Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending December 19, 2020, are as follows:

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

Recovery (J. Galayda):

Management — The project management team has devoted a concerted effort to prepare for the upcoming PPPL and DOE cost/schedule/project reviews in February and March. Preparations are on track.

Bus Supports — The water-cooled power cables were sent back to the vendor for repair. The materials required for the PF extension and OH coax bus connection were inspected and prepared for fabrication of the supports in conjunction with the work packages.

Coils — Preparations for machining the six production coils continued at PPPL. At Sigmaphi, the last spare coil (PF1A-S) was shipped and was received at PPPL.

Center Stack Casing (CSC) — Finish machining of the CSC continued in Camden, NJ. Engineering oversight continued at Turtle Creek and an issue with distortion was found in the bellows mockup welding; the issue was reviewed by PPPL Engineering and by Holtec machining. A new mockup at Holtec was in progress and analytic work continued at PPPL to resolve the distortion. Stud installation prototyping and organ pipe welding continued, while leak testing was performed in concert with the completion of the organ pipe welding.

IVPS — Installation of the pump and electrical and controls began last week.

Machine Core Structure (MCS) — Fabrication continued at Precision Boring in Michigan. The capture flanges were finished. The common flanges neared completion, with one flange in inspection, and machining finished on the other flange. Fixture plates fabrication also continued last week. In South Carolina, Carolina Fabricators' production of PF1A sling base parts continued, with 34 completing Phase 1 machining, and all moving into Phase 2 machining. G. J. Oliver completed the MRR and machining continued on the outer skirt support. In addition, the PF1C upper support was coated and will be shipped next week. The ceramic break flange was machined. At PPPL, mockup activities lessons learned were incorporated into assembly procedures. PF1B lower slings welding was completed, and post-weld inspection and heat treating began last week. Upper PF-1B sling fixturing began last week, as well as preparations to weld the PF1A slings. The PF1C support was dimensionally checked and moved into welding, cleaning, and testing.

PF-4 and PF-5 Coil Realignment Peer Review — A peer review was held Dec. 18 to review the PF-4/5 epoxy pad rework/repair hardware design, and to verify that the new method and process for the rework and new epoxy pad installation can achieve the initial goals to meet all requirements for the PF-4/5 coil realignment. During the installation of epoxy pads for the PF-4/5 coils realignment, it was discovered that the non-coplanarity in the epoxy pad forming can have as much as 0.25" variability in the surface location of the PF5 pancake coil clamps from a nominal value. This will cause unacceptable non-uniform loadings of the anvil plate onto the coil pack. The peer review addressed the changes needed to the installation procedure and hardware for the epoxy pads to properly rework the pads on the PF coils.

Research (S. Kaye):

An ST40 collaboration meeting was held on Dec. 18 among Tokamak Energy and U.S. researchers involved in ST40 research. N. Gorelenkov (PPPL) gave a progress report on improving the energetic particle distribution function that is used to determine linear and ultimately non-linear simulations of Alfven eigenmode stability. Present treatment of the energetic particle distribution is through truncated functions for sources and sinks. Future treatment, which will involve Gaussian smoothing of the distribution function as represented by Legendre polynomials, will streamline both the (quasi) linear and nonlinear simulations. M. Romanelli (Tokamak Energy) presented results on predictive modeling of ST40 reference scenarios. These predictions made use of a number of codes (ASCOT/GENRAY/AORSA/NUBEAM) for both fixed boundary (using ASCOT) and free boundary (using FIESTA) for reference scenarios for programs two and three. Core transport was based on the Bohm-gyroBohm and neoclassical transport models for both electrons and ions, and the pedestal boundary condition was based on data and results from NSTX. The reference scenarios will be uploaded to the ST40 MDSplus tree, which is mirrored at PPPL, for input to energetic particle and transport-related (gyrokinetic) simulations.

M. Lampert gave a presentation at the Dec. 11 NSTX-U / Magnetic Fusion Science seminar summarizing analysis on the dynamics of edge filaments during ELM crashes in NSTX H-modes as measured by the gas puff imaging diagnostic. A brief summary and discussion of the FES Long Range Plan, unanimously approved by FESAC during their meeting Dec. 7-10, was also held at this weekly seminar.

R. Maingi and A. Diallo finished their participation in the Office of Science panel on COVID impacts on research. The final panel findings and debrief were held this week, and a draft letter report was written by the panel.

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ITER PROJECTS (H. NEILSON)

Low Field Side Reflectometer — LFSR (A. Zolfaghari, S. Shirey):

A review of progress toward final design closure for the in-vessel antenna assembly showed that PPPL has completed over two-thirds of its action plan toward resolution of the fourteen Category 1 and 2 chits from the June 2020 final design review. In addition, twenty-five out of thirty-two deliverable documents have been approved by the ITER Organization.

Motional Stark Effect — MSE (A. Cohen):

PPPL engineer M. Messineo presented a 3D model of the EP01 optical design integrated with the diagnostics shield module in that port. The modeling work is intended to establish space claims in EP01 prior to freezing of interfaces. Certain component placements require further adjustment. The IO's optical design subcontractor presented progress on the MSE optical design in EP03. Mirror placement was reviewed and found to be acceptable, although there are some protrusions from the space claim that will need further work. This and other issues will be addressed when PPPL's subcontractor resumes its work. PPPL engineer G. Paraiso presented progress on the first mirror unit design. The unit has been extended as far back in the DSM as possible to allow for space for mirror cleaning and shutter components.

Equatorial Port Integration — EP03/09 (A. Basile):

The Port Integration team has received a 3D model definition of the EUDA's Equatorial Wide Angle Viewing System (WAVS). The availability of diagnostic system models now allows design integration into USDA-responsible equatorial port structures to proceed.

Toroidal Interferometer Polarimeter — TIP (M.-A. De Looz):

A meeting was held with PPPL's TIP design partner General Atomics to discuss near-term work on the project once the GA contract is re-started. It was agreed that development of a laser optical model would be one of the first tasks, in order to support decision making and design of the diagnostic first wall. Other tasks will be to evaluate updates to real-time alignment due to recently studied thermal distortion of the modular diagnostic shield modules, and to review recent developments on window material test results.

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ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson):

Research:

J. Wai, a graduate student at Princeton University, published the paper, "Infrared constrained equilibrium and application to snowflake divertor studies" in *Nuclear Materials and Energy*: https://doi.org/10.1016/j.nme.2020.100835. A novel technique is developed that uses the infrared heat flux diagnostic to resolve magnetic field structure in the divertor region more accurately. This technique opens the possibility for improved control of the snowflake divertor x-points. A strong correlation between the modified divertor shape and modified edge current is observed suggesting potential use for edge current diagnostics.

The paper, "CAKE: Consistent Automatic Kinetic Equilibrium reconstruction," by Princeton postdoctoral researcher Z.A. Xing, was accepted by *Fusion Engineering and Design*. A workflow is developed to process diagnostic measurements, calculate kinetic constraints and tune numerical fitting parameters to enable the automatic production of low numerical error kinetic equilibria using the EFIT solver for DIII-D. The results are found to be comparable to expert-made kinetic equilibria and suitable as inputs to MHD stability calculations. CAKE has been used to produce kinetic equilibria for the current experimental campaign.

International PMI and Liquid Metal PFC Concept Development (R. Maingi & A. Diallo):

R. Maingi hosted a periodic meeting of the domestic liquid metal PFC concept design program. In this meeting a debrief on the FESAC long range plan report was given; liquid metal PFC research is recommended for strengthening in the report. J. Jun (ORNL) also had a brief update on tensile tests at ORNL for metals exposed to liquid lithium.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates):

Development of the PPPL virtual engineering analysis workflow processes continues in the DOE Advanced Research Projects Agency-Energy (ARPA-E) permanent magnet (PM) stellarator program. Though being brought out under the ARPA-E PM stellarator program, the process workflow is addressing PPPL system-wide implementation and will provide a framework for the compact fusion pilot plant. The analysis configuration management system is being employed with the completion of Ansys procurement that will bridge the physics and engineering systems. Last week, data was brought full-circle

from physics to engineering with feedback to physics paving the way for a more automated process as the implementation proceeds.

Two members of the Advanced Project group attended the High Temperature Plasma Diagnostics virtual conference last week. K. Hammond presented a poster entitled, "Initial operation of a real-time Thomson scattering evaluation system on the Large Helical Device." N. Pablant presented a poster entitled, "Correction and Verification of XICS Analysis on W7-X Through X-Ray Ray Tracing." Papers on both topics will be submitted to be published as part of the HTPD special issue of *Review of Scientific Instruments*.

OFFICE OF ACADEMIC AFFAIRS (N. FISCH)

N. Fisch gave a virtual seminar to the Technology in Public Policy Club (TiPP) titled, "The Future of Nuclear Fusion" on Dec. 9. TiPP is a Princeton University undergraduate club.

N. Fisch delivered a virtual keynote titled, "Energy Transformations in Plasma," on Dec. 13 at the IVS-IPSTA 2020 – 38th Annual Conference of Israeli Vacuum Society (IVS), which was colocated this year with the Israel Plasma Science and Technology Association (IPSTA).

THEORY (S. HUDSON)

D. Schaeffer attended the virtual AGU meeting and presented a poster titled, "Laboratory Studies of Laser-Driven, Ion-Scale Magnetospheres."

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard):

The Office of Communications posted three press releases to the PPPL website. The first reported the development of an algorithm that could automatically detect the presence of plasmoids in the Earth's magnetosphere, possibly leading to better prediction of space weather.

The second reports that a subcommittee convened by the DOE's Fusion Energy Sciences Advisory Committee (FESAC) to develop a long-range plan for FES has released its report that lays out a strategic plan for fusion energy and plasma science research over the next decade. Its strategic plan charts a path for the U.S. as it seeks to develop fusion as a limitless and practical source of energy. The plan also embraces discovery plasma science to advance our understanding of the plasma state of matter and translate this

understanding into a wide range of transformative technologies in areas such as advanced manufacturing, medicine, and agriculture.

The third reports on research by PPPL scientists in coordination with MIT's Plasma Science and Fusion Center (PSFC) and Commonwealth Fusion Systems, a start-up spun out of MIT that is developing a tokamak fusion device called "SPARC." The goal of the project is to predict the leakage of fast alpha particles produced during the fusion reactions in SPARC, given the size and potential misalignments of the superconducting magnets that confine the plasma. These stories were also posted to the *Newswise* and *EurekAlert* press release distribution services.

L. Bernard participated remotely in the U.S. Department of Energy Communications and Public Affairs headquarters meeting held Dce. 15.

DIRECTOR'S OFFICE (S. COWLEY)

The PPPL Laboratory Leadership Council (LLC) held a second virtual strategic planning retreat on Dec. 14. The meeting was a follow-up from the prior retreat and had three specific focus areas: the attributes of future user/collaboration facility, the mission readiness of our staff and facilities as we pursue our evolving mission, and the accomplishment of PPPL notable outcomes both in science and mission support.

S. Cowley participated in the National Laboratory Director's Council (NLDC) meeting that was held on Dec. 15.

S. Cowley, J. Menard and M. Zarnstorff participated in the annual Fusion Power Associates (FPA) meeting on Dec. 16-17.

PPPLers participated in the annual State of the Laboratory (SOL) address, presented by Laboratory Director S. Cowley, on Dec. 18. The SOL included announcement of the recipients of the Kaul Foundation Prize for Excellence in Plasma Physics Research and Technology Development, and the Distinguished Engineering Fellow award, as well as other Laboratory awards.

This report is also available on the following web site:

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