PPPL PRINCETON PLASMA PHYSICS LABORATORY
A Collaborative National Center for Fusion & Plasma Research
U.S. DEPARTMENT OF ENERGY
WEEKLY
October 16, 2017

THIS WEEK

WEDNESDAY, OCT. 18

Council Café Lunch
12 p.m. ◆ Cafeteria
Andrea Moten,
Interim Head of HR

PPPL Colloquium
4:15 p.m. ◆ MBG Auditorium
Properties and Degradation of Polyimide in Extreme Hygrothermal Environments
Alan Zehnder, Cornell University

THURSDAY, OCT. 19

Open Forum with Dave McComas
2 p.m.
See page 6 for details.

FRIDAY, OCT. 20

Public Tour
10 a.m.
Email tours@pppl.gov for info.

UPCOMING

OCT. 23–27

59th Annual Meeting of the APS Division of Plasma Physics
Milwaukee, Wisconsin

THURSDAY, OCT. 26

Open Enrollment 2018 Benefits Fair
10 a.m.–2 p.m.
Vendors in LSB Lobby
Presentations in MBG Auditorium:
10–11 a.m.
Understanding Your Social Security Benefits
by Social Security Administration representatives
11 a.m.–12 p.m.
Introducing the New Roth Retirement Savings Option
by TIAA representatives

INSIDE

Physicists propose new way to stabilize next-generation fusion plasmas

By Raphael Rosen

A key issue for next-generation fusion reactors is the possible impact of many unstable Alfvén eigenmodes, wave-like disturbances produced by the fusion reactions that ripple through the plasma in doughnut-shaped fusion facilities called tokamaks. Deuterium and tritium fuel react when heated to temperatures near 100 million degrees Celsius, producing high-energy helium ions called alpha particles that heat the plasma and sustain the fusion reactions.

These alpha particles are even hotter than the fuel and have so much energy that they can drive Alfvén eigenmodes that allow the particles to escape from the reaction chamber before they can heat the plasma. Understanding these waves and how they help alpha particles escape is a key research topic in fusion science.

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Project Matterhorn physicist Rolf Sinclair returns to PPPL 45 years after he left

By Jeanne Jackson DeVoe

Rolf Sinclair, a physicist who worked at Project Matterhorn, came to PPPL on Sept. 29 to tour the Laboratory where he started work nearly 60 years ago after learning about it at the Atoms for Peace Conference in Geneva, Switzerland in 1958.

Sinclair was in Princeton last month to speak at a conference in connection with an exhibit at the Princeton University Art Museum on the painter Howard Russell Butler (1856–1934), who painted eclipses and other astronomical phenomena. Sinclair helped organize the exhibit. It closed earlier this month but some of the paintings can be seen online at http://artmuseum.princeton.edu/transient-effects/painter-sun.

Rolf Sinclair, center, with Michael Zarnstorff, PPPL's deputy director for research, left, and retired physicist Ken Young, a colleague of Sinclair's in the 1960s, in front of a model stellarator from the 1958 Atoms for Peace Conference, which Sinclair attended before joining Project Matterhorn. *(Photo by Elle Starkman)*

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Next steps in NSTX-U Recovery Project presented to staff

By Jeanne Jackson DeVoe

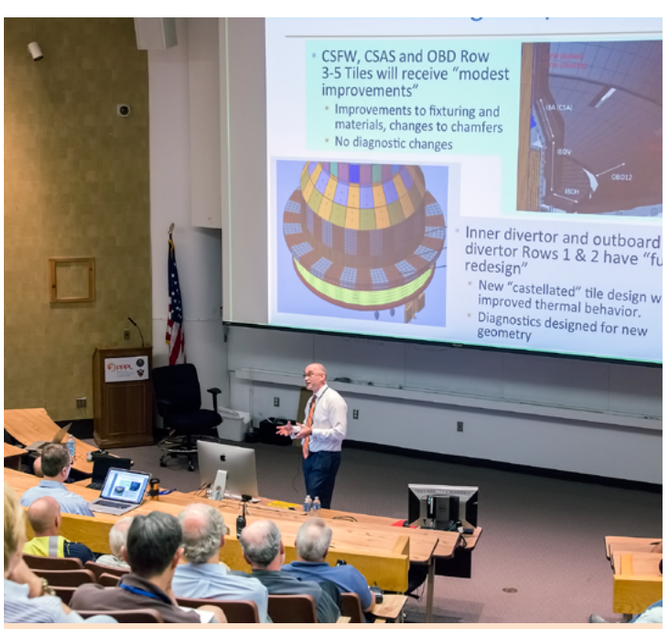
Jon Menard, head of the NSTX-U Recovery Project, speaks to staff in the MBG Auditorium Oct. 11. *(Photo by Elle Starkman)*

The National Spherical Torus Experiment-Upgrade (NSTX-U) will provide critical data for developing and optimizing future fusion devices. But this can only be accomplished by addressing critical technical issues that are essential to ensuring NSTX-U can achieve full performance and operate reliably, according to the heads of the NSTX-U Recovery Project.

Jonathan Menard, the head of the PPPL Recovery Project; Stefan Gerhardt, the deputy head, and Les Hill, the project manager in charge of the Extent of Cause effort gave an overview of plans to rebuild major components of the machine and institute new initiatives in project planning and other areas during a presentation with interested staff on Oct. 11 in the MBG Auditorium.

"These design changes will significantly enhance the facility's safety and reliability for the highest performance spherical tokamak in the world," said Gerhardt. "We will have to work together to achieve success."

Gerhardt outlined the detailed review of each system of the machine from January through May, consisting of 17 reviews, 12 of which were design, validation, and verification reviews (DVVRs) of each individual system. These also included two extent of condition reviews, a conceptual design review, and a cost and schedule review, with 47 external reviewers participating throughout the process.



Stefan Gerhardt, deputy head of the NSTX-U Recovery Project, discusses planned improvements to the NSTX-U. *(Photo by Elle Starkman)*

The Recovery Team has come up with a detailed plan focused on fixing components of the machine that are most critical to its operating reliably, Gerhardt said. These include rebuilding six magnets called poloidal field coils that shape the plasma. The new magnets will be mandrel-less, meaning they will be wound on metal spools but the spools will then be removed, to make it easier to conduct turn-to-turn electrical testing on them.

The estimated total cost for the Recovery Project is $63 million, including a $14-million contingency. The presently estimated early finish date is October 2019 with an 80 percent probability of completion by July 2020.

Providing a model for next generation fusion devices

Menard told staff that the NSTX-U will move fusion energy research forward once it begins operating again. It is a spherical tokamak, meaning that is shaped like a cored apple. The device's compactness and high power could provide a model for next generation fusion devices that could ultimately produce cost-effective, sustained fusion energy.

"I wanted to reiterate why we're doing what we're doing," Menard said. "A key feature of the NSTX-U is that it will be the highest performance spherical tokamak in the world."

This is due to the addition of a more powerful central magnet and the addition of a second neutral beam, which will double the plasma current and magnetic field of the device. This will allow PPPL to investigate how much these parameters can improve confinement.

The higher temperatures and magnetic field will make it possible for scientists to use results from the NSTX-U to understand plasma confinement in a spherical tokamak at temperatures closer to a working fusion reactor. It will provide key technical results for the next generation of fusion energy experiments, including ITER, Menard said.

The experiment will address several key issues as well, including:

- Better understanding of turbulence;
- Increased understanding of how to predict the confinement of fast ions from fusion reactions – an issue Menard said will be critical in burning plasma experiments such as ITER;
- Learning about the use of liquid metals on the inner walls of the tokamak to increase energy confinement and protect the walls from the super-hot plasma.

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NSTX-U Recovery Project

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Les Hill, who headed the Extent of Cause Review, gives his presentation. *(Photo by Elle Starkman)*

Ensuring reliable operation of the device

The challenge, Menard said, is to produce those results while at the same time ensuring the reliable operation of the device for the hundreds who rely on the device for their research. This includes 54 collaborating institutions, 362 data users, 40 of whom are international, 29 graduate students, and 25 post-doctoral researchers.

He noted that in FY 2016, NSTX-U exceeded the expectations for pulse duration and magnetic field, and for fast-ion physics discoveries. However, several technical failures ended operations in 2016, leading to the intensive technical reviews of the past year.

Hill, who headed the Extent of Cause Review and integrated corrective action plan outlined plans to change policies, procedures and operations at the Laboratory, that are similar to those at other laboratories. These includes changes in processes and management/systems in the following areas:

- Engineering design
- Configuration management
- Work planning and control
- Project management
- Training and qualification
- Quality assurance
- Performance management

PPPL submitted a required extent of cause report outlining a series of recommendations in these areas, along with an Extent of Condition report, to the Department of Energy on Sept. 29.

PPPL's ESU holds fire safety demonstrations for Fire Prevention Week

PPPL's Emergency Services Unit did a fire safety demonstration on Oct. 12 in front of the LSB for Fire Prevention Week. This year's Fire Prevention Week theme, "Every Second Counts: Plan 2 Ways Out!," reminded everyone to have a home escape plan with two exits and practice it in case of a fire.

Kenneth Bauer puts out a fire under the guidance of ESU Officer Aaron Green. *(Photo by Elle Starkman)*

Photographer Elle Starkman tries her hand at firefighting with ESU Officer Green as ESU Officer Jim Plagge looks on. *(Photo by Kenneth Bauer)*

Alfvén eigenmodes

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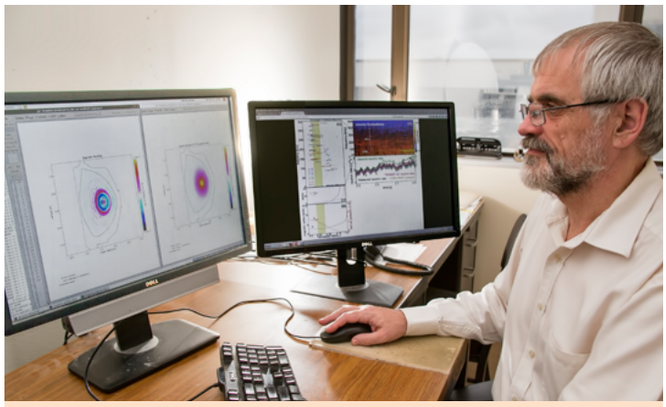
If only one or two of these waves are excited in the reaction chamber, the effect on the alpha particles and their ability to heat the fuel is limited. However, theorists have predicted for some time that if many of these waves are excited, they can collectively throw out a lot of alpha particles, endangering the reactor chamber walls and the efficient heating of the fuel.

Recent experiments conducted on the DIII-D National Fusion Facility, which General Atomics operates for the U.S. Department of Energy in San Diego, have revealed evidence that confirms these theoretical predictions. Losses of up to 40 percent of high-energy particles are observed in experiments when many Alfvén waves are excited by deuterium beam ions used to simulate alpha particles and higher-energy beam ions in a fusion reactor such as ITER, which is now under construction in the south of France.

In the wake of this research, physicists at PPPL produced a quantitatively accurate model of the impact of these Alfvén waves on high-energy deuterium beams in the DIII-D tokamak. They used simulation codes called NOVA and ORBIT to predict which Alfvén waves would be excited and their effect on the confinement of the high-energy particles.

The researchers confirmed the NOVA modeling prediction that over 10 unstable Alfvén waves can be excited by the deuterium beams in the DIII-D experiment. Furthermore, in quantitative agreement with the experimental results, the modeling predicted that up to 40 percent of the energetic particles would be lost. The modeling demonstrated for the first time, in this type of high-performance plasma, that quantitatively accurate predictions can be made for the effect of multiple Alfvén waves on the confinement of energetic particles in the DIII-D tokamak.

"Our team confirmed that we can quantitatively predict the conditions where the fusion alpha particles can be lost from the plasma based on the results obtained from the modeling of the DIII-D experiments" said Gerrit Kramer, a PPPL research physicist and lead author of a paper that describes the modeling results in the May issue of the journal *Nuclear Fusion*.



Gerrit Kramer *(Photo by Elle Starkman)*

The joint findings marked a potentially large advance in comprehension of the process. "These results show that we now have a strong understanding of the individual waves excited by the energetic particles and how these waves work together to expel energetic particles from the plasma," said physicist Raffi Nazikian, head of the ITER and Tokamaks Department at PPPL and leader of the Laboratory's collaboration with DIII-D.

The NOVA+ORBIT model further indicated that certain plasma conditions could dramatically reduce the number of Alfvén waves and hence lower the energetic-particle losses. Such waves and the losses they produce could be minimized if the electric current profile in the center of the plasma could be broadened, according to the analysis presented in the scientific article.

Experiments to test these ideas for reducing energetic particle losses will be conducted in a following research campaign on DIII-D. "New upgrades to the DIII-D facility will allow for the exploration of improved plasma conditions," Nazikian said. "New experiments are proposed to access conditions predicted by the theory to reduce energetic particle losses, with important implications for the optimal design of future reactors."

The DOE Office of Science supported this research. Members of the research team contributing to the published article included scientists from PPPL, General Atomics, Lawrence Livermore National Laboratory and the University of California, Irvine.

Rolf Sinclair

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Sinclair took a tour of the Laboratory arranged by retired physicist and former Deputy Director Dale Meade and led by physicists Greg Hammett and Devon Battaglia, along with Michael Zarnstorff, PPPL's deputy director for research. The 88-year-old caught up with some old friends and got to see the National Spherical Torus Experiment-Upgrade (NSTX-U) and the unfinished National Compact Stellarator Experiment now called Quasar. He also saw the model stellarator, then called a simulator, that he first saw at the Atoms for Peace Conference in 1958, and which played a part in bringing him to Project Matterhorn.

"Everyone was particularly kind and helpful and walked me through a lot of what's going on at the Lab," Sinclair said. "I was able to get a quick view in a few hours of about 40 years of PPPL history."

Sinclair first came to Project Matterhorn through the efforts of Thomas Stix, a pioneer in plasma physics who was a classmate of Sinclair's and fellow physics major at the California Institute of Technology. Sinclair went on to get a Ph.D. in nuclear physics at Rice University.

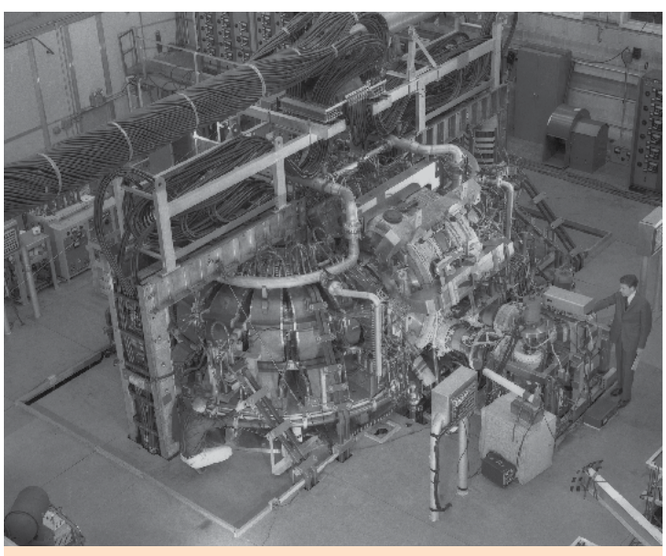
Through Stix, Sinclair received a telegraph from Melvin Gottlieb, then the head of research, asking him to come to the now famous Atoms for Peace conference in Geneva for a job interview. The conference drew hundreds of physicists from around the world who shared their research on fusion energy for the first time. Among them were Project Matterhorn scientists whose research had been declassified that year.

A meeting with Spitzer and Gottlieb

Sinclair not only met his friend Stix and Gottlieb at the conference but also the famous Princeton University physicist Lyman Spitzer, the founder of Project Matterhorn and U.S. fusion energy development, who was then the director of the Laboratory. Sinclair was also fascinated by the two stellarators on display at the conference, the working B2 stellarator and the model stellarator, which is still on view at PPPL.

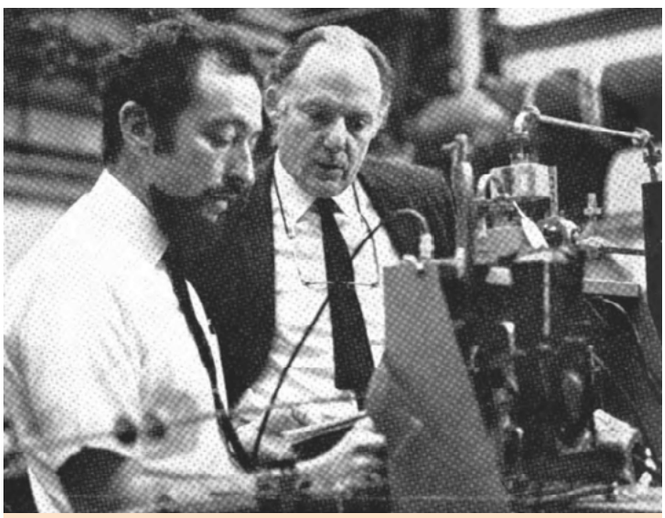
It was physicist Don Grove, who was working on a project to transform the traditional figure-eight stellarator into a more powerful device called the Model C, who convinced Sinclair to join Project Matterhorn the following month. "This was very interesting to me and it was a rare chance to do something more interesting than anything else I'd done," Sinclair recalled.

In 1961, Project Matterhorn became the Princeton Plasma Physics Laboratory and the Model C stellarator began operating. Sinclair switched from construction to research on the device and he remained at the Laboratory full-time until 1969.



A photo of the Model C Stellarator in the C Site high bay. The device was converted into the Symmetric Tokamak in 1969. *(Photo PPPL Archives)*

Rich Hawryluk, PPPL's interim director, front right, meets Sinclair, second from left in the LSB Lobby. From left are physicist Greg Hammett; Sinclair; Dale Meade, a retired physicist and former deputy director of PPPL; Ken Young, a retired physicist from PPPL; and Michael Zarnstorff, deputy director for research. *(Photo by Elle Starkman)*



A photo of Sinclair, left, conferring with PPPL director Melvin Gottlieb, from a 1969 issue of *Princeton Alumni Weekly*.

Double shifts on the Model C stellarator

Ken Young, now a retired PPPL physicist, worked with Sinclair starting in 1963. He recalls working late shifts from 4 p.m. to midnight on Sunday and then from 8 a.m. to 4 p.m. on Monday.. "It was fun," Young said. "It was pretty exciting." Sinclair said he and others often had to fix problems on the Model C as they came up. "We understood to fix things in place," he said.

Sinclair said he truly enjoyed working for Spitzer. "It was a tremendous pleasure to work with Lyman," he said. "I was perfectly happy to be Lyman Spitzer's hands. He'd think of an experiment and I'd do the experiment and then about nine at night, he'd call me. He wanted to know what we had learned that day."

Spitzer was far from a pushover, Sinclair said. "He had tremendous insight," he said. "He did not suffer fools gladly. You really had to be on your mark to work around him."

Early work on radio frequency heating

One developing field of research to which Sinclair and his colleagues contributed was the first of use of a type of radio frequency heating called ion cyclotron heating – a technique for heating the ions in the plasma. Stix had demonstrated the technique on simple machines and Sinclair and physicist Joel Hosea, who started at PPPL in 1968, refined it when Sinclair headed the RF group. When Sinclair left PPPL in 1969, Hosea became head of the group, a position he holds today as head of RF Science and Technology.

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Rolf Sinclair

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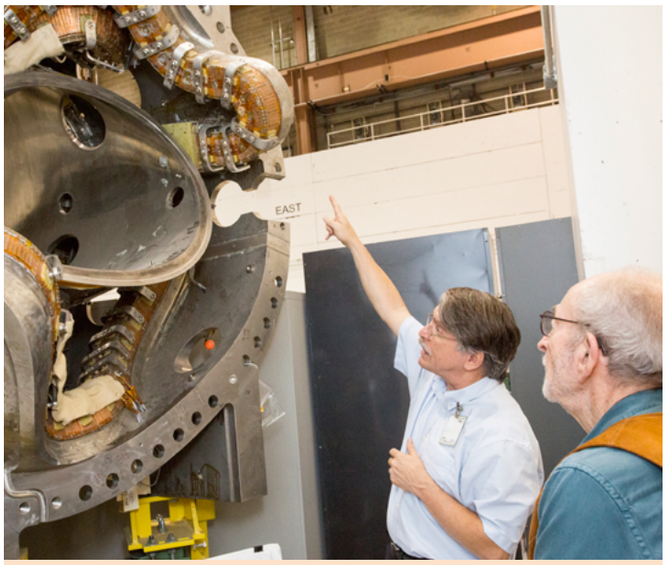
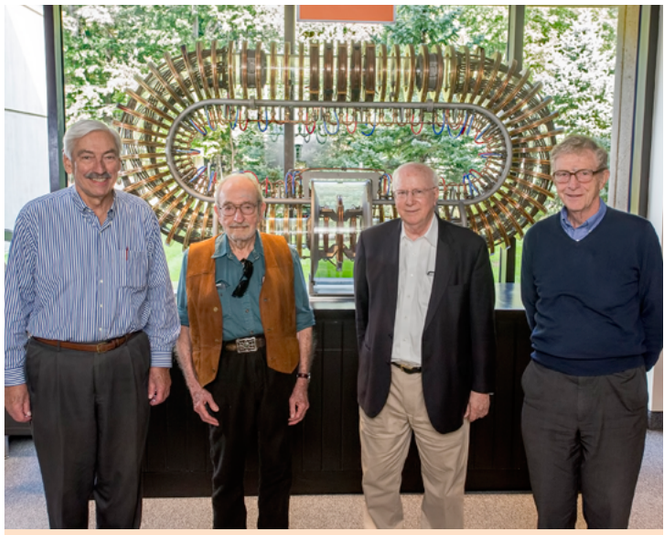
Another accomplishment was the use of a technique to map the magnetic field of the plasma with an electron beam. A much more sophisticated version of this technique was recently used by PPPL physicist Sam Lazerson and other researchers to map the magnetic field on the Wendelstein 7-X stellarator in Greifswald, Germany. Lazerson and his colleagues cited a paper by Hosea and Sinclair on the subject in a paper in *Nature* earlier this year.

By 1969, PPPL and the fusion field in general were transformed by news that British physicists had confirmed the accuracy of the excellent plasma confinement results claimed by Russian researchers in their new doughnut-shaped "tokamaks." That year, PPPL converted the Model C into the Symmetric Tokamak and Gottlieb recommended Sinclair as a project manager at the National Science Foundation.

Sinclair began work at the National Science Foundation (NSF) as a project manager in the Physics Division and continued to work part-time at PPPL for the next three years. He remained at the NSF until his retirement in 1998. In addition to his regular job, he headed two eclipse expeditions, to Canada in 1979 and to India in 1980. He also served as the NSF representative at the Amundsen-Scott South Pole Station in 1995 and 1996.



Michael Zarnstorff, PPPL's deputy director for research, shows Sinclair a coil from the National Compact Stellarator Experiment (NCSX), located in the C Site high bay where the Model C Stellarator was once located. *(Photo by Elle Starkman)*



Standing in front of the model stellarator that was displayed at the 1958 Atoms for Peace Conference, which Rolf Sinclair attended, are Sinclair, second from left, with two of his former colleagues, Joel Hosea, right of Sinclair, and Ken Young, far right, and Dale Meade, far left. *(Photo by Elle Starkman)*

Studying glaciers in retirement

Sinclair's adventures continued well after he retired nearly 20 years ago. Through a connection with the scientific advisor to the president of Chile, Sinclair spent several years studying the glaciers in the south of Chile and in West Antarctica as a member of the Centro de Estudios Científicos in Valdiva, Chile. "I found that fascinating work to do in my retirement," Sinclair said.

Sinclair has also pursued his lifelong interest in astronomy. For the past two decades, he has helped organize a series of informal conference called "the Inspiration of Astronomical Phenomena" on the cultural effects of astronomical phenomena visible to the naked eye. The tenth of these conferences was held last month in Santiago de Compostela, Spain.

"He's been interested in all these topics for a long time," Hosea said. "He's kept busy."

Sinclair and his wife, Sarah Richards, enjoy traveling. He is currently a visiting senior research scholar at the University of Maryland, not far from his home in College Park. He worked on the website for the Butler art exhibit and is putting together a book collecting the academic papers on the exhibit. He's also thinking about returning to Chile.

"He's a fascinating individual," said Hammett, who led the Laboratory tour for Sinclair. "It shows his diversity that he's worked on so many things from plasmas to glaciers, perhaps tied together by a theme of high quality measurements."

Register for an Open Forum with Dave McComas

Thursday, Oct. 19 at 2 p.m.

Register for PPPL's first open forum. It is intended to be an open dialogue with staff and leadership, without managers present. Please register here. Registration is anonymous.

For more information, contact Tori Sikkema, tsikkema@pppl.gov.

Council Café Lunch

This Week:

Andrea Moten,

Interim Head of HR

Wednesday, Oct. 18
12 p.m., PPPL Café

Next Week: Valeria Riccardo

BROCK

NICK PETTI
Chef Manager

Café at PPPL

BREAKFAST ..... 7 a.m. • 10 a.m.
CONTINENTAL BREAKFAST ..... 10 a.m. • 11:30 a.m.
LUNCH ..... 11:30 a.m. • 1:30 p.m.
SNACK SERVICE ..... until 2:30 p.m.

	Monday Oct. 16	Tuesday Oct. 17	Wednesday Oct. 18	Thursday Oct. 19	Friday Oct. 20
COMMAND PERFORMANCE **Chef's Feature**	**Chicken Marsala** over Egg Noodles	**Kung Pao Meatballs** over Fried Rice with Egg Roll	**Parmesan Herb-Crusted Tilapia** with Roasted Potatoes and Green Beans	**Octoberfest Sauerbraten** with Mashed Potatoes and Braised Cabbage	**Pasta with Clam Sauce** and Garlic Bread.
Early Riser	**Western Omelette**	**Huevos Rancheros**	**Frittata Lorraine**	**Omelette Florentine** with Spinach, Tomato & Mozzarella	**Breakfast Tacos**
Country Kettle	**Vegetable**	**Beef Barley**	**Chicken and Mushroom**	**Potato**	**Seafood Chowder**
Deli Special	**Smoked Turkey Baguette**	**Greek Tuna Salad** with Pita Chips over Lettuce	**Tomato & Fresh Mozz** on Ciabatta with Roasted Garlic Hummus	**Baked Ham and Swiss Sliders**	**Southwest Turkey,** Peppers & Cheddar with Jalapeño Ranch Spread
Grill Special	**Italian Grilled Cheese**	**Buffalo Chicken Steak Sandwich** with Fries	**Pizza Burger**	**BBQ Bologna Sandwich**	**Chicken Zen Sandwich**
Panini	**Buffalo Shrimp Wrap**	**Italian Grinder**	**Crab Cake** on a Kaiser with Lettuce & Tomato	**Knockwurst and Kraut**	**El Diablo—** Hot Ham, Pepperoni, Pepper Jack, Banana Peppers and Chipotle Sauce

MENU SUBJECT TO CHANGE WITHOUT NOTICE

HEART HEALTHY

VEGETARIAN OPTION

WEEKLY

Editor: **Jeanne Jackson DeVoe** ◇ Layout and graphic design: **Kyle Palmer** ◇ Photography: **Elle Starkman** ◇ Science Editor: **John Greenwald** ◇ Science Writer: **Raphael Rosen** ◇ Webmaster: **Chris Cane** ◇ Communications Director: **Larry Bernard**

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Comments: commteam@pppl.gov ◇ **PPPL WEEKLY** is archived on the web at: http://w3.pppl.gov/communications/weekly/.