Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending January 13, 2017 are as follows:

U.S. ITER FABRICATION (H. NEILSON):

This week, U.S. ITER Project Director Dr. Ned Sauthoff and Deputy Director for Non-Nuclear Systems Dr. Graeme Murdoch visited PPPL for discussions regarding the Laboratory's plans for accomplishing its assigned project responsibilities. This year PPPL will complete its remaining equipment deliveries for the Steady State Electrical Network and will complete R&D and analysis tasks supporting diagnostic designs and port plug integration. The wide-ranging set of discussion topics included project organization, milestones, risk management, interfaces, quality assurance, and procurement. Staff from throughout the Laboratory contributed to the meeting, including representatives of the Procurement, Quality Assurance, Business Operations, and Engineering organizations, the Director's Office, and the Laboratory's ITER project team. A highlight of the meeting was a presentation by Dr. Murdoch summarizing the impressive accomplishments of the Non-Nuclear Systems Division in 2016.

ITER Steady State Electrical Network (J. Dellas):

6.6kV Switchgear: Final inspection reports received from IO. No issues were reported.

Power Transformers: All shipments have arrived at the ITER site. The IO is in the process of inspecting the shipment of accessories since the exterior of some of the boxes is discolored due to weathering.

UPS, DC Distribution: Regular coordination meetings for both contracts are currently focused on preparation of Release for Manufacturing documentation packages.

ITER Diagnostics (R. Feder):

Diagnostic Residual Gas Analyzer (DRGA): An initial analysis was performed for a cylindrical iron magnetic shield with 25-mm thick walls surrounding the Hiden RGA prototypic 80-m cable RF match box. External fields were shown to be reduced from ~130 mT to below 10 mT throughout the box volume. An update to the DRGA Interface Spreadsheet status table was generated and distributed for comment.

Toroidal Interferometer and Polarimeter (TIP): The single channel TIP Prototype on DIII-D is in its final commissioning phase. With the DIII-D vessel pumped down, return beams have been obtained, and final tune up is taking place, with expectations of obtaining initial results by early February.

ITER Analysis Team: A seismic load input document for US ITER diagnostics system design was completed and will be uploaded to US ITER iDocs for approval. This document includes the acceleration response spectra under SL-2 earthquake conditions in the Inter-space, Port Cell, gallery, and diagnostic building regions of the Tokamak Complex. The information is needed now for diagnostic teams to complete their system component designs.

Low Field Side Reflectometer (LFSR): The Gaussian Telescope mechanism, designed and prototyped by PPPL for ITER LFS reflectometer, is being tested in the laboratory. A new adjustable window prototype is being designed and built for testing on the transmission line test stand at General Atomics. Interfaces between the diagnostic system and other ITER systems have been identified and reported to the ITER Organization.

Upper Wide Angle View VIS-IR Cameras (UWAVs): The Upper Camera design effort by General Atomics continues to make good progress. The Front End Optics Tube (FEOT) design completed is being documented. The Intermediate Optics Tube (IOT) Design is nearing completion. A kickoff meeting for the Back End Optics Camera (BEOC) design has been held.

Electron Cyclotron Emission (ECE): A molybdenum heater for the ECE calibration hot source prototype has been delivered to the University of Texas at Austin ahead of schedule. Assembly and testing of the hot source prototype will start next week. A sample piezo actuator for the ECE shutter/mirror successfully passed survival tests at PPPL, operating normally in vacuum at 100 C after 3 bakeouts of 72 hours at 200C. The performance of piezo actuator was also not affected by unsteady magnetic field pulses with rump rates of up to 10 T/s.

NSTX-U RECOVERY PROJECT (R. HAWRYLUK):

The first Design Validation and Verification Review (DVVR) is scheduled for January 18 and will review the NSTX-U Instrumentation and Control Systems. Progress continues on the development of NSTX-U System Design Descriptions (SDD's), and drafts are being reviewed and updated.

In the test cell, the removal of the lower ceramic break is in progress with the completion of electrical disconnections and the removal of the upper portion of the centerstack pedestal. The removal of the PF1AL support has been completed. The ceramic break lift and removal is scheduled for this coming Tuesday. Preparations for the removal of the PF1BL coil continue. Final machining of the PF1AL mandrel is nearly complete in the Tech Shop.

Re-commissioning of the coil winding facility continued with the ongoing fabrication of the coil winding brake skid. Also this week, work in the Neutral Beam clean room / decon facility continued on the disassembly of the spare ion source with an internal water leak, and on the decontamination and evaluation of an ion source last used on TFTR. The new source grid alignment machine has been fully commissioned in the clean room, and is being actively used on ion source assembly.

Voith Hydro Reps are on site for scheduled maintenance of the NSTX-U Motor Generator Thrust Bearing.

NSTX-U RESEARCH (J. MENARD):

M. Podestà gave an NSTX-U Monday physics meeting presentation on his recent research related to "Computation of Alfvén Eignenmode stability and saturation through a reduced fast ion transport model in TRANSP". The NSTX-U Boundary Science Group held discussions on possible FY17 and FY18 research milestones, and NSTX-U researchers also participated in liquid metal strategy discussions led by R. Maingi. Zhehui (Jeff) Wang from Los Alamos National Laboratory visited PPPL during the week of January 9 to discuss boundary science collaborations. J. Menard gave a PPPL colloquium entitled "Motivations for Spherical Torus research and initial results from NSTX Upgrade".

ITER & TOKAMAKS (R. NAZIKIAN):

DIII-D:

B. Grierson has developed new capabilities for predictive TRANSP modeling within the OMFIT framework for DIII-D, including a new "Shot Designer" workflow. This new workflow provides a simple user interface to allow the user to define the time history of the plasma current, toroidal field, heating powers and top of pedestal parameters. This does not require an existing TRANSP run. The simulation evolve the plasma consistent with resistive current diffusion including sawteeth and calculates core profiles from transport models such as GLF23 or TGLF. Torques from 3D field perturbations that are computed off-line using models such as GPEC are input to the momentum balance equation, permitting predictions of the rotation profile evolution for upcoming experiments in the DIII-D rotation thrust.

ADVANCED PROJECTS (H. NEILSON):

Stellarators (D. Gates):

The Laboratory reported completion of one of its FY-2017 Notable Outcomes by completing the delivery of the two divertor scraper units that have been fabricated as part of the U.S. collaboration on Wendelstein 7-X (W7-X). Receipt of the equipment and associated documentation package were confirmed in a video conference with the project's responsible officer, Dr. Joris Fellinger of the Max Planck Institute for Plasma Physics (IPP). The divertor scraper, a high-heat flux component designed to protect the edges of the divertor targets under certain operating conditions, has been a topic of the W7-X collaboration for several years. After developing a design solution for the steady-state phase of W7-X, an IPP-ORNL team developed an inertially-cooled version of the design that could be used to test its functionality during pulsed operation in the next operating campaign, OP1.2. Leadership of the fabrication phase was assigned to PPPL in 2015. It is forecast that the units will be installed in W7-X later in 2017. Currently, a multi-institutional scraper-related physics task force is performing analyses and developing an experimental plan for testing the scraper during OP1.2.

D. Gates participated in the first program committee meeting for the International Stellarator/Heliotron Workshop (ISHW2017). The workshop will be held in Kyoto, Japan from October 2-6 on the main campus of Kyoto University. The committee agreed on important dates and deadlines and discussed the process for selecting invited presentations. The workshop is biannually organized under the auspices of the IEA Stellarator-Heliotron Technology Collaboration Program, with the previous meeting being held in Greifswald, Germany. More information about the ISHW is available at http://www.ipp.mpg.de/4022808/ISHW

System Studies (C. Kessel):

A conference call with the CFETR (Chinese Fusion Engineering Test Reactor) team from ASIPP was held to share progress and update the device description. Xiaoman Cheng, visiting PPPL and working with A. Khodak, both reported on modeling of high pressure steam reactions with beryllium neutron multiplier in a blanket module. Although their analysis is continuing, CFD modeling can show the evolution of BeO and production of hydrogen, as well as pressure and temperature. These types of studies are critical to understand potential accident scenarios and how design can be used to mitigate them. Jiangang Li summarized the recent decision to make the CFETR device larger, from 5.7 m to 6.6 m major radius, maintaining a Phase I reaching 200 MW of fusion power and Phase II reaching > 1000 MW of fusion power. They are focused on both steady state plasma operation and very long partially inductive discharges, and have chosen a HTSC central solenoid to maximize volt-seconds. They have gone with 12 TF coils, from 16. They are actively pursuing HTSC and LTSC coil development, tritium technologies, divertor design and testing, materials research and remote handling and maintenance. Li Liu, soon to be visiting PPPL and working with C. Kessel, reported on his initial studies of volt-second consumption using TSC combined with ONETWO (GA). He demonstrated a series of approaches to minimize the consumption in the ramp-up phase and maximize an inductive flattop. The CFETR device is most closely related to the FNSF (studied in the US) and collaborations will continue to better understand the technical choices made among these facilities.

THEORY (A. BHATTACHARJEE):

M. Churchill, C.S. Chang, R. Hager, R. Maingi, R. Nazikian, and D. Stotler, with external coauthors John Canik and Tony Leonard, published a paper entitled "Kinetic simulations of scrape-off layer physics in the DIII-D tokamak" in Nuclear Materials and Energy journal, http://dx.doi.org/10.1016/j.nme.2016.12.013. The abstract is as follows: "Simulations using the fully kinetic code XGCa were undertaken to explore the impact of kinetic effects on scrape-off layer (SOL) physics in DIII-D H-mode plasmas. XGCa is a total-f, gyrokinetic code which self-consistently calculates the axisymmetric electrostatic potential and plasma dynamics, and includes modules for Monte Carlo neutral transport. Fluid simulations are normally used to simulate the SOL, due to its high collisionality. However, depending on plasma conditions, a number of discrepancies have been observed between experiment and leading SOL fluid codes (e.g. SOLPS), including underestimating outer target temperatures, radial electric field in the SOL, parallel ion SOL flows at the low field side, and impurity radiation. Many of these discrepancies may be linked to the fluid treatment, and might be resolved by including kinetic effects in SOL simulations. The XGCa simulation of the DIII-D tokamak in a nominally sheath-limited regime show many noteworthy features in the SOL. The density and ion temperature are

higher at the low-field side, indicative of ion orbit loss. The SOL ion Mach flows are at experimentally relevant levels (Mi ∼ 0.5), with similar shapes and poloidal variation as observed in various tokamaks. Surprisingly, the ion Mach flows close to the sheath edge remain subsonic, in contrast to the typical fluid Bohm criterion requiring ion flows to be above sonic at the sheath edge. Related to this are the presence of elevated sheath potentials, $e\Delta\Phi/Te \sim 3-4$, over most of the SOL, with regions in the near-SOL close to the separatrix having $e\Delta\Phi/Te > 4$. These two results at the sheath edge are a consequence of non-Maxwellian features in the ions and electrons there."

Michael Cole, Max Planck Institute for Plasma Physics, Greifswald, presented a Theory Seminar titled "Global electromagnetic gyrokinetic and hybrid simulations of Alfvén eigenmodes". The abstract reads: "The pursuit of commercial fusion power has driven the development of increasingly complex and complete numerical simulation tools in plasma physics. Recent work with the EUTERPE particle-in-cell code has made possible global, electromagnetic, fully gyrokinetic and fluid-gyrokinetic hybrid simulations in a broad parameter space, where previously global gyrokinetic simulations had been hampered by the so-called 'cancellation problem'. This has been applied to the simulation of the interaction between Alfvén eigenmodes and energetic particles. In this talk, the range of numerical methods used will be detailed, and it will be shown with practical examples that self-consistent global simulations may be necessary for even a qualitatively accurate prediction of the perturbation of the magnetic field and fast particle transport due to wave-particle interaction. A brief outline will be given of the future direction of this work, such as the possibility of gyrokinetic simulation of the interaction between fine-scale turbulence and MHD modes."

Ravindra Samtaney, King Abdullah University Sci. & Technology (KAUST), presented a Theory Seminar titled "Discrete Exterior Calculus Discretization of the Navier-Stokes Equations". The abstract reads: "A conservative discretization of incompressible Navier-Stokes equations over surface simplicial meshes is developed using discrete exterior calculus (DEC). The DEC discretization is carried out for the exterior calculus form of Navier-Stokes equations, where the velocity field is represented by a 1-form. A distinguishing feature of our method is the use of an algebraic discretization of the interior product operator and a combinatorial discretization of the wedge product. Numerical experiments for flows over surfaces reveal a second order accuracy for the developed scheme for structured-triangular meshes, and first order accuracy for general unstructured meshes. The mimetic character of many of the DEC operators provides exact conservation of both mass and vorticity, in addition to superior kinetic energy conservation. The employment of various discrete Hodge star definitions based on both circumcentric and barycentric dual meshes is also demonstrated. The barycentric Hodge star allows the discretization to admit arbitrary simplicial meshes instead of being limited only to Delaunay meshes, as in previous DEC-based discretizations. The convergence order attained through the circumcentric Hodge operator is retained when using the barycentric Hodge. The discretization scheme is presented in detail along with numerical test cases demonstrating its numerical convergence and conservation properties. Preliminary results regarding the implementation of hybrid (circumcentric/barycentric) Hodge star operator are also presented. We conclude with some ideas for employing a similar method for magnetohydrodynamics."

Computational Plasma Physics Group (S. Jardin):

Visualization work led by E. Feibush is described in an article written by Catherine Zandonella of the Office of the Dean for Research at Princeton University. In this project, PPPL collaborates with the University's Princeton Institute for Computational Science and Engineering (PICSciE), and the Department of Commerce's National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory (GFDL). Entitled "Taming Oceans of Data with New Visualization Techniques", the article includes a computer-generated movie of high resolution climate model data that evolves over a calendar year. The movie is scripted by Matthew Harrison (GFDL) and narrated by R. Camp (PPPL). The visualization workflow is tailored for data that is f(x,y,t) such as sea surface temperature and salinity. The color-coded rendering helps researchers understand complex heat transport in the ocean. High performance is achieved by parallel computing on the GPU and multi-core processing on the CPU. Software developers include Department of Energy Science Undergraduate Laboratory Interns Michael Knyszek and Matthew Lotocki.

The article was published January 3 on the Princeton University home page and subsequently mirrored on the Department of Energy Office of Science website (University Research) and njtoday.net. The article was also featured in the Princeton Weekly Bulletin on January 5.

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