

THIS WEEK

WEDNESDAY, FEB. 8

PPPL Colloquium
4:15 p.m. ♦ MBG Auditorium
[Princeton Campus Development
1756-2017](#)
Joshua E. Linkov, Princeton University

SATURDAY, FEB. 11

Science on Saturday
9:30 a.m. ♦ MBG Auditorium
[Meat, Monkeys, and Mosquitoes:
A One Health Perspective on
Emerging Diseases](#)
Laura Kahn, Princeton University

UPCOMING

SATURDAY, FEB. 18

Science on Saturday
9:30 a.m. ♦ MBG Auditorium
[Cities in the 21st century:
the nexus of the climate,
water, and energy challenges](#)
Elie Bou-Zeid, Princeton University

FRIDAY, FEB. 20

**Final day to apply to present
at Princeton Research Day**
[See page 6 for more information.](#)

FEB. 24-25

**New Jersey Regional Middle
and High School Science Bowls**
[See page 6 for information
on how to volunteer](#)

WEDNESDAY, MAR 1

PPPL Colloquium
4:15 p.m. ♦ MBG Auditorium
[Future Electrical Energy Supply
Metrics Including Dynamic Energy
Return on Investment \(EROI\)](#)
Charles Neumeyer, PPPL

SATURDAY, MAR. 11

Princeton Research Day

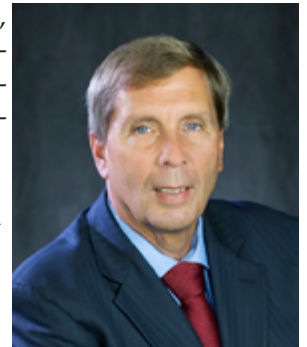
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Brog and Hawryluk outline NSTX-U recovery plan to FESAC as system reviews continue

By Jeanne Jackson DeVoe

Terry Brog, interim director of PPPL, and Rich Hawryluk, director of the National Spherical Torus Experiment Upgrade (NSTX-U) Recovery Project, outlined plans to identify any gaps in how NSTX-U was constructed at a meeting of the Fusion Energy Sciences Advisory Committee (FESAC) in Washington, D.C. on Feb. 1. Addressing the gaps will be part of a corrective action plan, Brog and Hawryluk told FESAC, which advises the U.S. Department of Energy's (DOE) Office of Science on issues related to the Fusion Energy Sciences program.



Terry Brog, interim director of PPPL. (Photo by Elle Starkman)

"I was very pleased with the FESAC presentations we made in Washington," Brog said. "We presented PPPL's detailed and methodical plan to address recent issues with NSTX-U through an analysis of each system, sub-system and component as part of the extent of condition assessment. While



Rich Hawryluk, head of the NSTX-U Recovery Project. (Photo by Elle Starkman)

we're working on NSTX-U we will continue to excel in other major projects and external collaborations."

The 10 weeks of NSTX-U operation yielded several engineering and research results. It was shut down in July due to the failure of a poloidal field coil used to shape the magnetic field, Brog said. He described the steps PPPL has taken as part of its NSTX-U recovery project in the wake of the failed coil that forced the shutdown last summer.

One step was management changes, including the appointment of the NSTX-U Recovery Project team, headed by Hawryluk and Charles Neumeyer, NSTX-U Engineering Director. PPPL has also begun a detailed design verification and validation review (DVVR) of each of NSTX-U's systems

[continued on page 3](#)

PPPL scientist uncovers physics behind plasma-etching process

By Raphael Rosen

Physicist Igor Kaganovich and collaborators have uncovered some of the physics that make possible the etching of silicon computer chips, which power cell phones, computers, and a huge range of electronic devices. Specifically, the team found how electrically charged gas known as plasma makes the etching process more effective than it would otherwise be. The research, published in two papers appearing in the September and December 2016 issues of *Physics of Plasmas*, was supported by the U.S. Department of Energy's Office of Science.

Kaganovich, deputy head of the PPPL Theory Department, together with Dmytro Sydorenko of the University of Alberta, knew that the plasma etching process was effective, but were not sure exactly how the process worked. So they investigated the process's theoretical underpinnings.

[continued on page 4](#)

Princeton University physicist offers a “fresh perspective” on cancer research in Science on Saturday lecture

By Jeanne Jackson DeVoe

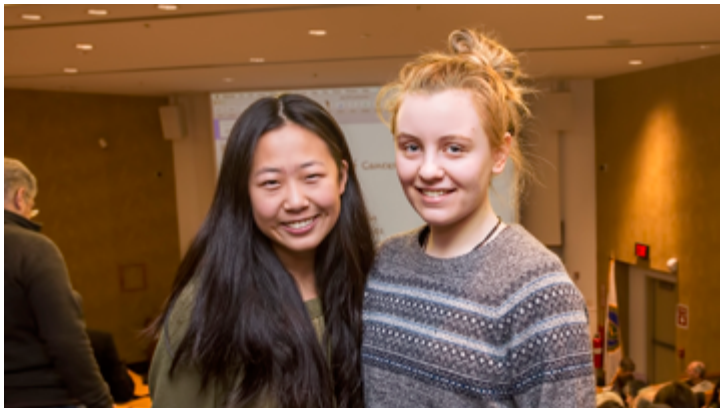
Cancer research should focus on the “fundamentals of the origins” of mutating and rapidly reproducing cancer cells that make the disease so difficult to treat. So said Princeton University physicist Robert Austin at the Jan. 28 Ronald E. Hatcher Science on Saturday lecture series.

Austin was the third of nine scientists to speak in the weekly lecture series, which is held at 9:30 a.m. every Saturday through March 18 at PPPL. [See the Science on Saturday webpage for a complete schedule.](#) (There is no lecture Feb. 25 due to the DOE’s New Jersey Regional High School Science Bowl).

Austin, a member of the Princeton faculty since 1979, is head of the Robert H. Austin Research Group in Biophysics, which studies bioorganisms under stress. He was one of many physicists and mathematicians recruited by the National Cancer Institute (NCI) to research cancer. He was the principle investigator of the Physical Sciences Oncology Center, sponsored by the NCI, which worked with Johns Hopkins and other institutions on cancer research.

Physics and mathematics bring a fresh perspective to cancer research, said Austin. “Physicists try to face with a cold eye and hard facts what nature says,” he said.

In a sense, scientists like Austin who are trying to replicate the process by which cancer cells mutate, are replicating an evolutionary process, Austin said. The ability of cancer cells to replicate themselves and mutate makes researching cancer and curing cancer challenging, he said. For example, prostate cancer generally spreads slowly and is therefore easily treatable. But certain prostate cancers spread rapidly and can often be fatal as a result, Austin said.



Lucy Tian, left, and Elisabeth Peters, both seniors at Hopewell Valley Central High School, at the lecture. (Photo by Elle Starkman)

Austin and his team replicated multiple myeloma cells in the laboratory. He showed the audience a video of myeloma cells being treated with doxorubicin, a chemotherapy medicine used to treat breast cancer, bladder cancer, Kaposi’s sarcoma, lymphoma, and acute lymphocytic leukemia. After a few days, the drug reduced the cancer cells, but after 20 days the cancer cells mutated to drug-resistant cells and began multiplying quickly again. A cocktail of cancer drugs may be more effective than a single drug and can buy the cancer patient time, but ultimately the cancer still mutates to resist the drugs, Austin said.

Austin believes cancer may be an evolutionary response to stress in the body’s system. If that is true, then cancer drugs may be working against nature because they stress the system and may therefore create an environment where cancer can thrive, Austin said. He noted that some oncologists are actually advising patients who have a non-aggressive form of prostate cancer to wait and monitor the cancer rather than starting them on drugs right away.



Robert Austin, a physics professor at Princeton University, discusses the “Physics of Cancer,” at the Jan. 28 Ronald E. Hatcher Science on Saturday lecture. (Photo by Elle Starkman)

Some 90 percent of cancers are caused by the environment or lifestyle choices and only 10 percent are genetic, Austin said. He argues that 70 percent of all cancers could be avoided with lifestyle changes. One obvious environmental cause, for example, is smoking, which causes lung cancer, the leading cause of death from cancer in the United States and worldwide, Austin said. While smoking rates are lower among educated people in the United States, cigarette companies are exporting more cigarettes to other countries, he said. Cancer is also caused by other lifestyle choices like tanning or not protecting oneself from the sun, which is linked to skin cancer. Obesity also contributes to the cancer rate, Austin said. The National Cancer Institute predicts obesity will cause an additional 500,000 additional cancer deaths in the United States by 2030.

Focusing on cancer-resistant genes

Austin believes researchers might be better off focusing on genes that are resistant to cancer rather than researching the genetics of cancer. “There might be certain critical genes that are never allowed to mutate. Maybe those are the ones we should concentrate on,” he said.

When Austin and his team analyzed data on the human genome, they found just 163 genes that never mutated. They then selected those that are “up-regulated,” meaning they have a protective code that may protect them. They found 13 genes that had “up-regulated” four times and were very old. “This is what physicists do,” Austin said. “They look at massive amounts of data and try to get down to the basic kinds of things that may be driving the whole thing.”

An evolutionary purpose

Cancer may have an evolutionary purpose, Austin said. It may be nature’s way of rebooting the body that returns to genes that harken back to man’s evolutionary origins, he said. “Perhaps cancer represents a return to unicellularity that is represented by these crucial and ancient genes, with cancer abandoning high-level genes,” Austin said.

But Austin said he and other scientists have embarked on a long journey. “There are many fundamental problems in cancer that need to be solved before we go to the moon,” he said.

Audience members appreciative

Audience members were very appreciative of the lecture. “If I had four thumbs, they’d all be up,” said Gary Grubb, of Hightstown, who has been coming to the lectures for 20 years.

NSTX-U recovery

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as part of a comprehensive extent of condition review. Any construction gaps will be addressed in a corrective action plan that will specify the cost, schedule and technical specifications to solve potential problems, Brog said. He noted that the DVVRs are underway and three have been completed.

PPPL will also do a separate extent of cause review that will focus on policies and procedures for design and construction of the NSTX-U and other PPPL projects, Brog said.



Engineers Robert Ellis, left, and Nevell Greenough, gave presentation on the RF wave system. Valeria Riccardo, center, the head of engineering, chaired the meeting. (Photo by Elle Starkman)

“A comprehensive review of our experiment”

Hawryluk gave the FESAC members a detailed description of the recovery project. He said PPPL is “embarking on a comprehensive review of our experiment” through the weekly DVVRs scheduled through April. “The Design, Verification and Validation Reviews so far have been very constructive,” Hawryluk said in an interview after the meeting. “We’ve identified many issues and we’ve had very frank and open discussions. People have been very engaged in identifying how we can make the machine more reliable and address problems in the future.”

The DVVR process produces chits on any identified issues, which are then evaluated for their potential impact on the NSTX-U operation. “We’re finding items that will be just fine and other items that are at the end of life and should be replaced,” Hawryluk said. “This is especially true for some data acquisition equipment. We also have components, like the PF1A coil, that we know we need to redesign and build.”

Plans are also underway for an external review committee that will include representatives from national and international laboratories and institutions to conduct a review of the corrective action plan. Until the reviews are completed, Brog said, it cannot be determined when NSTX-U will be back online.



Physicist Matt Reinke, right, describes a control room in the RF Building to Richard Goulding, left, of Oak Ridge National Laboratory, as physicist Joel Hosea looks on. (Photo by Elle Starkman)

Hawryluk also discussed specific problems on the NSTX-U. These include an ohmic heating arc flash in April of 2015; discovery that the inboard divertor cannot get to the proper temperature for a bakeout; a deformed upper bus bar, and some passive structural issues with the center stack.

Extensive forensic tests on PF1A upper coil

After the failed coil was removed from the center stack in August, the forensic team sectioned the coil very carefully and performed “a battery of tests” on the coil sections, Hawryluk said. These included electrical, pressure, and vacuum tests on individual water channels.

The investigators found the failure was caused by an electrical short that was most likely associated with poor vacuum pressure impregnation (VPI) and other factors, Hawryluk said. With the benefit of hindsight, additional oversight when the coil was being manufactured would have been useful, he said. The investigation is continuing and PPPL engineers and external experts are now evaluating the VPI process and performing additional tests, Hawryluk said.



Engineer Tim Stevenson presents at the review of the neutral beam injection system.

At the same time, Hawryluk said, a new design for the PF1A upper coil is proceeding and will be ready for peer review this week. The final design review will take place in the next three months. PPPL is evaluating whether to manufacture new coils at PPPL, at a company or a national laboratory or a combination of those options, Hawryluk said. Researchers are evaluating whether other coils need to be rebuilt in addition to the failed coil, Hawryluk said. The PF1A lower coil and the PF1C upper coil were removed in November. The PF1C lower coil was removed two weeks ago and the PF1B upper and lower coils were removed Jan. 31. The successful disassembly of the machine enables further inspections and testing to proceed.

DVVR focuses on RF waves and neutral beams

Meanwhile, the NSTX-U Recovery Team last week presented its third DVVR on PPPL’s plasma heating and current drive systems, which included presentations on radio frequency (RF) waves and neutral beams.

Engineers Robert Ellis and Nevell Greenough gave presentations on January 30 on how RF waves are injected into the plasma to heat and drive currents in the plasma.

Six transmitters powered by high-voltage power supplies in the C Site RF Building generate the RF waves. The transmitters date back to the Princeton Large Torus (PLT) machine in the late 1970s and were later used on the Tokamak Fusion Test Reactor. Each source can generate 1.5 megawatts. The RF waves are transmitted to D site on six coaxial transmission lines. The RF waves enter the NSTX-U vacuum vessel on 12 antenna straps.

Plasma-etching

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During the etching process, a piece of silicon is placed in a chamber and immersed within a thin layer of plasma, about two centimeters wide. Also within the plasma are two electrodes spaced a couple of centimeters apart that produce a beam of electrons. As the electrons flow through the plasma, they start a process known as a two-stream instability, which excites plasma waves that enable the plasma to etch the silicon more efficiently.

Sydorenko and Kaganovich modeled this process. They showed that the waves created by the electron beam can become much more



Igor Kaganovich
(Photo by Elle Starkman)

intense than in plasmas that are not bounded by electrodes. In other words, when a plasma is bounded, the wave driven by the two-stream instability can become very strong. "The simulations indicate that the placing of plasma within a pair of electrodes supports the excitation of large plasma waves, which then lead to the acceleration of plasma electrons that can aid etching," Kaganovich said.

Understanding the physics undergirding the plasma etching technique could help researchers design more efficient processes to etch circuits on silicon chips. 📷

NSTX-U recovery

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In addition, a smaller system is used to break down the gas in the torus and pre-ionize the plasma. This system is located in the NSTX-U test cell.

The second half of the DVVR, presented on Jan. 31 by engineer Tim Stevenson, focused on the neutral beam injection system. The upgrade of the NSTX added a second neutral beam that doubled the experiment's heating power. The beams inject neutral atoms into the plasma to potentially heat the plasma to temperatures up to 100 million degrees Centigrade and to help drive the plasma current. The second beam will also reduce plasma instabilities. Both beam lines operated in 2016 and the beams were capable of generating 12 megawatts of heating power during experiments, Stevenson said.

Each of the beam lines has three power supplies that are located in the Neutral Beam Power Conversion Building at D site next to the NSTX-U test cell. The beamlines are lined with cryogenically cooled panels filled with liquid helium that is kept at a temperature near absolute zero.

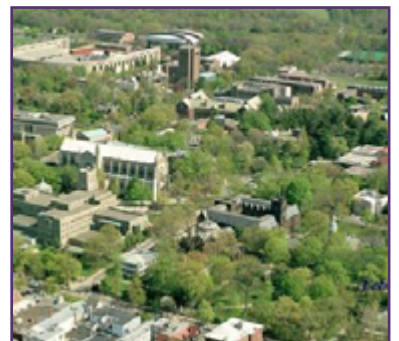
Some potential issues for the NSTX-U heating systems are that the systems may need some additional spare components and may need to use more modern electronics, Hawryluk said.

The committee was chaired by Valeria Riccardo, head of Engineering, and consisted of external reviewers Richard Goulding, an Oak Ridge National Laboratory scientist; Elizabeth Surrey, technology program leader at the Culham Centre for Fusion Energy in Oxfordshire, England; and retired PPPL physicists Larry Grisham and Randy Wilson. Attending remotely were Tim Scoville, head of the neutral beam group at the DIII-D tokamak that General Atomics operates for the DOE in San Diego; physicist Stephen Wukitch of MIT's Plasma Science and Fusion Center; and Tom Todd, the retired chief technologist at the Culham Centre, who will head the Extent of Condition Committee.

The DVVR this week from Feb. 7 through Feb. 10 will focus on PPPL's magnet system, a crucial system for the experiment and one that includes the PF1A coils and the other coils. 📷

COLLOQUIUM

Princeton Campus Development 1756-2017



Joshua E. Linkov
Princeton University

Wednesday, Feb. 8
4:15 p.m., M.B.G Auditorium, Lyman Spitzer Building

Science on Saturday

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"I learn a little bit here and a little bit there. It fills out the world for me," said Bob Akins, also of Hightstown. "I hope they continue these because I think they're a very real addition to the community."

Elisabeth Peters and her friend, Lucy Tian, both 17-year-old seniors at Hopewell Valley Central High School, came to a lecture last year and now they say they're hooked. "We were like, 'Oh my God, that's so cool,'" said Peters. "We had a really good time. Today we thought we know the biology and chemistry of cancer so let's find out about the physics." "We're big science nerds," Tian added.

Galina Chernaya, of Princeton, a scientist who works in the pharmaceutical industry, said she has been coming to the

lectures ever since her son came for a school assignment 10 years ago. "I like the variety of topics," she said. "I always learn something."

"It's an excellent opportunity for the general public to hear scientists firsthand," said her friend, Jennifer Hartford, of Princeton, who came for the first time. "We don't get that opportunity very often. It's a beautiful thing you're doing here."

Emerging diseases focus of next talk

The next Science on Saturday lecture is a Feb. 11 talk on "Meat, Monkeys, and Mosquitoes: A One Health Perspective on Emerging Diseases," by Laura Kahn, a research scholar at Princeton University's Woodrow Wilson School. [▶](#)

Ronald E. Hatcher

Science on Saturday LECTURE SERIES

Feb. 11

Meat, Monkeys, and Mosquitoes: A One Health Perspective on Emerging Diseases

Laura Kahn, Princeton

Feb. 18

Cities in the 21st century: the nexus of the climate, water, and energy challenges

Elie Bou-Zeid, Princeton

Feb. 25

NO SCIENCE ON SATURDAY LECTURE— Department of Energy's 2017 New Jersey Regional High School Science Bowl

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

Save the date: American Red Cross Blood Drive March 15

Mark your calendar!

American Red Cross Blood Drive at PPPL,
Wednesday, March 15

More information will be sent out at a later date.

Application opens for presenters at 2017 Princeton Research Day

Applications are being accepted through Feb. 20 for non-faculty researchers at Princeton University, such as undergraduates, graduate students and postdoctoral researchers, to present at the second annual 2017 Princeton Research Day on May 11.

The application is available at <https://researchday.princeton.edu>.

[The link to the Research Day website is available here.](#)

[The link to the application is available here.](#)

Science Bowl Volunteers Needed: Feb. 24 and 25

PPPL will host 48 teams of middle and high school students (about 250 students total) on Friday, Feb. 24 and Saturday, Feb. 25 for the New Jersey Regional Middle and High School Science Bowls.

We need your help! Please sign up to help out in technical (science judge, moderator) at goo.gl/forms/a5SoxOiJhufQgIm63 or in non-technical positions (score-keeper, registration, lunch, before/after prep) at goo.gl/forms/aF2PsP009W0EF1H63. Lunch will be provided for competition day volunteers.

Please contact Deedee Ortiz at dortiz@pppl.gov or ext. 2785 to sign up or for more information.

Volunteers wanted for Mercer Science and Engineering Fair

Organizers of the Mercer Science and Engineering Fair are looking for scientists and engineers to volunteer as judges of fourth to twelfth-grade science projects during the fair in March at Rider University.

Students from Mercer County schools show off their original science projects at the fair from March 12 to March 15. Judging takes place March 12 to 13. Additional information about the fair is available at <https://mercersec.org/about/msef>.

To volunteer, go to <http://mercersec.org/help/BecomeAJudge> or contact volunteers Kevin Lamb, klamb@pppl.gov or Hans Schneider, hschneid@pppl.gov.

PPPL Welcomes New Employees!



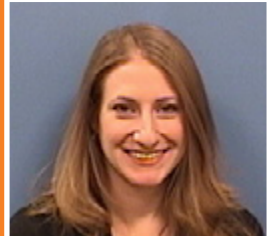
KATINA GARTHE
Human Resources generalist
Human Resources



LASZLO GLANT
Junior systems/HPC engineer
Information Technology



PAUL HUGHES
Associate research physicist
PS&T



AILEEN PRITCH
Administrator of procedures,
publications and patents
Office of the Director



HARRY TSAMUTALIS
Senior media support specialist
Information Technology

BRÖCK

NICK PETTI
Chef Manager



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 February 6	Tuesday February 7	Wednesday February 8	Thursday February 9	Friday February 10
COMMAND PERFORMANCE Chef's Feature	Chicken Parmesan served with Pasta	Bruschetta Chicken with Orzo Pilaf	Orecchiette Pasta Bake	Baked Meatloaf with Mashed Potatoes and Gravy	Kielbasa with Sauerkraut and Pierogies
Early Riser	Bacon, Egg & Cheese Croissant	Biscuits with Sausage Gravy	Mango & Blueberry Pancakes served with Choice of Breakfast Meat	Turkey Bacon, Egg and Cheese Sandwich	2 Eggs, 2 Pancakes, Choice of Breakfast Meat & Potatoes
Country Kettle	Creamy Chicken	Cream of Mushroom	Beef Barley	Vegetable Noodle	Chicken Orzo
Deli Special	Middle Eastern Stacked Veggie Sandwich with Hummus, Eggplant, Red Onion, Red Pepper, Tomato, Mozzarella & Balsamic on Wheat Roll	Caesar Turkey Focaccia	Ham and Smoked Gouda with Pineapple Slaw	Portobello Mushroom & Fontina Cheese with Roasted Peppers on Ciabatta	Chicken, Mozzarella, Red Onion, Basil, Arugula and Balsamic Tomatoes on French Bread
Grill Special	Chili Burger with Crisp Onions & Cheddar Cheese on an Onion Roll with Chipotle Mayo	Teriyaki Chicken Cheesesteak with Asian Slaw	Burgerlicious BBQ Beef in a Blanket	Turkey, Bacon, Cheddar, Diced Tomato, Red Onion and BBQ Chipotle Mayo Flatbread	Roast Vegetable Stromboli
Panini	Tomato, Fresh Mozzarella, Spinach and Pesto Flatbread	Spicy Italian Grinder	Turkey Meatball Parmesan Torpedo	Grilled Ham and Cheese on Texas Toast	Foot-long Chili Dog

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/>.