Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending December 16, 2017, are as follows:

NSTX-U RECOVERY AND RESEARCH (J. MENARD)

Recovery:

A Preliminary Design Review (PDR) for the inner poloidal-field coils was completed on Dec. 14. The PDR highlighted the material testing and finite element analysis (FEA) techniques required to validate and verify the design. Reliability-driven enhancements to design and manufacturing based on lessons learned from the DVVR and Extent of Condition process were also reviewed.

A Systems Integration PDR was completed on Dec. 15. The PDR highlighted the improved requirements management and change control program aspect of the recovery project. Signed versions of the general requirements document (GRD) and key system requirements documents (SRDs) were presented to the review committee. Since these documents are the basis for the project baseline, any needed revisions will go through a change control process.

Work continues in two parallel streams in the PPPL coil winding shop. Technicians are co-winding glass and kapton tape for use at PPPL and for shipment to the prototype subcontract coil shops. An innovative automated machine-vision tape inspection system has been deployed for tape quality assurance inspections. The second work stream in the magnet area is preparation for PF1 prototype winding at PPPL.

A new capture system for outboard high-heat flux tiles has been developed. The system features a compressible copper capture scheme that will restrain motion and lock components in place. This design solution was driven by the PPPL design review process in responding to PDR chits.

Research:

Several NSTX-U team-members participated in the second U.S. Magnetic Fusion Research Strategic Directions Workshop hosted by the University of Texas at Austin from Dec. 11-15. F. Ebrahimi gave a presentation on the progress of the working group for Strategic Approach 3 titled, “Theory and Modeling Innovations.” F. Poli and W. Guttenfelder served in leadership roles in the workshop discussion groups 3 and 5 respectively, and D. Boyer, R. Goldston, G. Hammett, R. Majeski, and S. Sabbagh also made significant contributions to workshop working groups and/or discussion groups. J. Menard served as a workshop co-chair and gave the workshop summary presentation titled, “Overall Summary of Areas of Consensus / Non-consensus and Future Activities.”

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U.S. ITER FABRICATION (H. NEILSON)

The monthly management meeting between the U.S. ITER and Central Team (IO-CT) Diagnostics teams was held on Dec. 14. Expectations for two preliminary design reviews (PDRs) to be held in FY-2018 were discussed. For the low-field-side reflectometer (LFSR), the PPPL team has recently made modifications to the port plug closure plate and interspace support structure to increase clearance for personnel access. The teams are iterating on design documentation requirements for the PDR that is scheduled for June 2018. For the upper wide-angle-viewing (UWAV) system, a PDR focused on the adaptive image recognition instrumentation and control is being planned for the May-June 2018 timeframe. The PPPL and IO-CT teams are currently iterating on document requirements for this limited-scope PDR. This work is continuing under a contract with Bertin Technologies while other work on the UWAV system is suspended due to budget reductions.

ITER & TOKAMAKS (R. NAZIKIAN)

R. Nazikian, B. Grierson, S. Haskey, and A. Bortolon attended the fusion community workshop in Austin to discuss strategic directions for the U.S. fusion program in support of the National Academy of Science study.

DIII-D

Research:

D. Iglesias from the UKAEA visited DIII-D for two weeks to work with M. Knolker and C. Lasnier on divertor heat flux analysis. Iglesias tested the ALICIA code on DIII-D data. In contrast to the standard THEODOR code, ALICIA uses an implicit solver and promises more precision. As a first result, there were still negative heat fluxes found in the test discharge file, an indicator for changes in the uppermost layer of the divertor on DIII-D. Researchers are still investigating whether the fluxes are due to changes in the surface density, roughness, or conductivity. Iglesias will visit a second time next year: he will be able to use the results of the DIII-D data analysis for research involving MAST-Upgrade.

Z.R. Wang visited DIII-D to plan for the upcoming experiment titled, “Nonambipolar Transport and Neoclassical Toroidal Viscosity (NTV) of Energetic Particles,” scheduled for Dec. 18th. Scientists will try to use data from the experiment to verify the existence of energetic particle NTV, which may be important for rotation control in tokamaks. Z.R. Wang is also working with Y.Q. Liu for the development of the MARS-K code for

hybrid kinetic-MHD simulation, and applying resistive DCON and MARS code in DIII-D and NSTX-U experiments.

EAST

F. Poli attended the 3rd EAST/DIII-D planning workshop in Beijing from Nov. 30-Dec. 4. The workshop covered various topics relevant for long pulse operation on EAST, including scenario development and modeling, control, 3D physics and ELM control, and heating and current drive. The purpose of the workshop was the identification of joint experiments and research activities to be conducted on the two tokamaks. Poli gave a presentation on how integrated modeling can support scenario development and optimization of access to steady state operation, and discussed research to be undertaken to understand how the synergy between the heating and current drive sources on EAST can be used to improve the access to steady state operation, and to study reactor relevant regimes of dominant electron heating.

R. Maingi and K. Tritz (Johns Hopkins University) visited EAST to continue analysis of previous experiments and collaborate on a number of joint in-progress papers with the ASIPP PSI team. Discussion of new capabilities of the impurity powder dropper, along with recent dropper wall conditioning results from ASDEX-Upgrade, were presented in a talk titled, “Impurity Powder Dropper: Results from ASDEX-Upgrade and Considerations for EAST.” The team is on track to install the new dropper in Jan. or Feb. 2018.

C-MOD

A manuscript titled, “Verification of GENE and GYRO with L-mode and I-mode Plasmas in Alcator C-Mod,” by D.R. Mikkelsen, N.T. Howard, A.E. White, and A.J. Creely has been submitted to *Physics of Plasmas*. The study shows that linear gyrokinetic benchmark calculations, by GENE and GYRO, agree very well, but that nonlinear simulations predict different heat fluxes. Further simulations are proposed to uncover the causes of the discrepancy in the nonlinear simulations.

KSTAR

R. Maingi, A. Bortolon, E. Gilson, R. Lunsford, D. Mansfield, D. Mueller, and A. Nagy held a conference call with KSTAR staff to discuss the benefits of the impurity powder dropper for KSTAR. Initial results of the boron and BN powder dropper on ASDEX-Upgrade were presented, and existing impurity injection technologies were discussed by KAIST. Strong interest was shown in the application of powder droppers to KSTAR and further discussions are planned.

ADVANCED PROJECTS (H. NEILSON)

Stellarators (D. Gates)

During the recently completed OP1.2a experimental campaign on Wendelstein 7-X (W7-X), N. Pablant organized and led the development of an experimental program on the topics of neoclassical transport, core heat transport, and core impurity transport. This set of experiments used power and density scans in each of the W7-X magnetic configurations to provide an overview of core heat and impurity transport in both helium and hydrogen plasmas. The shots for this experiment were carefully designed to allow all available core profile and turbulence diagnostics on W7-X to simultaneously measure high-quality data. Also included in this program was the seeding of impurities to enable the study of impurity transport and impurity recycling. These experiments form the basis of a systematic study of W7-X performance in OP1.2a, and this data set is expected to be used by the entire W7-X team for analysis. In addition, Pablant participated as a co-lead on several additional experimental programs dedicated to profile shaping though off-axis heating, impurity transport and diagnostic commissioning.

The U.S.-supplied trim coils were to modulate and symmetrize divertor heat loads throughout the OP1.2a campaign on W7-X. In experiments led by S. Lazerson, the amplitude and phase of trim coil-applied field perturbations were systematically varied in the standard and narrow mirror configurations. The heat flux to each divertor was measured using both thermocouples mounted in the backside of each divertor target and infrared camera data showing the rise in temperature on each target surface. This data were compared to field line tracing simulations to predict the amplitude and phase which should symmetrize the divertor heat flux. These simulations took into account the “as-built” position of the superconducting coils along with finite-element simulations of electromagnetic loading. The data acquired will enable the Laboratory to address a FY-2018 notable outcome pertaining to the use of trim coils to control divertor heat flux distribution.

System Studies (C. Kessel)

C. Kessel participated in the community’s MFE Strategic Directions Workshop held in Austin, TX. Kessel presented the results of a Working Group on Access to ITER, showing the physics, technical, and present program benefits of continued U.S. participation in ITER. In addition, alternate paths that the U.S. might take in the event of a withdrawal from ITER were briefly described, and the working group's impressions of the programmatic aspects were also presented. This report and a series of questions were subsequently used in discussion group sessions, whose goal was to synthesize the major points and any consensus (and non-consensus) views.

Weekly HIGHLIGHTS

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U.S. DEPARTMENT OF ENERGY

THEORY (A. BHATTACHARJEE)

The article, "Magnetic connections in curved spacetime," by F. Asenjo and L. Comisso has been published in *Phys. Rev.* D **96,** 123004 (2017).

The paper, "Theory and observation of the onset of nonlinear structures due to eigenmode destabilization by fast ions in tokamaks," by V. N. Duarte, H. L. Berk, N. N. Gorelenkov *et al*. is a featured article on the *Physics of Plasma*s website.

The paper "High-Mach Number, Laser-Driven Magnetized Collisionless Shocks" by D. Schaeffer, W. Fox, A. Bhattacharjee and co-authors was recently published in *Physics of Plasmas* and selected as an Editor's Pick.

Links to the above mentioned articles may be found on the Theory website here:
http://theory.pppl.gov/news/seminars.php?scid=4&n=publications

S.R. Hudson presented a seminar on stellarator coil design at the University of Maryland. He was hosted by M. Landreman.

E. Hirvijoki visited Los Alamos National Laboratory on Dec. 14 and15 and worked with L. Chacon's group on implementing a conservative relativistic collision operator for runaway electron studies. He gave a talk titled, "Metriplectic Dynamics."

Copies of the above presentations are available here:
http://theory.pppl.gov/news/seminars.php?scid=6&n=external-seminars

M. Churchill attended the U.S. Magnetic Fusion Research Strategic Directions Workshop in Austin, TX. The goal of the workshop was to provide feedback to the National Academy of Sciences (NAS) on the importance and opportunities for burning plasmas within the US magnetic fusion community.

F. Ebrahimi gave a presentation at the same meeting titled "Transformative Theory and Predictive Modeling — A Pathway Toward Fusion Energy." A copy of the presentation is available here:
http://theory.pppl.gov/news/seminars.php?scid=3&n=invited-talks

Theory seminars titled, "Investigation of whistler-electron interaction in Earth's radiation belt," presented by L. Zhao from the New Mexico Consortium, and "Nonlinear ECDI and anomalous transport in ***E×B*** discharges," presented by S. Janhunen from the University of Saskatchewan, were presented. The abstracts and presentations are available on the Theory website:

Weekly HIGHLIGHTS

http://theory.pppl.gov/news/seminars.php?scid=1&n=research-seminars

COMPUTATIONAL PLASMA PHYSICS GROUP (S. Kaye, S. Jardin)

S. Jardin participated in the ITER Integrated Modeling Expert Group meeting at the ITER IO in Cadarache, France, along with Lang Lao as the two U.S. representatives. Representatives from each of the ITER parties made presentations on how they are adapting simulation codes, and in some cases experimental data, to the IMAS (ITER Modeling and Simulation) standards and conventions. We also reviewed the progress of the ITER Integrated Modeling program and made recommendations for their future activities. There was great interest in the PPPL developed translators that convert data from the TRANSP data model to and from the IMAS data model. There was also considerable interest in having the NUBEAM fast-particle code (used in TRANSP) being made into a IMAS component that could be used in workflows developed by ITER IO and the other parties. This work has begun and is expected to be completed in the near future.

S. Ethier presented a CPPG Seminar on the parallelization framework "MPI" that covered both basic usage and some advanced topics.

ENGINEERING & INFRASTRUCTURE (V. RICCARDO)

Fiber Bragg Grating strain and temperature sensors have been spot welded to PF1A Lower outer stiffeners and inner mandrel. These sensors will be used to measure how the coil behaves during testing. Additional sensors will be epoxied to the coil itself.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

COMMUNICATIONS (L. BERNARD)

The Office of Communications posted two stories to the PPPL website. The first focused on S. Prager, PPPL director from 2009 to 2016, being awarded a 2017 Distinguished Career Award from Fusion Power Associates. Prager, a leading contributor to the advancement of plasma physics and fusion science, received the award at the 38th annual meeting of FPA held Dec. 6-7 in Washington, D.C. The association provides students, media and the public with information about the status of fusion development and other applications of plasma science. The second story describes how PPPL physicist B. Tang is leading a team of PPPL and Princeton University scientists developing software with machine-learning capability that can predict plasma disruptions in ITER. Members of the PPPL and Princeton University machine-learning team are the first to systematically apply a deep learning approach to the problem of disruption forecasting in tokamak

fusion plasmas. Both stories were posted on the *Newswise* and *EurekAlert!* press release distribution services.

DIRECTOR'S OFFICE (R. HAWRYLUK)

Dec. 12-13, T. Brog attended the National Laboratories Chief Operations Officers (NLCOO) meeting in Washington, D.C.

On Dec. 13, J. Lukes of the University of Pennsylvania presented a colloquium entitled, "Predicting Thermal Transport in Nanostructured Materials."

Dec. 13-14, R. Hawryluk attended the National Laboratory Director's Council (NLDC) meeting in Washington, D.C.

Dec. 12-15, M. Zarnstorff attended the Austin Community Workshop titled, "Strategic Directions for U.S. Magnetic Fusion Research," held in Austin, Texas.

On Dec. 15, R. Hawryluk presented to the National Academy of Sciences Committee, which met in Austin, Texas.

This report is also available on the following web site:

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