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PPPL news

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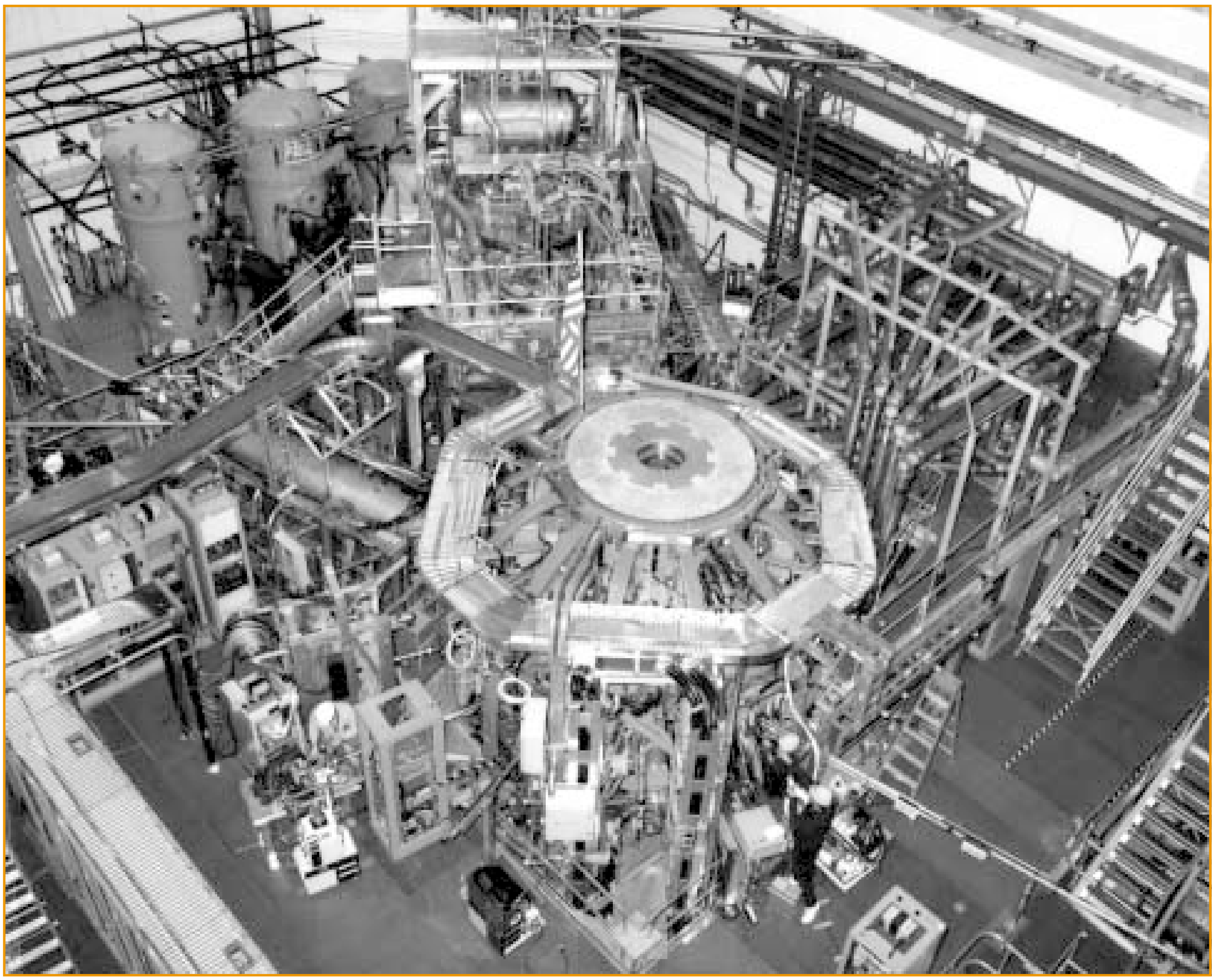
Scientists Encouraged by NSTX Results

High Beta with Good Confinement Reported



The National Spherical Torus Experiment

By Anthony DeMeo

The use of neutral-beam injection heating on the National Spherical Torus Experiment (NSTX), coupled with good confinement, has allowed the NSTX National Research Team to produce a plasma toroidal beta of up to 22.5 percent based on magnetic measurements. "Initial results are extremely encouraging. We hope to reach 25 percent during the next experimental campaign, more than one year ahead of schedule," noted NSTX Project Director Masa Ono.

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NSTX

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Fusion power production is roughly proportional to the square of the plasma pressure. Toroidal beta is the ratio of plasma pressure to magnetic field pressure applied in the long direction of the spherical torus. A higher beta means that greater plasma pressure, thus substantially more fusion power output, is achieved with a given magnetic field strength. The cost of a fusion reactor will rise with the strength and size of the magnetic field coils. Consequently, higher betas in NSTX could lead to the development of smaller, more economical fusion reactors. The highest toroidal beta value produced by a tokamak stands at about 13 percent.

PPPL physicists, their colleagues from 13 other U.S. institutions comprising the NSTX team, and collaborators from Japan, Korea, and the United Kingdom, worked together on the recent experiments. The highest beta was achieved with only three million watts of neutral-beam heating power. Five million watts of heating power will be applied during the next campaign to enable the physics studies at increased plasma pressures.

Quite surprisingly, the observed energy containment efficiency of the NSTX plasma improved by as much as a factor of two as neutral-beam heating was added to the resistive heating. Furthermore, the NSTX plasma entered a state known as the "High Confinement Mode"— the first time for NSTX. Plasmas in the so-called H-Mode demonstrate substantially improved confinement with a density that is about as high at the edge of the plasma as it is at the center. This bodes well for the prospect that NSTX eventually will have adequate heating power to test the theoretically predicted toroidal beta values in the range of 40 percent. In the coming months, the NSTX National Research Team and the PPPL Theory Department will use results now emerging from NSTX to refine and expand models for high-beta spherical torus plasmas, enabling a better understanding of the plasma stability and confinement properties.

Ono attributes the recent success to the December 1999 achievement of one million amperes of plasma current, nine months ahead of schedule, which set the stage for the current experiments. He also noted that NSTX is building on previous results from machines such as PPPL's Tokamak Fusion Test Reactor (TFTR) and the DIII-D tokamak at General Atomics in San Diego. For example, the NSTX neutral-beam injection system, which became operational on September 13 within budget and ahead of schedule, draws heavily on TFTR design, hardware, and operating experience. The system cost $6 million and took two years to complete.

Using techniques developed on TFTR and other tokamaks, researchers have been able to minimize plasma impurities in NSTX, especially heavy metals, which absorb energy from the plasma and release it as ultraviolet light and X-rays. Such foreign matter enters the plasma when it interacts with walls of the vacuum vessel. To minimize this infiltration, large portions of the NSTX vacuum vessel walls and center column were covered with protective graphite tiles. Just prior to the neutral-beam experiments, the vacuum vessel and tiles were heated to 150˚C and the center stack to 300˚C to drive out water vapor. A helium glow discharge was used to reduce the influx of hydrogen bound up in the walls. The reduction of hydrogen helps make plasma operation more reliable and improves performance. A glow discharge is a tenuous plasma produced in the vacuum vessel using an electrode. The vacuum vessel wall being cleaned is biased negatively against the electrode. This causes the ions in the glow plasma to bombard and "scrub" the wall surface free of contaminants. Finally, all the walls and graphite tiles were coated with a thin layer of boron using trimethyl boron gas, which also helps keep heavy metals from entering the plasma.

Other Work Underway

While striving to understand the physics behind NSTX's excellent plasma confinement and high-beta performance, physicists are working on other fundamen-

PPPL NEWS

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tal goals. Among the most important of these are experiments relating to Coaxial Helicity Injection (CHI) and High Harmonic Fast Waves (HHFW). If successfully applied, CHI could lead eventually to the elimination of the central solenoid, resulting in smaller, more powerful fusion reactors. HHFW will heat plasma electrons to high temperatures and sustain plasma current needed for steady-state fusion reactors.

State-of-the-art Spherical Torus

In a state-of-the-art spherical torus, the plasma current essential for start-up, heating, and confinement is induced by rapidly reversing the current in a solenoid running through the hole at the center of the vacuum vessel. This coil occupies space, which could be used more productively for additional toroidal windings, yielding a stronger toroidal magnetic field. For example, doubling the toroidal magnetic field could result in as much as 16 times the fusion power output. CHI, a method of noninductive start-up, involves the establishment of voltage between the center column and the vacuum vessel outer wall. Electrical breakdown occurs propelling a plasma ring into the chamber resulting in the creation of a toroidal plasma. Separation of the plasma from the wall occurs by means of magnetic reconnection, a phenomenon under study in PPPL's Magnetic Reconnection Experiment, as well in NSTX. To date, NSTX researchers have been able to start up a plasma current of 0.26 million amperes. Their goal is 0.50 million amperes or more.

NSTX is the first device of its size to test the physics of HHFW. HHFW heats electrons and maintains plasma current using a plasma wave at many times the frequency with which ions gyrate around the magnetic field. Strong electron heating using HHFW was observed for the first time in recent NSTX experiments. Electron temperature was increased from about 4 million degrees to above 10 million degrees Centigrade using 2 megawatts of power. NSTX Program Director Martin Peng said, "It is encouraging to already have achieved good electron heating. We look forward to exploring the new and rather intriguing properties of HHFW and learning how to utilize this method in spherical torus and other high-beta plasmas."

In the mid-1980s, experiments on TFTR verified the existence of the theoretically predicted bootstrap current, which can sustain itself when the plasma pressure is high. If NSTX experiments establish the effectiveness of CHI,

From left, Joel Hosea, Dave Swain, Ben LeBlanc, Randy Wilson, Bob Pinsker, and Jon Menard stand in front of the High Harmonic Fast Waves transmission lines at NSTX.

it may be used in conjunction with bootstrap plasma current and HHFW to allow steady-state operation of a fusion power plant. NSTX researchers hope to determine if the bootstrap current will start automatically, or will require a small seed current of a few percent of the total. Bootstrap current may ultimately account for as much as 70 percent of the total plasma current flowing in NSTX.

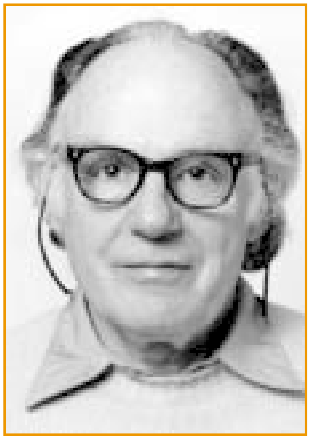
Intriguing Experimental Results

The next NSTX experimental campaign is scheduled to begin in February. "With many intriguing experimental results coming out of NSTX, as well as new capabilities being implemented, clearly there are far more experiments we would like to conduct than the available machine time and resources will permit. Obviously we would like to explore and increase our understanding of the high-beta plasma regime. We must continue the development of key spherical torus reactor tools, such as CHI and HHFW. So we must choose carefully to come up with an optimized run plan," Ono said. ●

NSTX

A Tribute to Mel Gottlieb, Former PPPL Director

Former PPPL Director Melvin B. Gottlieb, an international leader in the field of research on fusion energy, died on December 1 in Haverford, Pennsylvania. He was 83.



Melvin B. Gottlieb

Gottlieb, Director of PPPL from 1961-1980, was known for his tireless dedication to the fusion concept and for his constant inspiration to the fusion program worldwide, as well as for his leadership and for being the consummate "people person."

"Mel was deeply loved at PPPL. My warmest memory is of his support for me as a graduate student, struggling to help Harold Eubank with the neutral injection experiments on the ATC [Adiabatic Toroidal Compressor] machine, around 1975. His calm assurance and easy good humor seemed to suggest that we would, indeed, get the needed 'typical data,' sooner rather than later," recalled PPPL Director Rob Goldston.

Added Advanced Projects Head John Schmidt, "When I came to PPPL, I decided to accept a postdoctoral position here rather than more lucrative and permanent positions at other fusion laboratories. A significant reason for this was the impression Mel left on me. I obviously have never regretted the decision. Mel stood very tall physically, as a scientist, and as a fusion leader."

During his 26-year association with PPPL, Gottlieb saw the Laboratory grow from a small contingent of investigators to a full-blown experimental facility on the leading edge of magnetic fusion research. Under his leadership, the Laboratory's budgets expanded from $7 million during the early 1970s to $100 million in 1980. Said former PPPL Director Harold Furth, "I think of Mel as a benign gravitational force, which held world fusion research together during its most thriving years."

Throughout the growth of research projects, budgets, and staff, he stressed the importance of explaining to the layperson what fusion scientists were doing and why they were doing it, without using highly technical language. "Since we are publicly supported, we have a duty to the public to make our ideas clear, our hopes clear, our dreams clear," said Gottlieb in 1980.

Asked then about the nation's energy options, he answered, "The long-term solutions for energy are: fission, fusion, and solar. The question has always been: How much is it going to cost? If it costs ten times existing levels, we're obviously going to have a great deal of trouble supporting present population levels at the present standard of living. The attainment of an economic, environmentally acceptable energy source is of enormous importance for the future of mankind."

Gottlieb led the Laboratory at an exciting time. In the mid-1960s, initial experimental results from the Soviet Union pointed to a new path to the very high-temperature plasmas needed for making fusion energy. Under Gottlieb's leadership, the Laboratory took the international lead in extending these results, passing quickly through three generations of highly successful tokamak experiments. The Tokamak Fusion Test Reactor, whose construction started under Gottlieb, produced a world-record plasma temperature of 510 million degrees centigrade and a record 10.7 million watts of fusion power.

Legacy of Plasma Science

PPPL Advanced Reactor Concepts Head Dale Meade said, "Mel Gottlieb left a legacy of plasma science and scientists that will carry the torch of plasma physics and fusion energy forward for generations to come. Mel's wisdom and guidance were crucial in leading the U.S. fusion program from the shadows of the post-World War II era through the turbulence of the 1960s into the energetic fusion program of the 1980s. Mel's personal warmth and genuine concern nurtured and inspired generations of scientists and staff at the Princeton Plasma Physics Laboratory. We will miss him greatly, and we will remember him always as an inspiring leader, an insightful scientist, and a close personal friend."

Indeed, Gottlieb, known as "Mel" to everyone, is remembered as much for his warm personal style as for his insightful scientific leadership. His thoughtfulness and calm — often expressed by putting his reassuring arm around the shoulder of an over-stressed researcher — is a cherished memory at PPPL.

"Mel was one of the finest people I have ever had the pleasure of meeting and working with. There just are not enough words to express what a great person he was. He will be deeply missed by all who knew him," said PPPL Benefits Manager Bobbie Forcier.

Information Services Head Anthony DeMeo recalled Gottlieb as a kind man who openly cared about the welfare of PPPL staff. "Mel had a unique sensitivity to the feelings and problems of his staff. For example, if he learned that you or a member of your family was ill, he never forgot to ask how things were going," DeMeo said.

Cathy Howard, now retired, was Mel's administrator from 1974 through 1980 and she added, "I spent six years by Mel's side. He was a warm and compassionate leader who believed in equality and practiced it by conducting an 'open door' policy for all, regardless of position or stature in the organization. There was always time, even during the busiest of schedules, for a kind word to put in perspective an individual's view of his or her problem. I remember during a very hectic and stressful period of time at the Lab when Mel walked me to the large office window which overlooked the adjacent woods and said, 'Cathy, everyone should take time to smell the roses.' He touched many lives in this way, and, he occupied a very important chapter in my life. He will be missed by all who had the privilege of knowing him."

Melvin B. Gottlieb is pictured with employees of PPPL, where he was Director from 1961 through 1980. Gottlieb's hand rests on a torus, representing the donut shape of the magnetic confinement chambers used in fusion research during his tenure.

Gottlieb, who was educated at the University of Chicago and also had been Professor of Astrophysical Sciences at Princeton University, devoted considerable time during his career to working toward better understanding and cooperation with other nations in the development of fusion power. The fusion program at Princeton was classified until 1958. Thereafter, the program became international, involving cooperation and sharing of information. Lab personnel including Gottlieb made frequent trips to meet with scientists abroad and encouraged extended visits here by foreign scientists.

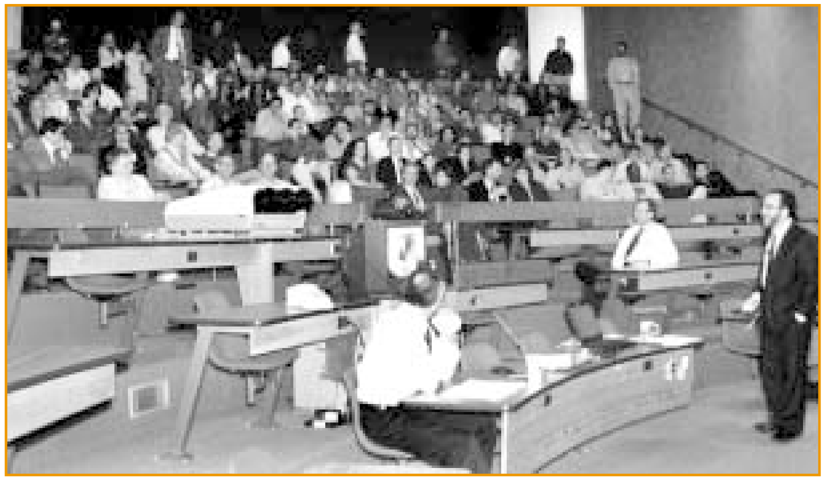
During his tenure as Director at PPPL, Gottlieb was also involved in high-level discussions with government officials responsible for energy policy in many countries, including France, England, Germany, Italy, Norway, Japan, China, South Korea, Spain, Brazil, Canada, U.S.S.R., and the European Economic Community. He was a member of the U.S. Fusion Power Coordinating Committee; the U.S.-U.S.S.R. Joint Committee on Atomic Energy; the U.S.-People's Republic of China Committee on Fusion Cooperation; and the U.S.-Japan Fusion Cooperation Committee. In 1971, he was a recipient of the North Atlantic Treaty Organization (NATO) Senior Foreign Fellowships in Science.

At the national level, Gottlieb was active in many organizations whose purposes included finding alternative safe sources of energy. He had a long association with the American Physical Society and was founder and first chairman of its Plasma Physics Division. In 1980, he was Vice Chairman of its panel on Public Affairs. He was also a member of the American Nuclear Society and of Scientists and Engineers for Safe Energy.

After his retirement from the Laboratory, Gottlieb continued consulting in his field and, from 1980-1992, served as Chairman of the Nuclear Oversight Committee of the Public Service Electric and Gas Company of New Jersey.

Gottlieb is survived by his wife, Golda, whom he married in 1948; his daughter, Paula Bastian, of Cedar Run, New Jersey; two grandchildren, Will and Mary Kate Bastian; and two nephews, David and Edward Mehlman, of Chicago. He was pre-deceased by his daughter, Martha, who died in an automobile accident in 1986. ●

The State of the Lab ...



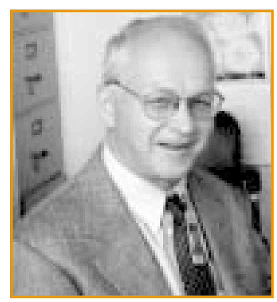
On November 2, PPPL Director Rob Goldston delivered his annual "State-of-the-Lab" address to staff in a packed MBG Auditorium. Goldston lauded the Lab's research accomplishments, as well as the goals and successes of our external relations efforts and operations, stressing that PPPL's programs were "off and flying." The talk was followed by an ice-cream reception in the Lobby. At right is Goldston giving the address. ●

Kaul and Distinguished Fellow Awards Given

From left are Kaul recipients Ronald Bell and Edmund Synakowski and PPPL Distinguished Engineering Fellow Charles Neumeyer. Francis "Rip" Perkins (pictured at right) received the PPPL Distinguished Research Fellow award via videoconference.

On November 2, PPPL Director Rob Goldston presented awards to four PPPL researchers. Ronald Bell and Edmund Synakowski received the Kaul Foundation Prize for Excellence in Plasma Physics and Technology Development. Francis "Rip" Perkins and Charles Neumeyer were named PPPL Distinguished Research and Engineering Fellows, respectively. The four recipients were honored during a ceremony and reception following Goldston's State-of-the-Lab talk.

The Kaul award recognizes Bell and Synakowski for novel measurements of the dynamics of hot ionized gases, or plasmas. By modifying the flow of plasma confined by magnetic fields, they found that the efficiency of the magnetic field in confining the plasma's heat can be altered and improved. Such flows act on plasma turbulence, the underlying cause of heat loss from these plasmas. The work suggests that generating plasma flows in a fusion reactor might increase the reactor efficiency, thus reducing its cost and size.



Francis "Rip" Perkins

Perkins, who is on long-term assignment at General Atomics in San Diego, received the PPPL Distinguished Fellow Award for his outstanding contributions in many critical areas of plasma physics research with applications in fusion, basic plasma physics experiments, and ionospheric physics, and for leadership in an international collaborative effort to document and assess the physics basis of a next-step burning plasma experiment. He was further honored for contributing prominently to graduate education in plasma physics.

Neumeyer, the lead project engineer for the National Spherical Torus Experiment (NSTX), received the PPPL Distinguished Engineering Award for contributions and technical leadership of the engineering effort to design power systems for several magnetic fusion devices, including the Tokamak Fusion Test Reactor, the Tokamak Physics Experiment, and NSTX, and for extraordinary creativity and accomplishments in the development of control systems for fusion devices. ●

President Honors PPPL Scientist Lin

Lin Also Receives Department of Energy Early Career Award

On October 24, President Clinton named 59 young researchers — including Zhihong Lin, a physicist at PPPL — as recipients of the fifth annual Presidential Early Career Awards for Scientists and Engineers (PECASE). This award is the highest honor bestowed by the United States government on young professionals at the outset of their independent research careers. The researchers received their awards during a White House ceremony.

Established by President Clinton in February 1996, the award embodies the high priority the Administration places on producing outstanding scientists and engineers ready to contribute to all sectors of the economy. Eight Federal departments and agencies join together annually to nominate the most meritorious young scientists and engineers who will broadly advance the science and technology that will be of the greatest benefit to fulfilling the agencies' missions.

"These extraordinarily gifted young scientists and engineers represent the best in our country," President Clinton said. "Through their talent, ability, and dedication, they will quicken the pace of discovery and put science and technology to work advancing the human condition as never before."

The young scientists and engineers receive up to a five-year research grant to further their study in support of critical government missions. The Federal agencies involved include: the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Veterans Affairs, the National Aeronautics and Space Administration, and the National Science Foundation.

Zhihong Lin

Also on October 24, Ernest J. Moniz, Under Secretary of Energy, Science and Environment, presented Lin and three others with the Department of Energy's Office of Science Early Career Award in Science and Engineering during a Department reception prior to the White House ceremony.

Both the Presidential and Department of Energy awards cited Lin for "performing advanced simulations with unprecedented realism and resolution leading to results demonstrating the positive impact of modern massively parallel computers and for outstanding contributions to improved understanding of plasma turbulence."

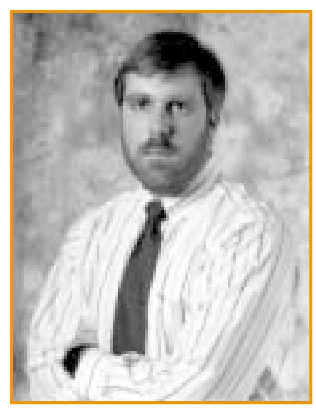
Lin's goals are to advance the physics understanding of transport processes in magnetically confined, high-temperature plasmas and to demonstrate the exciting discoveries that are made possible by the application of modern, massively parallel computers in challenging areas of plasma physics research. ●

American Nuclear Society Awards Williams

Michael Williams is the recipient of last year's Outstanding Achievement Award from the American Nuclear Society's Fusion Energy Division. Williams is Head of the Engineering and Technical Infrastructure Department at PPPL. He received the award October 18 during the American Nuclear Society's 14th Topical Meeting on the Technology of Fusion Energy in Park City, Utah. The award recognizes Williams' longstanding research and leadership in PPPL's Poloidal Divertor Experiment, Tokamak Fusion Test Reactor (TFTR), and National Spherical Torus Experiment (NSTX) projects.

It is the most prestigious award from the society's Fusion Energy Division and is presented to a member in recognition of exemplary individual achievement requiring professional excellence and leadership of high caliber in the fusion science and engineering area.

Williams, who is also Deputy Director of the NSTX project at PPPL, led several project teams and served as the Deputy Project Head of TFTR from 1992 until the project was closed down in 1997.



Michael Williams

Williams has been Head of the PPPL Engineering and Technical Infrastructure Department since 1991, where he is responsible for managing all technical engineering and computing resources at the Lab. He came to PPPL in 1976 after graduating magna cum laude from Rutgers University with a bachelor's degree in electrical engineering. ●

Energy Secretary Visits PPPL

Photo by Dietmar Krause

On October 25, Bill Richardson (above), who was the U.S. Energy Secretary then, brought welcome news to PPPL, announcing a five-year extension of the contract between Princeton University and the U.S. Department of Energy for the operation of the Laboratory. Richardson made the announcement to a large assembly of PPPL personnel, media, and visitors at the MBG Auditorium.

DOE Pulse

Science and Technology Highlights from the DOE National Laboratories

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