PPPL PRINCETON PLASMA PHYSICS LABORATORY
A Collaborative National Center for Fusion & Plasma Research
U.S. DEPARTMENT OF ENERGY
WEEKLY
February 19, 2018

THIS WEEK

WEDNESDAY, FEB. 21

Council Café Lunch
12 p.m. ◆ Cafeteria
Jerry Levine
Head of ES&H

Open Forum with Michael Zarnstorff
2 p.m. ◆ B318
See page 5 for details.

FEB. 23–24

N.J. Middle School & High School Science Bowls

SATURDAY, FEB. 24

No Science on Saturday
due to Science Bowl

UPCOMING

WEDNESDAY, FEB. 28

Colloquium
4:15 p.m. ◆ MBG Auditorium
Gravitational Waves: Discoveries and Future Detectors
Professor Matthew Evans, MIT Physics

SATURDAY, MAR. 3

Science on Saturday
9:30 a.m. ◆ MBG Auditorium
Looking Ahead A Split Second: How The Brain Learns Predictions In An Unpredictable World
Sam Wang, Princeton University

INSIDE

Former astronaut and NASA administrator Maj. Gen. Charles Bolden Jr. lands at PPPL

By Jeanne Jackson DeVoe

Maj. Gen. Charles Bolden Jr. (USMC retired), a retired astronaut, former administrator of NASA under President Barack Obama, and retired U.S. Marine of 34 years, brought some star power to PPPL on Tuesday, Feb. 13, when he visited the Laboratory and met with leadership and staff.

Bolden was hosted by David McComas, the Princeton University vice president for PPPL, who worked with Bolden when McComas chaired the Science Committee of and served as the science representative on the NASA Advisory Council (NAC) – NASA's top advisory group. Bolden delivered a lecture the day after his visit at Princeton University's Woodrow Wilson School of Public and International Affairs, entitled "Humanity's Exploration."

Touring the National Spherical Torus Experiment-Upgrade (NSTX-U) test cell are, from left: Russ Feder, project manager for the NSTX-U Recovery Project; Michael Zarnstorff, PPPL deputy director for research; Dave McComas, Princeton University vice president for PPPL, Maj. Gen. Charles Bolden; Rich Hawryluk, interim director of PPPL; and Stefan Gerhardt, deputy director of the Recovery Project. *(Photo by Elle Starkman)*

continued on page 3

Lithium — it's not just for batteries:

The powdered metal can reduce instabilities in fusion plasmas, scientists find

By Raphael Rosen

You may be most familiar with the element lithium as an integral component of your smart phone's battery, but the element also plays a role in the development of clean fusion energy. When used on tungsten surfaces in fusion devices, lithium can reduce periodic instabilities in plasma that can damage the reactor walls, scientists have found.

continued on page 5

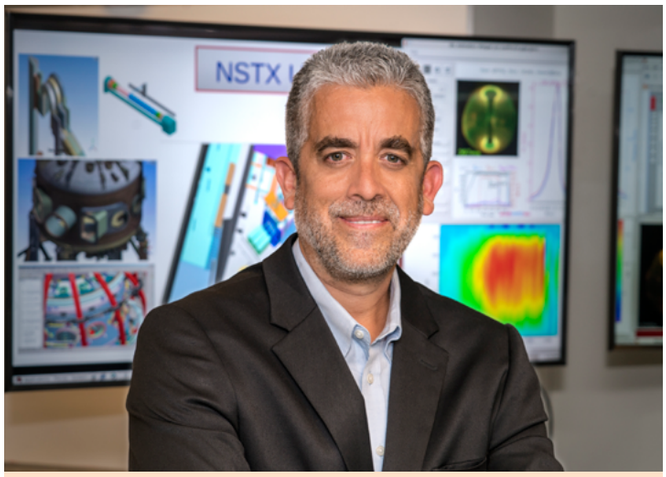
PPPL physicist wins award to collaborate on experiments on EAST

By Jeanne Jackson DeVoe

PPPL physicist Luis Delgado-Aparicio has won an award to collaborate on experiments on the Experimental Advanced Superconducting Tokamak (EAST) in Hefei, China. The experiments aim to create better understanding of how to measure and control a key impediment in the quest to create fusion energy.

Delgado-Aparicio and a collaborator at the Institute of Plasma Physics (ASIPP) in Hefei were the only plasma physicists selected for the competitive award offered by the president of the Chinese Academy of Sciences (CAS).

"I think it's a unique opportunity because it's bridging a gap between our program in Princeton and our programs in Asia," said Delgado-Aparicio, who will collaborate with Bo Lyu of ASIPP.



Luis Delgado-Aparicio *(Photo by Elle Starkman)*

The award is the latest honor for Delgado-Aparicio, who won a prestigious $2.6 million Early Career Award in 2015 to pursue similar research focused on eliminating impurities from the core of the plasma that fuels fusion reactions. Such impurities can cool down the plasma and halt the reactions.

Early Career Award

With the Early Career Award Delgado-Aparicio plans to begin installing diagnostic equipment on the Madison Symmetric Torus at the Madison Physics Lab at the University of Wisconsin-Madison the week of Feb. 19. He will later install a sister diagnostic and do research on the DIII-D tokamak at General Atomics in San Diego, and plans to bring the equipment back to PPPL when the National Spherical Torus Experiment–Upgrade (NSTX-U) resumes operations.

PPPL already has a large collaboration on EAST led by physicist Rajesh Maingi that is focused on the use of lithium to protect plasma-facing components inside the fusion device, known as a tokamak. "The work Luis is doing relies very heavily on hardware equipment and would have cost hundreds of thousands of dollars and now he has an alternative way of doing this," Maingi said. "Because we have an existing collaboration, we can fold him right in and work together."

Fusion occurs when the superhot, electrically charged state of matter called plasma is heated to temperatures hotter than the sun, becoming hot and dense enough to force atomic nuclei called ions to fuse together and create a burst of energy, just as the sun and most stars create energy. The ASIPP award allows Delgado-Aparicio and collaborator Lyu to study the behavior of impurities that infiltrate the plasma and cause instabilities or heat loss that can halt the fusion process. Such research could lead to a "star in a jar," to produce fusion energy on Earth.

The award gives Delgado-Aparicio and his partner the ability to do experiments on EAST and also covers equipment and travel, and the work of two graduate students who are writing their theses on the research.

Calibrating spectrometers designed at PPPL

The physicists plan to use two X-ray crystal spectrometers developed by PPPL physicists Manfred Bitter and Ken Hill to analyze the behavior in EAST of two different gases, argon and xenon. These elements will be puffed into the tokamak during a plasma experiment and will act as stand-ins for impurities.

The spectrometer will chart the paths of the gases, which will likely be different for argon than for the much heavier xenon. The paths will provide a map of the impurities so that researchers can find a way to control them.

Such control is particularly important in large tokamaks like EAST, which uses molybdenum and tungsten for tiles and other plasma-facing components. Particles coming from those metals, which are used for their durability and heat resistance, are impurities that radiate energy away from the plasma and essentially cool it off, slowing down or halting the fusion process.

The ASIPP award covers the cost of calibrating the spectrometers, which must be fitted with new crystals for each element, as well as the cost of modern computer-controlled X-ray tubes using cadmium and titanium targets. Expenses have already amounted to $100,000, Delgado-Aparicio said.

A method to flush out impurities

The researchers will also use the spectrometers to analyze a method aimed at flushing the impurities out of the plasma. With argon and xenon standing in for the impurities, the researchers will use magnetic coils to create resonant perturbations that will "tickle" the gas and hopefully carry the impurities out of the plasma, Delgado-Aparicio said.

The results could have applications for eliminating impurities on EAST and on future experiments like ITER, the international fusion experiment being constructed in France, and on the China Fusion Engineering Test Reactor (CFETR), a new tokamak being planned in China. The research could also be applied to the NSTX-U, the spherical tokamak under repair at PPPL, if the Laboratory carries out plans to replace graphite on the divertor that acts as an exhaust system with heavier molybdenum

Delgado-Aparicio has been a physicist at PPPL since 2009 and spent three-and-a-half years as a visiting scientist at MIT before returning to PPPL in 2013. He is a native of Lima, Peru, where his late father was a congressman. Delgado-Aparicio earned a bachelor's degree in physics from the Pontifica University Catholica del Peru, and a master's degree in astrophysics from Princeton University in 2001. He earned a second master's in physics from Johns Hopkins University and received his Ph.D. in physics from Johns Hopkins in 2007 with thesis work on the National Spherical Torus Experiment (NSTX) at PPPL. He is a member of the Peruvian Academy of Sciences.

He expects to travel to China to set up the experiment in May and return to complete the research in July.

Maj. Gen. Charles Bolden Jr.

continued from page 1

Bolden had visited PPPL once before in the early 1980s and said he enjoyed getting a behind-the-scene view on this visit to the National Spherical Torus Experiment-Upgrade (NSTX-U), the Lithium Tokamak Experiment (LTX), and the Science Education Laboratory.

"It was really exciting to have an opportunity to visit once again and just to see all the work going on here," Bolden said. "I was particularly impressed with the educational outreach lab. That gives me hope for the future."

Four space shuttle missions

Bolden served as NASA's twelfth administrator from 2009 to 2017. Among NASA's achievements under his leadership were the Mars landing with the Curiosity rover, the launch of a spacecraft to Jupiter, and continued progress toward the launch of the James Webb Space Telescope that is scheduled to take off in 2019 as successor to the Hubble Space Telescope. He served 34 years in the U.S. Marine Corps, including 14 years as a member of NASA's Astronaut Office. He logged more than 680 hours in space during four space shuttle missions between 1986 and 1994, two of which he commanded and two as a pilot. He retired from the Marine Corps in 2003. Bolden received numerous honors during his career, including the Distinguished Flying Cross Air Medal, three NASA Exceptional Service Medals and four NASA Space Flight Medals. He received the National Space Trophy in 2014 and was inducted into the U.S. Astronaut Hall of fame in May 2006 and enshrined in the National Aviation Hall of Fame in October 2017.

DOE, PPPL and Princeton University leaders meeting with Bolden: Front row: Sandy Rogan, deputy site office manager for the U.S. Department of Energy's Princeton Site Office; Richard Hawryluk, PPPL's interim director; Bolden; Dave McComas, Princeton University vice president for PPPL. Back row: Pete Johnson, Princeton Site Office manager; Andrew Zwicker, head of Communications and Public Outreach; Michael Zarnstorff, PPPL deputy director for research; and Scott Weidner, Princeton University assistant vice president for engineering for PPPL. *(Photo by Elle Starkman)*

Russ Feder, center, NSTX-U Recovery Project manager, and Gerhardt, show Bolden the NSTX-U center stack. *(Photo by Elle Starkman)*

Maj. Gen. Charles Bolden left, with Stefan Gerhardt, deputy director for the NSTX-U Recovery Project, center, and Dave McComas, Princeton University vice president for PPPL, at the top level of the NSTX-U test cell. *(Photo by Elle Starkman)*

Rich Hawryluk, PPPL's interim director, gave Bolden an overview of PPPL's research mission to develop fusion energy. He described how PPPL collaborates in fusion energy projects around the world, from EAST in China to the international fusion experiment ITER being constructed in France, and the role of NSTX-U in developing innovative solutions.

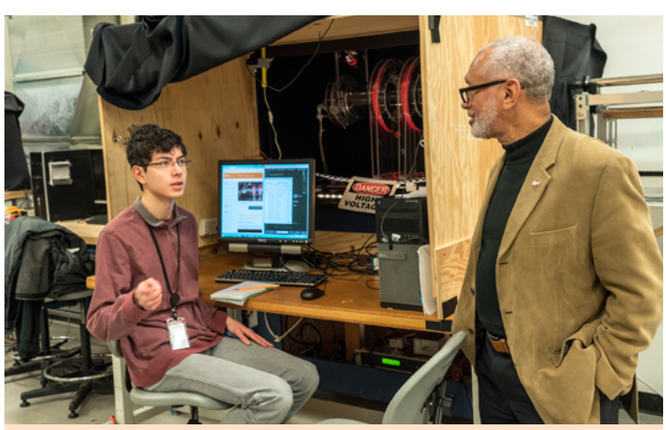
"My favorite part of this is when someone asks, do we know if fusion really works, and I just point at the sun and say yes," McComas said.

Mike Zarnstorff, PPPL's deputy director for research, also described the Laboratory's research. He noted that PPPL has had numerous inventions stemming from that research, from a technique to produce the medical isotope technetium-99m to a new way of whitening teeth. He also touched on a synthetic muscle experiment that PPPL helped develop that was on board the space shuttle, and a fusion-powered rocket engine technology that has been licensed commercially.

Excited by science education

Andrew Zwicker, head of Communications and Public Outreach and Science Education, described the work his group does in training the next generation of scientists, a topic Bolden said is near and dear to his heart. "That is one thing that really excites scientists and engineers at NASA," Bolden said.

continued on page 4



Bolden speaks with high school intern Kevin Marx, a senior at Highland Park High School, in the Science Education Laboratory. *(Photo by Elle Starkman)*

Maj. Gen. Charles Bolden Jr.

continued from page 3

Zwicker reminded Bolden that he had met him along with Nichelle Nichols, the actress who played Lt. Uhura in television's original "Star Trek" series several years ago, when Zwicker led a program with science teachers that was partly sponsored by NASA and included a ride in the zero gravity plane.

Stefan Gerhardt, deputy head of the NSTX-U Recovery Project, led a tour of the NSTX-U test cell. Physicist Richard Majeski told Bolden about research on the LTX on a tour of that facility. The final stop was the Science Education Laboratory where Bolden met some of the high school and college interns working at the Laboratory.

Bolden met PPPL scientists and staff members at the end of the day. The scientists included some PPPL physicists who have won the U.S. Department of Energy's Early Career Award.

Arturo Dominguez, a senior program leader in Science Education, discussed the challenge of making the plasma physics field more diverse during the end-of-the-day meeting. "It's such an interesting field and yet we see we have so few women in the field and so few under-represented minorities," he said.

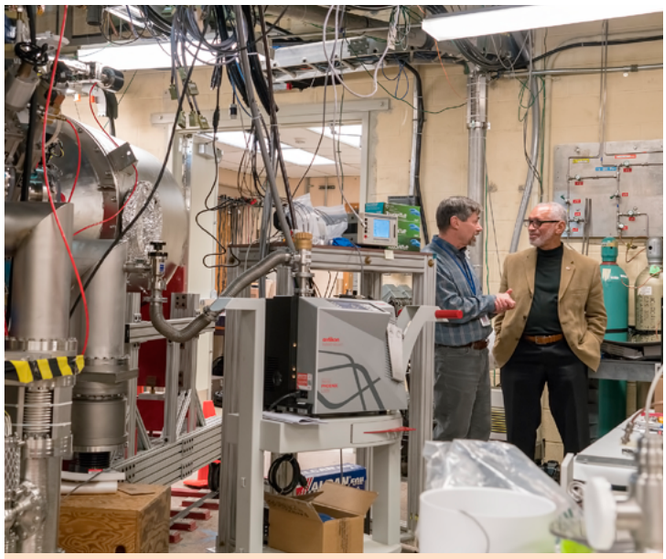
A shift in focus to deep space

Gerhardt, an Early Career Award winner, asked Bolden how he had managed the shift away from the shuttle program as NASA administrator. Bolden said he focused on the future of the space program and the vision of sending people to Mars or back to the moon. "I think we had to get the organization to understand we really needed to focus on deep space exploration," he said.

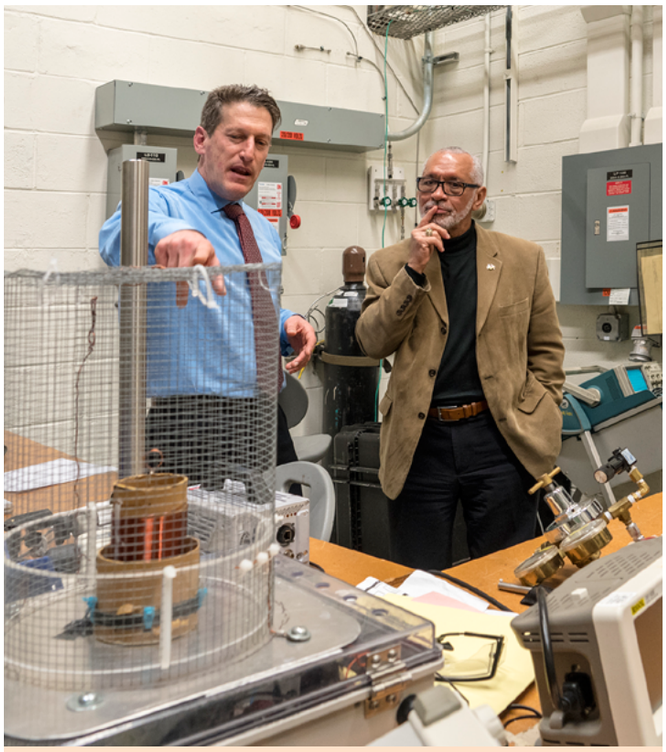
But Bolden admitted that the shift wasn't easy. "It was a challenge to the organization to see if we could break that paradigm," he said. "We've told people we're going to Mars in 2030."

Bolden told the early career scientists and staff members to persist in pursuing their vision. "My message is don't ever give up even if you're the only person that believes in what you're doing," he said. "That's what's important."

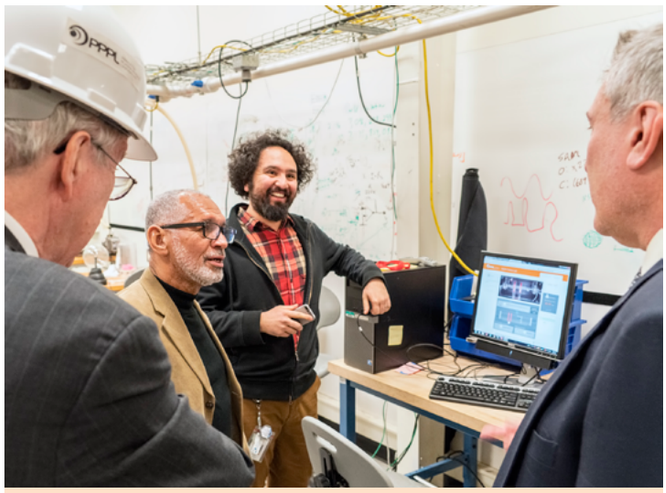
Maj. Gen. Charles Bolden meets with early career scientists and staff, from left: physicist Jong-Kyu Park; Arturo Dominguez, senior program leader in the Science Education Office; Shannon Greco, a program leader in Science Education; Andrew Zwicker, head of the Office of Communications & Public Outreach; Deedee Ortiz, Science Education program manager; and Luis Delgado-Aparicio, a U.S. Department of Energy Early Career Award recipient. *(Photo by Elle Starkman)*



Physicist Richard Majeski, head of Innovative Fusion Concepts & Technology, shows Bolden the Lithium Tokamak Experiment (LTX). *(Photo by Elle Starkman)*



Andrew Zwicker, head of Communications and Public Outreach, shows Bolden the plasma speaker in the Science Education Lab. *(Photo by Elle Starkman)*



Arturo Dominguez, senior program leader in Science Education, center, shows Bolden the Remote Glow Discharge Experiment in the Science Education Lab, as Rich Hawryluk, PPPL's interim director, and Dave McComas, Princeton University vice president for PPPL, look on. *(Photo by Elle Starkman)*

Lithium

continued from page 1

The results, demonstrated by scientists at PPPL and collaborators on China's Experimental Advanced Superconducting Tokamak (EAST), found that lithium powder can eliminate instabilities known as edge-localized modes (ELMs) when used to coat a tungsten plasma-facing component called the "divertor" — the unit that exhausts waste heat and particles from plasma that fuels fusion reactions. If left alone, such instabilities can damage the divertor and cause fusion reactions to fizzle.

The results are good news for future devices that plan to use tungsten for their own divertors that are designed to work with lithium.

Past experiments with lithium powder on EAST have confirmed the metal's ability to eliminate or reduce the frequency and intensity of periodic bursts of ELMs that occur in the outer edge of plasmas that can damage the divertor. ELMs develop regularly when the plasma enters a high-energy state known as high-confinement mode, or H-mode, which holds heat within the plasma more efficiently. ELMs can also unleash large amounts of heat that damage the plasma-facing components and release eroded material that can enter the plasma and cool the fusion reactions.

Rajesh Maingi
(Photo by Elle Starkman)

During past experiments, EAST's upper and lower divertors were coated with light and porous carbon rather than the heavy metal tungsten. "So, the question was whether lithium will have the same effect on tungsten walls as it does with carbon walls," said PPPL physicist Rajesh Maingi, lead author with Jiansheng Hu of the Institute of Plasma Physics at the Chinese Academy of Sciences (ASIPP) of a paper describing the results in the journal *Nuclear Fusion*.

The issue was in question because recent research on other doughnut-shaped tokamaks, such as the Axi-Symmetric Divertor Experiment-Upgrade (ASDEX-U) in Germany, have suggested that plasma-facing components made of tungsten actually reduce the ability of lithium coatings to control ELMs. Lithium was injected into ASDEX-U via large fast pellets, as compared with the lithium powder that was gravitationally injected into the EAST experiments.

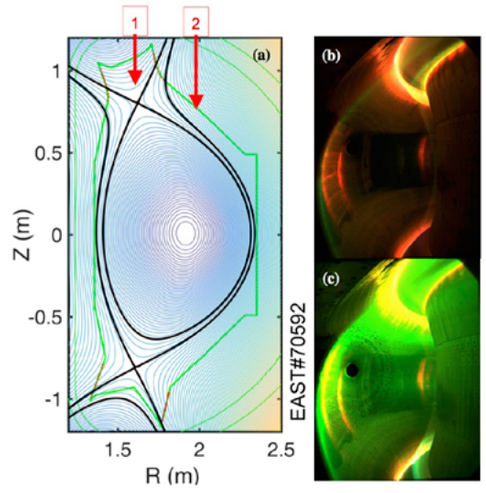


Figure showing the location of the two lithium injectors, as well as color images of plasma before and after lithium injection. Red indicates light emitted from both deuterium and lithium, while yellow and orange show lithium line emission. *(Courtesy of K. Tritz and Z. Sun)*

In the recent experiments, researchers manipulated the plasma within EAST so that it exhausted its waste heat on the upper of the two divertors within the tokamak. Unlike the lower divertor, which was made of carbon, the upper divertor is fabricated from tungsten.

The results showed that lithium injected into plasma in contact with tungsten reduces ELMs just as much as lithium does when the plasma exhausts its heat on carbon. Physicists now have increased confidence that the techniques used to reduce ELMs in current fusion machines will be able to reduce ELMs in larger machines in the future, as long as they are designed to be compatible with lithium.

The research team noted that it became easier to eliminate ELMs as the experiments progressed, suggesting that elimination could require less lithium as time went on. Scientists would therefore like to find a way to regulate how much lithium is injected into the plasma, perhaps reducing the injection rate once the ELMs have disappeared to control the lithium inventory and optimize the performance of the plasma.

This research was funded by the DOE's Office of Science together with the National Key Research and Development Program of China, the National Nature Science Foundation of China, and the National Magnetic Confinement Fusion Science Program of China. The team included scientists from PPPL, ASIPP, Johns Hopkins University, the Department of Applied Physics in China's Hunan University, Oak Ridge National Laboratory, and General Atomics.

Open Forum with Michael Zarnstorff

Wednesday, Feb. 21
2 p.m.
Room B318

Please join the next Open Forum for staff only with Michael Zarnstorff, deputy director for research. Please register here so organizers will know how many people to expect.

Innovation Discovery Event explores ways to commercialize inventions

By Jeanne Jackson DeVoe

A PPPL inventor and two Princeton University inventors got the opportunity to explore a myriad of ideas for commercial applications for their inventions at the Innovation Discovery Event at PPPL on Feb. 9.

Sponsored by PPPL and the University, the event is a much kinder, gentler version of the television show "Shark Tank," in which inventors present their inventions and venture capitalists pick the idea apart and offer their ideas for developing the ideas into commercial businesses.

The event was hosted by PPPL and Princeton University's Office of Technology Licensing and underwritten by the Federal Lab Consotrium-Northeast Region. It was moderated by Mike Reilly, of RimFire Enterprises, LLC, who moderated the event at PPPL in 2016 and many such events around the country.

This year's session featured PPPL physicist Johan Carlsson showing off his invention of a plasma contact microphone that would pick up ultrasonic signals from a structure that is under stress. The invention could be used, for example, for structural tests on bridges, jet engines, or submarine hulls.

Another invention presented by Arsalan Mosenia, a postdoc at Princeton's School of Engineering and Applied Science, presented a technique to enhance programmability and connectivity in individual automobiles. The third invention was a technique to detect speed through a bending filament velocity sensor by Marcus Hultmark, Princeton University assistant professor of mechanical and aerospace engineering.

The panelists were Joe Studholme, executive-in-residence at Princeton's Office of Technology Licensing; Katherine Kish, director of Einstein's Alley, a non-profit economic development organization; Arve Hantsvelt, an angel investor at New York Angels Jumpstart; Victoria Scott, a Princeton University student and entrepreneur; Oye Olukotun, CEO of CR Strategies, LLC, a medical products consulting company; and Seyi Fasoranti, a graduate student in Princeton University's Department of Chemistry.

Moderator Mike Reilly served as master of ceremonies at the Innovation Discovery Event. *(Photo by Elle Starkman)*

Physicist Johan Carlsson answers questions from panelist Joe Studholme, executive-in-residence at Princeton University's Office of Technology Licensing. *(Photo by Elle Starkman)*

Carlsson shows the panel his invention. *(Photo by Elle Starkman)*

Organizer Laurie Bagley, head of Technology Transfer, at the event. *(Photo by Elle Starkman)*

PPPL's Shannon Swilley Greco is monstrously good at Princeton University's Frankenstein Day

Shannon Swilley Greco, a program leader in the Science Education Office, explored her inner monster as the bride of Frankenstein at Princeton University's Frankenstein Day Feb. 3, celebrating the 200th anniversary of the publication of "Frankenstein" by Mary Shelley. The event was sponsored by the Princeton Center for Complex Materials (PCCM) and the Council for Science and Technology.

Greco as the Bride of Frankenstein with laboratory assistant children Lukas, 5, Annika, 8 months, and Ryan, 3. PPPL volunteers Brian Kraus, left, and Kevin Lamb are in back. *(Photo by Elle Starkman)*

Frankenstein Day organizer Dan Steinberg, director of education outreach for PCCM, far left, with Greco as the bride of Frankenstein, Susan Marie Frontczak as Mary Shelley; and Sara Rodriguez Martinez, education outreach coordinator, PCCM, another organizer. In front are Greco's children Lukas, age 5, and Ryan, age 3. *(Photo by Elle Starkman)*

Can I get in trouble as a result of the STOP program?

No!

No punitive measures are associated with the STOP program - ever!

Safety first:
Use the STOP program!

Ronald E. Hatcher

Science on Saturday LECTURE SERIES

Feb. 24	**No Science on Saturday**
Mar. 3	**Looking Ahead A Split Second: How The Brain Learns Predictions In An Unpredictable World** **Sam Wang,** Princeton University
Mar. 10	**Control in the Sciences of Vast Length and Timescales** **Herschel A. Rabitz,** Princeton University **Andrea Woody,** University of Washington
Mar. 17	**On the Path to Clean Fusion Energy** **Michl Binderbauer,** TAE Technologies

Saturdays at 9:30 a.m., MBG Auditorium

Submit your questions for Plasma 101 Lunch & Learn

Please submit your questions about fusion energy, plasma, or any of the research we do here in the box in the LSB lobby.

Sample questions:
What is plasma?
How is what we do different from “nuclear power?”
Why don’t we have fusion energy on the grid yet?

Council Café Lunch

This Week:

Jerry Levine, Head of ES&H

Wednesday, Feb. 21
12 p.m., PPPL Café

Feb. 28: Marc Cohen

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 Feb. 19	Tuesday Feb. 20	Wednesday Feb. 21	Thursday Feb. 22	Friday Feb. 23
Early Riser	**Bacon, Egg and Cheese English Muffin**	**Mexican Breakfast Burrito**	**Scrapple and Eggs**	**Cinnamon-Raisin Pancakes** with Homemade Apple Compote	**French Toast Sticks**
Country Kettle	**Soup of the Day**	**Vegetable**	**Chicken Noodle**	**Tomato Soup**	**Chili Bean**
Deli Specialty	**Autumn Chicken Salad Wrap**	**Smoked Salmon and Herb Cream Cheese Bagel**	**Cajun Egg Salad Wrap**	**Sushi Day**	**Spicy Crab Wrap**
Grill Specialty	**Mushroom Quesadilla**	**Burgerlicious Old Macdonald Burger**	**Bacon, Arugula, and Fried Green Tomatoes**	**Ham and Cheese Pizza Roll**	**Breakfast for Lunch "Fill Your Box"**
COMMAND PERFORMANCE **Chef's Feature**	**Chicken Cordon Bleu** with Wild Rice Pilaf	**Pasta Bake** with Meat Sauce and Garlic Bread	**Carved Turkey** with Mashed Potatoes and Gravy	**Sushi Day**	
Grilled Panini	**Ham and Swiss Melt**	**Turkey Reuben**	**Pastrami and Swiss** on Marble Rye		

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**

The **PPPL WEEKLY** is published by the PPPL Office of Communications on Mondays throughout most of the year and biweekly during the summer, except for holidays.
DEADLINE for calendar item submissions is noon on WEDNESDAY. Other stories should be submitted no later than noon on TUESDAY.
Comments: commteam@pppl.gov ◆ **PPPL WEEKLY** is archived on the web at: http://w3.pppl.gov/communications/weekly/.