment of Tokamak Energy in its commitment to make this collaboration a successful one and a possible paradigm for public-private partnerships.

R. Maingi presented a seminar at the University of Illinois at Urbana-Champaign (UIUC) on Dec. 5 entitled, “Proposed plans for liquid metal plasma-facing component research in NSTX-U.” The talk outlined the near-term NSTX-U priorities over the next five years, possible liquid lithium elements at the end of this period, and aspirations during the five-year period from 2025 to 2029. D. Andruczyk hosted the visit and UIUC students shared their most recent R&D activities in liquid metal research at UIUC.

U.S. ITER FABRICATION (H. NEILSON)

Structural analysis of the Low Field Side Reflectometer (LFSR) antenna assembly is proceeding in preparation for a final design review (FDR) in 2020. An initial analysis has been performed by PPPL engineer W. Syed to study the effect of electromagnetic (EM) loads on the system. The EM load data was imported as body force densities (force per unit volume) from a previously completed Maxwell simulation. The results show behavior that is in line with similar analyses conducted in the past. The enclosing port plug experiences a torque, with a maximum total displacement of approximately 2.2 mm on the diagnostic first wall. The next step is to update the system geometry to incorporate the latest designs for the remote handling camps, flex clamps, thermal straps, and cooling channels in the horns. Additionally, thermal loads resulting from nuclear and microwave heating will also be included for the next set of analyses.

Diagnostics Team Lead H. Neilson participated as an invited lecturer in the 2019 Costa Rica Training Workshop in Fusion for the Latin American Region, held Nov. 25-29 in Cartago, Costa Rica. The workshop, conducted as part of a strategy to strengthen the participation of Latin American countries in fusion research, was attended by 70 students from Colombia, Mexico, Honduras, Ukraine, China and Costa Rica. About ten lecturers from fusion research centers around the world covered a range of important topics in the week-long program. Neilson presented lectures titled, “ITER Physics, Engineering, and Status,” and “ITER Diagnostics: Design Challenges.”

Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson)

Research:

The paper titled, "Setting the H-mode pedestal structure: variations of particle source location using gas puff and pellet fueling," by A. Nelson has been accepted for publication in *Nuclear Fusion*. The paper demonstrates that pellet fueling increases the height of the pedestal density, while gas fueling both increases the pedestal density and shifts the density pedestal outwards towards the separatrix. Contrasting equivalent fueling rates, the pedestal pressure does not degrade with increased pellet fueling, but the pedestal pressure does degrade with strong gas puffing.

This week, a PPPL team of machine learning and control experts visited DIII-D to coordinate the implementation of a deep learning disruption predictor into the real-time plasma control system. Princeton's Fusion Recurrent Neural Network code (FRNN) uses convolutional and recurrent neural network components to integrate both spatial and temporal information for predicting disruptions in tokamak plasmas with unprecedented accuracy and speed. The team includes W. Tang, J. Kates-Harbeck, A. Svyatkovskiy, E. Feibush, D. Boyer, K. Erickson, G. Dong, and K. Felker. They were hosted by DIII-D 3D & Stability Physics and Control group leaders for highly productive strategization meetings in which near-term action items were set to ensure successful PCS integration into the 2020 DIII-D run campaign. Tang presented the FRNN at the DIII-D Friday science meeting.

International PMI and FES LM PFC Development Program (R. Maingi):

R. Maingi conducted a periodic meeting of the liquid metal PFC development program. In this meeting, participants discussed the prioritization of near-term plasma-surface interaction modeling tasks and near-term experiments at ORNL, PPPL, and UIUC.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates):

E. Gilson led a PPPL Impurity Powder Dropper (IPD) team at NIFS to conduct the first IPD experiments on LHD. Successful experiments were conducted on both Tuesday and Friday with both boron and boron nitride being injected. Initial results presented at the regular NIFS LHD physics meeting were received with interest and excitement. Plans are being made for follow-on IPD experiments during LHD long-pulse operation at the end of the current campaign in early 2020.

F. Nespoli traveled to NIFS together with E. Gilson and R. Lunsford to perform experiments on LHD. Here, the PPPL-designed and -built impurity powder dropper successfully delivered powders into the LHD plasma for the first time. Preliminary results were presented at LHD physics meeting and an abstract on these experiments has been submitted for the upcoming PSI conference. The steps necessary for modeling IPD LHD experiments with XGC-S have been discussed on site with PPPL's M. Cole and the NIFS collaborators.

R. Lunsford travelled to LHD as part of the PPPL Impurity Powder Dropper team. While on site, he modified the IPD control program to permit remote dropper operation interlocked into the LHD control system. The newest version of the LabVIEW-based control program provides independent dropper operation for multiple bursts within the shot sequence as well as onboard diagnostic recording for prompt analysis. It also permits rapid user modification of the experimental settings allowing operational flexibility within the three-minute LHD shot cycle. These new capabilities permitted IPD operation without failure or unwanted injections over the full experimental program.

THEORY (S. HUDSON)

T. Stoltzfus-Dueck published an article titled, "Orbit-modulated plasma transport and sources," in *Nuclear Fusion*. In the article, a general conservative gyrokinetic framework is used to show that the steady-state orbit-loss boundary fluxes are determined by upstream transport (turbulent and collisional) and upstream sources and sinks. Within the framework, the details of the equilibrium orbits, even accounting for large but axisymmetric and time-independent electric fields and poloidal pressure gradients, contribute only by modulating the upstream transport and source terms. This reformulation provides a theoretical basis for numerical and theoretical evaluation of multi-physics contributions to the edge radial electric field.

A letter titled, "Collisional resonance function in discrete-resonance quasilinear plasma systems," by V. Duarte was published in *Physics of Plasmas*: https://doi.org/10.1063/1.5129260. The letter describes a first-principles analytic method to calculate resonance functions in quasilinear theory in the presence of collisions or background micro-turbulence. The results are currently being programed into the resonance broadened quasilinear (RBQ) code and are being applied to the modeling of fast ion transport due to several discrete modes in DIII-D discharges.

W. Lee gave a seminar at Courant Institute, New York University, on Dec. 3. The title of the talk was "Finite Larmor Radius effects at the H-mode pedestal and their implication for the force-free MHD equilibrium." The material is mostly based on the recently published paper by Lee and R. White in *Physics of Plasmas*.

Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard):

The Office of Communications posted two news stories to the PPPL website this week. One focused on research by C. Clauser into eddy and halo currents in fusion plasmas; Clauser found that any increase in the halo current is offset by a reduction in the eddy current. The other story explains a new program that will allow new engineers to do six month-rotations through four jobs in four different engineering areas over two years, while learning skills and receiving mentoring. New engineers will be added to the program each year. Both stories were also posted to the *Newswise* and *EurekAlert* press release distribution services.

DIRECTOR'S OFFICE (S. COWLEY)

S. Cowley, J. Menard, and R. Hawryluk attended the 40th Fusion Power Associates Meeting and Symposium held Dec. 3-4 in Washington, D.C. The event was titled, "Fusion Energy: Perspectives and Planning."

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