The PPPL Highlights for the week ending November 7, 2014, are as follows:

U.S. ITER FABRICATION (D. JOHNSON):

UCLA presented preliminary loss measurements for a transmission line run designed by ORNL for the ITER low field side reflectometer. This test line consists of straight sections of circular corrugated waveguide with several miter bends. In the frequency range 30 - 50 GHz, observed losses were higher than theory would predict. Further measurements are planned to understand whether this enhanced loss originates in the straight sections or the miter bends.

Bill DeVan and Eva Freer, of the USIPO I&C Group, presented "Introductory Session on ITER Instrumentation and Control" in the first of two scheduled web meetings to diagnostic teams supporting US ITER diagnostic designs. The same presentation will be given on November 14.

Joe Beno, engineer at the Center for Electromagnetics at the University of Texas, presented work towards the selection of heaters for the in-port hot calibration source for the electron cyclotron emission diagnostic. Some of the requirements on the source have been called into question and are now being reviewed. In addition, it was recognized that vibration loads need to be estimated and provided to the design team.

NSTX (M. ONO):

Jack Berkery and Steve Sabbagh of Columbia University attended the MHD Stability Control Workshop hosted by Auburn University, delivering the presentations “Kinetic resistive wall mode stability evaluation and physics insight application in NSTX” and “Physical Characteristics of Neoclassical Toroidal Viscosity in Tokamaks for Rotation Control and the Evaluation of Plasma Response,” respectively, which showed results and analysis from NSTX, DIII-D, and KSTAR.

NSTX researchers participated in and contributed significant analysis to a DIII-D National Fusion Science Campaign experiment "Controlling H-mode particle transport with ECH", the results of which were presented as orals at both recent IAEA-FEC and APS-DPP meetings. The experiments were led by D. Ernst (MIT) and co-led by K. Burrell (DIII-D), W. Guttenfelder (NSTX) and T. Rhodes (UCLA). The APS presentation was featured as a press release for the annual DPP 2014 conference titled "Using radio waves to control density in fusion plasmas" http://www.aps.org/units/dpp/meetings/vpr/2014/upload/ernst.pdf.

A concerted effort was undertaken to develop a means to run TRANSP automatically between NSTX-U discharges. This process is called BEAST (BEtween and Among Shots Transp). Code modifications along with detailed timing runs to optimize namelist parameters were undertaken as part of this process. A 1.1 sec NSTX H-mode discharge was used as the basis for this study. The timing tests, which were done on 32 dedicated processors, indicated, as expected, that most of the modification and optimization necessary was in the NUBEAM (fast ion) calculation. Namelist parameters controlling the beam time step, number of beam particles, goosing parameter and fast ion distribution output were tested. With proper optimization, still preserving acceptable output statistics, the 1.1 sec H-mode discharge calculation wall clock time was reduced to 5.5 minutes. Estimating approximately one to two minutes of overhead in run setup and post-processing, this would enable a run to finish within eight minutes of the plasma discharge, within the between shot time of 10-20 minutes. Additional run profiling will be done in an attempt to further optimize the time, and a new 32 cpu cluster will be implemented dedicated to tBEAST calculations.

Preparations for plasma operations in the NSTX-U configuration also continued. RF transmission line re-installation/testing continues, and the NSTX-U neutron detectors were installed in their permanent locations in the test cell. A dynamic end-to-end calibration of the neutron detectors with a known source was performed this week using a temporary track system installed in the vessel. Preparations are underway for the in-vessel alignments of the Multi-pulse Thompson Scattering diagnostic (MPTS), which is scheduled to occur the week of November 10, immediately following the neutron detector calibrations.

ITER & TOKAMAKS (R. HAWRYLUK):

The review paper "Enhanced confinement scenarios without large edge localized modes in tokamaks: control, performance, and extrapolability issues for ITER" was published in Nucl. Fusion 54 (2014) 114016. It can be downloaded at http://stacks.iop.org/0029-5515/54/114016. The abstract describes the scope: "Large ELMs typically accompany good H-mode confinement in fusion devices, but can present problems for plasma facing components because of high transient heat loads. Here the range of techniques for ELM control deployed in fusion devices is reviewed. Two strategies in the ITER baseline design are emphasized: rapid ELM triggering and peak heat flux control via pellet injection, and the use of magnetic perturbations to suppress or mitigate ELMs. While both of these techniques are moderately well developed, with reasonable physical bases for projecting to ITER, differing observations between multiple devices are also discussed to highlight the needed community R&D. In addition, recent progress in ELM-free regimes, namely quiescent H-mode, I-mode, and enhanced pedestal H-mode is reviewed, and open questions for extrapolability are discussed. Finally progress and outstanding issues in alternate ELM control techniques are reviewed: supersonic molecular beam injection, edge electron cyclotron heating, lower hybrid heating and/or current drive, controlled periodic jogs of the vertical centroid position, ELM pace-making via periodic magnetic perturbations, ELM elimination with lithium wall conditioning, and naturally occurring small ELM regimes."

DIII-D (R. Nazikian):

The Lithium Granule Injector (LGI) was installed on the DIII-D vessel this week. The installation at a midplane port took five hours and was completed in time for the pit closing for

neutral beam conditioning. The base pressure after one day of pumping was eight micro Torr. The calibration and testing of camera fiber optics and the high intensity illumination system was completed. Further checks on the air motor/impeller are scheduled for November 8. The LGI on-site team grew by the addition of A. Bortolon's arrival at General Atomics this week.

The pole shield work continues to move smoothly. The copper plates have been completed and are presently at the plasma sprayer. In the meantime, the machining of the TZM Moly tiles continues.

P. Titus and A. Khodak will be attending TOFE meeting in California to present a paper on the Pole Shield design analysis.

C-Mod (R. Hawryluk):

Procurement for the C-Mod ten-channel MSE background polychrometer is complete, and electrical and mechanical assembly has begun.

W. Guttenfelder contributed an APS poster to the C-MOD session titled "Investigating electromagnetic effects on core transport in Alcator C-Mod H-mode discharges".

ADVANCED PROJECTS (D. GATES):

S. Lazerson presented an invited talk entitled "Numerical optimization of three dimensional coils for NSTX-U" at the Workshop on MHD Stability Control on November 3-5 held at Auburn University in Auburn, Alabama. The results of recent work, which applied a modified version of the STELLOPT code called IPECOPT.

Fusion Socioeconomics: A small group got together to review the very recent IPCC AR5 Synthesis report, and its possible implications for fusion. The extreme constraints on CO2 emissions prescribed by the end of the century indicate that if truly ubiquitous carbon-capture and storage is not viable, particularly in combination with large-scale biomass energy production, then other non-carbon sources, such as fusion, will need to expand to control atmospheric CO2 levels as specified.

THEORY (A. BHATTACHARJEE):

On November 3, P. Ricci discussed SOL simulations using the Braginskii code GBS: One of the greatest uncertainties in the success of ITER and future fusion reactors is related to the turbulent dynamics of the plasma fusion fuel in the scrape-off layer (SOL). The plasma behavior in this region governs the overall confinement properties of the device, regulates the impurity dynamics and the level of fusion ashes, and determines the heat load to the tokamak vessel walls – a showstopper for the whole fusion program if material requirements cannot be met. A project is being carried out in Lausanne, Switzerland with the goal of improving our understanding of plasma turbulence in SOL-relevant conditions and the Global Braginskii Solver (GBS) code has been developed for this purpose. Considering configurations of increasing complexity, we have initially studied linear magnetic configurations and simple magnetized toroidal devices. GBS has

now reached the capabilities of performing non-linear self-consistent global three-dimensional simulations of the plasma dynamics in limited tokamak SOL. By solving the drift-reduced Braginskii equations, the code evolves self-consistently the plasma flux from the core, turbulent transport, and the plasma losses to the limiter plates. This gradual approach has allowed us to advance the basic understanding of SOL turbulence, making progress in the identification of the driving instabilities, in estimating the turbulence saturation amplitude, and the generation of intrinsic toroidal rotation. The main focus of our research has been on the mechanisms that regulate the SOL width, leading to a first-principle based scaling for the SOL pressure scale length. The comparison of our theoretical and simulation results against data from several tokamaks worldwide (TCV, Alcator-C Mod, Tore Supra, JET, and COMPASS) yielded very good agreement.

On November 7, D. Pfefferle discussed fast ion transport in 3D saturated MHD configurations: Designed to accurately solve the motion of energetic particles in the presence of 3D magnetic fields, the VENUS-LEVIS code leans on a non-canonical general coordinate Lagrangian formulation of the equations of motion (guiding-centre and full-orbit). Fast ion redistribution is investigated with this numerical tool in various 3D saturated MHD equilibria, which are modelled via the ANIMEC code. First, slowing-down simulations are applied to NBI (neutral beam injection) populations in MAST helical core configuration. It is observed that co-passing particles helically align in the opposite side of the plasma deformation whereas counter-passing particles are barely affected by the kinked structure. Results are compared with experimental neutron camera traces recorded during MAST hybrid plasmas with long-lived modes (LLM). Then, two opposing approaches to include resonant magnetic perturbations (RMPs) in fast ion simulations are compared, one where the vacuum field caused by the RMP current coils is added to the axisymmetric MHD equilibrium, the other where the MHD equilibrium includes the plasma response within the 3D deformation of its flux-surfaces. The first model admits large regions of stochastic field-lines that penetrate the plasma without alteration. The second assumes nested flux-surfaces with a single magnetic axis, which excludes stochastic field-lines, and embeds the RMPs within a 3D saturated ideal MHD state. Simulations of MAST NBI populations in the presence of n = 3 RMPs show that, at low beam energies, particle losses are dominated by parallel transport due to the stochasticity of the field-lines (vacuum-RMP model), whereas at higher energies, losses are accredited to the 3D structure of the perturbed plasma and the resulting drifts (equilibrium-RMP model).

Also on November 7, D. Brunetti discussed fast growing instabilities and nonlinear saturated states in hybrid tokamak and RFP plasmas: The stability of large scale m = 1 helical displacements of tokamak and RFP plasmas with reversed shear are investigated using the 3D equilibrium code VMEC/ANIMEC and the non-linear initial value stability code XTOR. These modes occur when an extremum in the safety factor is close to a low order rational ($q_{min} \approx 1$ in tokamaks, and $q_{max} \approx 1/7$ in RFPs). If the exact resonance can be avoided, the essential character of these modes can be modeled assuming ideal plasmas with nested magnetic flux surfaces. The non-linear amplitude of such saturated modes obtained with XTOR is compared both with the helical core structure resulting from VMEC/ANIMEC calculations, and with analytic predictions which extend the nonlinear treatment of reversed q plasmas to arbitrary toroidal mode numbers. A preliminary study of the impact of an n = 1 RMP coil on the saturated kink-like mode in MAST plasmas by using free boundary ANIMEC code, is presented for conditions where the magnetic shear is allowed to become small over a large portion of the plasma, which typically occurs either in hybrid tokamak scenarios or following reconnection of a

global instability such as a sawtooth, resistive sidebands coupled to a core kink-like mode exhibit extremely fast growth. The sensitivity of the dependence of the growth rate upon the Lundquist number to two-fluid effects, shear flow and viscosity has been examined analytically and numerically with the XTOR code. It is found that these additional non-MHD effects tend to moderately reduce the extreme growth rate of resistive modes in low shear plasmas. A family of modes are obtained, including modes with novel scaling on Lundquist number, some of which rotate in the electron diamagnetic direction, and others in the ion diamagnetic direction, consistent with experimental observations in TCV during hybrid-like operation.

PLASMA SCIENCE AND TECHNOLOGY (P. EFTHIMION):

The PS&T Department seminar was presented by Walter D. Gonzalez from National Institute of Space Research in Brazil. The title of his talk was "Interplanetary origin of intense, superintense and extreme geomagnetic storms" and abstract "A review on the interplanetary causes of intense geomagnetic storms (Dst < -100 nT) will be presented for solar cycle 23. It was reported that the most common interplanetary structures leading to the development of intense storms were: magnetic clouds, sheath fields, sheath fields followed by a magnetic cloud and corotating interaction regions at the leading fronts of high speed streams. However, the relative importance of each of those driving structures has been shown to vary with the solar cycle phase. Superintense storms (Dst< -250 nT) have been studied in more detail also for solar cycle 23, confirming initial studies done about their main interplanetary causes. The storms are associated with magnetic clouds and sheath fields following interplanetary shocks, although they frequently involve consecutive and complex ICME structures. Concerning extreme storms (Dst < - 400 nT), due to the poor statistics of their occurrence during the space era, only some indications about their main interplanetary causes are known. For the most extreme events, a review on the Carrington event will be presented and a discussion about the distribution of historical and space era- extreme events, in the context of the sunspot and Gleissberg activity cycles, will be also given."

ENGINEERING AND INFRASTRUCTURE (M. WILLIAMS):

NSTX Upgrade (R. Strykowsky, E. Perry, L. Dudek, T. Stevenson):

Construction: The lower row one tiles have been installed and a floor has been installed to support neutron calibration and MPTS calibration. The vessel will be closed following the MPTS calibration that ends November 12. Measurements for PF bus inside the umbrellas continue as CHI bus installations are occurring. The glow discharge and category 4 cables are being connected. Re-machining of the TF lead extensions continues.

CS Upgrade: Insulation of the PF Bus bars continued in the CS winding area. Cleaning and silver-plating of the TF Flex connectors started in winding area. A successful peer review was held to review the Halo Side Load Block design.

NBI Upgrade: Services work continued on the turbo vacuum lines. The lines were completed and leakchecked. The HVE leakcheck was completed. The N4ABC high voltage systems were configured for power and reactivation tests were performed. A LCC reactivation took place in

parallel and controls issues were identified. The reactivation of Accel systems is imminent. Controls work continues with installation of cable, trays, and terminations and progress continues on PLC software pages. Cryogenics maintenance and repairs in preparation for operations continues. The shield wall drawing was forwarded to Facilities for wall installation. The development of NB procedures continues. Management attended the monthly status meeting.

Digital Coil Protection System: The real world pre testing procedure was approved and tests continue. DCPS software tweaks, PTP testing, and bug investigations continues as background activities. Development of a DCPS System Design Description and Reliability Assessment continues per the requirements. A junction area interface chassis concept for DCPS FCC signals was discussed and is moving forward. A review of DCPS chits to update and close action items took place with a Question and Answer session. The Operations procedure for setup and startup of DCPS is in development.

DIRECTOR'S OFFICE (C. AUSTIN):

A. Cohen attended a meeting of the ITER-MAC Conference in Cadarache, France on October 26-October 31, and visited W7-X in Greifswald, Germany on November 1-3.

On November 4, Professor Dennis Whyte from the Massachusetts Institute of Technology presented a colloquium entitled, "MIT - HTS and ARC for Fusion".

November 5-6, the bi-annual PPPL Advisory Committee was held at PPPL. The purpose of the PPPL Advisory Committee is to review the efficiency and effectiveness of the Laboratory science and operations.

INVITED TALKS:

Lazerson, S., "Numerical Optimization Of Three Dimensional Coils For NSTX-U," Workshop on MHD Stability Control, Auburn University

PUBLICATIONS:

Maingi, R., "Enhanced Confinement Scenarios Without Large Edge Localized Modes In Tokamaks: Control, Performance, And Extrapolability Issues For ITER," Nuclear Fusion 54 (2014) 114016, http://stacks.iop.org/0029-5515/54/114016.

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