PPPL
PRINCETON PLASMA PHYSICS LABORATORY
HOTLINE

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Discovery of Twin Stars Brings Hulse the Nobel Prize

When Russell Hulse's radio alarm went off at 7 a.m. the morning of October 13, little did he expect his own name to come beaming across the airwaves. Surely he must be dreaming! But the announcement that he had joined the ranks of his boyhood idols who were Nobel Prize winners was very real.

Hulse, a principal research physicist at PPPL, and Joseph Taylor Jr., a physics professor at Princeton, had indeed won the Nobel Physics Prize jointly, along with $825,000, for their 1974 discovery of the first binary pulsar—a twin star system that provides a rare natural laboratory in which to test Albert Einstein's prediction that moving objects emit gravitational waves, as well as other aspects of his general theory of relativity.

Later that day, Hulse joined Taylor at a standing-room-only press conference at Princeton University, where he told the audience that he had chosen pulsars as his graduate thesis topic because it combined his interests in physics and radio astronomy. He described winning the Nobel Prize as "a rather incredible culmination of an extraordinary graduate student career."

In his letter of congratulations to Hulse, Lab Director Ron Davidson, said, "On behalf of the Princeton Plasma Physics Laboratory, please accept our enthusiastic congratulations on receiving this well-deserved recognition of your extraordinary scientific achievements. Your award brings great honor and distinction to the Laboratory and to the University, and we are very proud of your accomplishments."

Photo: Dietmar Krause

1993 Physics Nobel Laureates Joseph H. Taylor (left) and Russell A. Hulse answer a question during the news conference at Princeton University on October 13.

It is unusual for graduate students to be recognized along with their thesis advisors even if they have done the greater part of the work on a project. Hulse was deeply appreciative of the honor, but noted that his thesis advisor had made the greater contribution to binary pulsar research. Said Hulse, "Dr. Taylor has continued to work in the field, while for the last sixteen years I've been doing fusion research at PPPL."

The Story of the Discovery

Just how did this wonderful discovery of the first binary pulsar occur?

It all started back in '74 after Taylor, then an enthusiastic young professor at the University of Massachusetts in Amherst, encouraged grad student Russ Hulse to do his thesis research pulsar-hunting via a 300-meter-diameter radio telescope built over a bowl-shaped valley in Arecibo, Puerto Rico.

Radio telescopes were certainly not new to Hulse, who had built his first one from homemade antennas and television antennas while still in high school. He had also helped build a radio telescope of chicken wire and telephone poles at the University of Massachusetts. Said Hulse, "Radio telescopes are really just big radio or TV antennas, and pulsar signals are pretty close to the TV spectrum."

In preparation for his work, Hulse developed a computer program to

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sort out the pulsar data that would be collected by the huge telescope, and he expected to spend his stay in Puerto Rico detecting the characteristic beacons of radio waves that these collapsed stars beam out through the universe—not unlike the blinking lights from a lighthouse. In fact, pulsars emit radio signals that are so predictably timed that astronomers initially thought the regular pulses might be signals from intelligent beings which they dubbed LGMs (little green men).

However, in the late 1960s, as more pulsars were located, it became clear that they are actually neutron stars so dense that their 6 to 12 mile span is as massive as our sun. (If you're concerned about your weight don't visit a pulsar—because of its tremendous gravitational pull, you'd weigh several hundred billion times more there than here. You'd also be squashed to a thin film!)

When Hulse set out in search of new pulsars, their existence had only be known for seven years and only about 100 had been discovered. The search he launched for pulsars was about ten times more sensitive than any previous search, because it combined the largest available telescope and a dedicated minicomputer devoted to analyzing the signals in great detail. With this increased sensitivity, Hulse was able to detect 40 new pulsars in the small section of the plane of our galaxy (the Milky Way) visible with the Arecibo telescope.

According to Hulse, his success in locating new pulsars that serendipitous summer was also partly due to the fact that the Arecibo telescope was undergoing upgrades and was thus not available for many of the types of observations that most astronomers required. Explains Hulse, "Since the pulsar search could be done during the upgrade process, and because I was able to live at the observatory for a number of months, I was able to be present during times when the telescope was available."

However, with so much data coming in, Hulse could have easily passed over the very weak pulsed signal that first appeared on July 2, 1974.* In fact, had the signal been just four percent weaker, it would not have even been picked up by his computer's search routine! Hulse did finally get back to the signal on August 25, intrigued by its surprisingly short period of pulsation, only 0.059 seconds.

But as he began observing the data more closely, Hulse ran into trouble—different periods for the pulses were being produced. Over and over he recorded new data and checked it. Always, inconsistent periods of pulses appeared. Annoyed, he assumed there must be a problem with his computer program.

However, instead of abandoning this troublesome pulsar for others with clearer data, as he could easily have done, Hulse persevered, taking further observations and writing a special computer program to compensate for any problems in resolving the pulses. Still, his data remained unlike any of his data for single pulsars.

Perhaps the problem wasn't in the computer program after all! When the periods he recorded began repeating themselves, it occurred to Hulse that the pulsar did have a predictable pulse rate, but it wasn't alone—it was in orbit around some kind of companion object whose pulses he was also picking up. (Later, it was determined that this object was an equally heavy unseen companion pulsar just a few times as far away as the moon is from earth.)

Through a series of daily observations, Hulse soon found evidence that his idea was correct. This was indeed a binary system—with two stars rotating around a mutual axis. In great excitement, he contacted Taylor via shortwave radio back at the University in Amherst. Taylor took the next plane out, and the two researchers worked together to affirm and clarify their data.

By late September, word was out—a binary pulsar had been discovered! Scientists whose work is based on Einstein's general theory of relativity were delighted. Here was an ideal laboratory (albeit 16,000 light years from earth) for studying general relativistic effects. (A light year, the distance travelled by light in one year, is 5.9 trillion miles.)

Proving Einstein Right

It was within his general theory of relativity that Einstein first presented his new definition of gravity in 1915. Einstein theorized that gravity is caused by changes in space and time: the curvature of space-time increases with the size of nearby masses. Although his theory was considered aesthetically beautiful and probably correct, the weak

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Photo: Dietmar Krause

Delighted Nobel Prize winner Russell Hulse enjoys a slice of cake at a reception in his honor at the Lab on October 14. In a talk before the reception, Hulse described the discovery of the first binary pulsar.

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gravitational fields within our solar system made it difficult to test.

However, the discovery of the Hulse-Taylor binary pulsar system was to change all that. This particular binary pulsar has proven unique in its ability to exhibit strong relativistic effects along with ease of measurement using its precise pulsar clock—ideal for testing this theory.

One of Einstein's most dramatic predictions was that two objects *(such as the stars within a binary pulsar)* should lose energy as they give off gravitational radiation. Although their gravity waves cannot be measured directly with present technology, this loss of energy can be.

This binary system is gradually losing energy, so that the two stars rotate faster and faster around each other and at the same time draw closer together. The change, measured by Taylor, matches Einstein's theory within better than five percent accuracy.

Year after year, the data from the Hulse-Taylor binary pulsar has remained unerringly true to Einstein's predictions. Because of this, when making the Nobel Award to Hulse and Taylor, the Royal Swedish Academy of Sciences was able to state, with resounding confidence, that Einstein's theory has "passed the tests with flying colors."

Said Hulse, "This discovery is one illustration of how wonderful physics and science can be. I feel fortunate that I was in the position to experience that. Science works by proof, and I'm glad I was able to make a contribution to proving Einstein right."❖

*The story of the discovery of the first binary pulsar, summarized here, is described in entertaining detail in ***Was Einstein Right?*** by Clifford M. Will. The second edition, published in 1993 by Basic Books, is available through the PPPL Library.

Hulse Today

Computer Modeling CRADA Comes Through

Russell Hulse had other things on his agenda the morning the radio woke him with the announcement that he'd won the Nobel prize. At the time he was more concerned with preparing for the upcoming American Physical Society (APS) meeting and with the status of the CRADA (Cooperative Research and Development Agreement) proposal that he and Walter Stark had submitted to the Department of Energy.

Last year, Hulse was awarded a technology transfer personnel exchange grant for the project, titled Advanced Computer Modeling Environments. The CRADA proposal asked for continued funding for the project, whose purpose is to develop new approaches to scientific computing that encourage innovative work by enabling the creation of powerful yet easily modifiable computer codes. ***(See HOTLINE, November 13, 1992.)***

On the heels of the Nobel announcement, approval for the CRADA funding came through—$135,000 for each of the next three years. This funding means that Hulse and Stark can move full speed ahead with their work—in cooperation with Superconcurrency System Solutions (S3 Inc.), a small, high technology company involved in the development of advanced solutions for distributed heterogeneous supercomputing.

For Hulse, this project grew out of work he has been concentrating on since first joining PPPL—developing and applying computer codes for tokamak plasma transport modeling. One code he developed for modeling impurity transport has been titled MIST (Multiple Impurity Species Transport) and is used at fusion laboratories nationally and internationally. Another area of his work, about which he reported at this year's APS meeting, is modeling electron particle transport, particularly in pellet-fueled plasmas.

It is these codes that will be used as a testbed application environment for computer codes that will be encapsulated in modular chunks. These modules can then be plugged together to create modular, reconfigurable codes—increasing the ease of use for a wide variety of applications.

Getting from There to Here

Just how did Hulse get from mapping pulsars to developing reconfigurable computer codes? Said Hulse, "When I completed my postdoctoral work at the National Radio Astronomy Observatory, for various reasons, I decided to look into the field of plasma physics and fusion. Following up on a suggestion from a friend, I wrote a letter of inquiry to PPPL physicist Tom Stix. Fortunately, I soon found myself on board here at the Laboratory where I've been working on tokamak transport problems ever since."

Hulse describes himself as interested in many things. "I like to take the broad view, and I'm fascinated to know how the world works. That's why I became a scientist," he explains.

One common thread in Hulse's ability to move comfortably in a number of areas of science is his facility with computer codes. It was through his development of specialized computer programs that he was able to map pulsars and discover the Nobel-winning binary pulsar in 1974. And now, it's through work with computer modeling and code development that he's won the CRADA that will help keep him busy for the next three years.❖

Letters of Congratulation to Hulse

Among the many letters of congratulation that have been pouring in to the Laboratory addressed to Nobel Prize winner Russell Hulse are those from ***President of the United States, Bill Clinton; Secretary of the Department of Energy, Hazel O'Leary; Governor of New Jersey, Jim Florio; and Carl-Olof Jacobson, Secretary General of the Royal Swedish Academy of Science,*** *who invites Hulse to "receive your prize from the hands of His Majesty the King on December 10th."* ❖

KUNGLIGA
VETENSKAPSAKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

October 13, 1993
Secretary General
Professor Carl-Olof Jacobson/ks

Dr. Russell A. Hulse
Plasma Physics Laboratory
Princeton University
P.O. Box 451
Princeton, NJ 08543
USA

Dear Dr. Hulse,

Hereby I have the honour and pleasure to confirm in writing that the Royal Swedish Academy of Sciences has decided to award you and Professor Joseph H. Taylor, Jr. the Nobel Prize in Physics for 1993 for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation.

On behalf of the Academy I congratulate you warmly and hope that you will come to Stockholm to receive your Prize from the hands of His Majesty the King on December 10th.

According to the statutes of the Nobel Foundation, each Laureate is required to give a lecture within six months after the day the award was presented to him. The subject of the lecture should be on or associated with the work for which the Prize was awarded and will be published in "Les Prix Nobel". In accordance with tradition most Laureates give their lectures during the visit in Stockholm in December. This year the lectures in physics will take place at the Royal Swedish Academy of Sciences on December 8th at 10.00 a.m. Will you kindly let me know the title of your lecture at your earliest convenience, not later than October 31. It should last about 45 minutes. You may expect an audience of not only trained scientists, but of students and other interested persons as well. Please, let us know what kind of arrangements you need (slide projection etc.).

I hope to hear from you soon about your lecture and the invitations to reception and dinner and look forward to meeting you in Stockholm in December. The Office of the Nobel Foundation is responsible for the other arrangements during the Nobel week and will contact you directly to inform you of the program. All correspondence about these other arrangements should be directed to the Office of the Foundation.

Yours sincerely,
Carl-Olof Jacobson

cc: The Nobel Foundation.

STATE OF NEW JERSEY
OFFICE OF THE GOVERNOR
CN-001
TRENTON
08625

JIM FLORIO
GOVERNOR

October 14, 1993

Dear Dr. Hulse and Dr. Taylor:

Please accept my congratulations upon being named recipients of the 1993 Nobel Prize for Physics.

Your contributions to science are renowned and New Jersey is especially proud to have you as our own at Princeton University.

My very best wishes for a distinguished honor well deserved.

Very truly yours,

J. Florio

JIM FLORIO
Governor

THE WHITE HOUSE
WASHINGTON

October 20, 1993

Dr. Russell A. Hulse
Plasma Physics Laboratory
Princeton University
Post Office Box 451
Princeton, New Jersey 08543

Dear Dr. Hulse:

Congratulations on winning the 1993 Nobel Prize in Physics.

Your pioneering work with pulsars has deepened our understanding of the universe. Your findings greatly improve the world's knowledge of gravity and represent a major contribution to the fields of physics and astrophysics. This achievement is a great honor for you, as well as our nation.

I am proud to commend you for your extraordinary contribution, and I look forward to greeting you personally at the White House.

Sincerely,

Bill Clinton

The Secretary of Energy
Washington, DC 20585

October 15, 1993

Dr. Russell A. Hulse
Princeton Plasma Physics Laboratory
P.O. Box 451
Princeton, NJ 08543

Dear Dr. Hulse:

My heartiest congratulations on winning the Nobel Memorial Prize in Physics for 1993.

We are extremely proud that you are associated with the Department of Energy and the Princeton Plasma Physics Laboratory. While the Department cannot claim credit for directly supporting the specific work that won the prize, we value all the work you have done in plasma physics. We share the joy and pride you and your family feel.

A fellow physicist, Dan Kleppner, has characterized your prize-winning work as "patient scholarship." Our hearts, like those of your colleagues, are with you on this special occasion.

Sincerely,

Hazel R. O'Leary

PPPL Co-Hosts 15th Symposium on Fusion Engineering

Thanks to Lab Organizers

More than sixty PPPL engineers and physicists were among the approximately 500 people attending the Fifteenth Symposium on Fusion Engineering, held October 11 -15 in Hyannis, Cape Cod, Massachusetts. The Institute for Electric and Electronic Engineers' Nuclear and Plasma Science Society (IEEE/NPSS) organizes this biennial gathering. This year's meeting was co-hosted by PPPL and the Massachusetts Institute of Technology (MIT) Fusion Center.

Said Mike Williams, Head of the PPPL Engineering Department: "The hard work and dedication of the PPPL organizers and volunteers helped make this a most successful meeting."

Highlighting the PPPL contributions were Wayne Reiersen's plenary talk on: *The Engineering Design of TPX* and Mike Williams' plenary talk on TFTR: *Realizing the D-T Mission*. Williams was also awarded the Fusion Technology Award. *(See accompanying article on page 7.)*

Explained Phil Heitzenroeder, who coordinated the Princeton effort and is a member of the IEEE/NPSS Standing Committee on Fusion Technology, "The IEEE/NPSS Symposium is one of the most prominent meetings for fusion engineers and scientists from around the world to exchange information which is specifically fusion oriented. The Symposium is held biennially in various parts of the country with volunteers from the fusion community in that region serving as hosts."

PPPL Volunteer Contributions

Preparing for the IEEE Symposium was a big job for both PPPL and MIT. Site arrangements and overall logistics were handled by MIT's Conference Services, General Conference Chairman, Alberta Dawson, and Conference Secretary Barbara Keesler. PPPL was responsible for helping "to make it happen" through several important committees.

Photo: Dietmar Krause

PPPL Fusion Engineering Symposium organizers gather for a planning session. Standing, left to right, are: Ned Sauthoff, Don Knutson, Dori Barnes, Phil Heitzenroeder, and Norman Fromm. Seated are: Dolores Bergmann, John Spitzer, and Rosemarie Fuchs. Not pictured is Jeanne Salerno.

For example, the eye-catching red, white, and blue lighthouse posters were the brainstorm of the Publicity Committee, chaired by Dori Barnes and Steve Davis. Barnes, Davis, Paul Hagar, and Rosemarie Fuchs, together with the PPPL Print Shop and Mail Room, were responsible for the Call for Papers which was the real "kick off" of the 15th. Barnes and Fuchs also coordinated the preparation and review of PPPL's contributions.

Ned Sauthoff and John Spitzer put together a very interesting and imaginative program and worked many long hours in handling the myriad of details such as working with the IEEE Program Committee in sorting abstracts, arranging for the guest speakers, inviting session chairman, and processing all of the information required for the program book. For Sauthoff and Spitzer, much remains to be done. Presently they are gathering contributions from various Session Chairpersons and working with IEEE to publish a summary of the Symposium. Alex Nagy and Norm Fromm, who co-chair the Publications Committee, worked with IEEE to develop the publication guidelines

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IEEE Symposium

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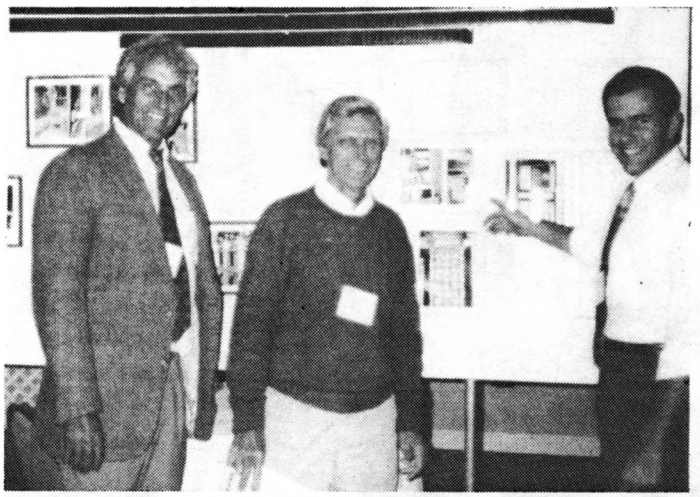
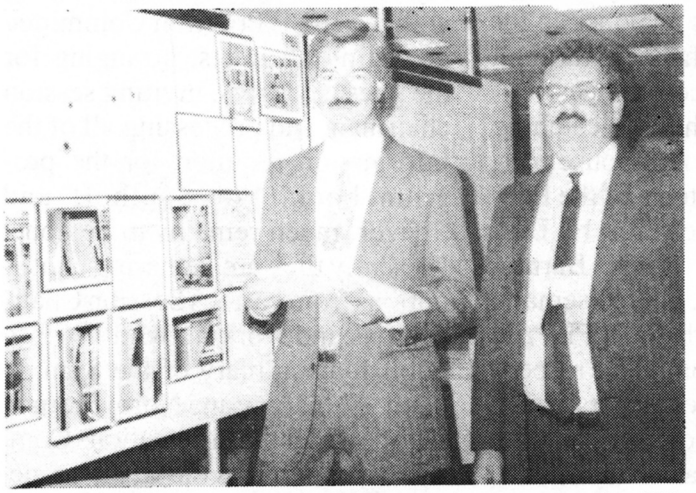
which, for the first time, permitted and highly encouraged "camera ready" papers, thus eliminating the former "blue line paste-ups" and simplifying paper preparation. However, their work is only now beginning. Having collected the papers in Hyannis, they now must do the final "detail" work, such as making sure that all of the papers are ready for printing, preparing the tables of content and index, and coordinating the actual printing of the Proceedings.



Bill Rausch (center) discusses their IEEE poster with George Barnes (left) and Dwight Bashore.

Other PPPLers worked hard to round out the Symposium agenda and to handle the details of Symposium operations. Said Phil Heitzenroeder, "Don Knutson and Holt Murray did a spectacular job, considering the soft economy, in selling all 24 industrial exhibit spots. The exhibitors brought attendees up to date on industrial offerings ranging from the latest in superconductivity to specialized engineering services."



Tim Senko (left) and John Spitzer review a poster by Mike McCarthy, Jim Faunce, Alan Janos, and Zhehui Wang, titled "TFTR Second Grating Polychromator Diagnostic."

At Hyannis, PPPLers joined with the MIT staff in providing "people services" which are so essential in making a large, complex undertaking such as this work smoothly. "Jeanne Salerno, Dolores Bergmann, and Rosemarie Fuchs worked with the MIT staff in manning the Registration, Information, and Publications booths with their customary efficiency and grace," noted Heitzenroeder.

Fun for Fusion Engineers

Dan Kungl and Don Knutson solicited contributions from nine industrial firms, which helped to fund the coffee breaks and social programs. An essential ingredient in the success of the Symposium, these informal settings were conductive to in-depth discussions and in formulating lasting personal and professional relationships.

Heeding the axiom about what "all work and no play" does to Symposium attendees, the planners also built in time for fun and recreation—from the thwack of hard-hit golf balls during the presymposium golf tournament to the oompahs of the German-style band at the Octoberfest gathering. Said Barnes, who organized the golf tournament, "By setting up teams that included people from different Labs and businesses we developed an atmosphere of collaboration for recreation that later carried over into collaboration for business purposes. This approach was very successful."❖

Thanks to Phil Heitzenroeder for major contributions to this article and to Dori Barnes and Rosemarie Fuchs for taking all the great photos.

Wearing bibs and feasting on lobsters are (left side of table) George Barnes and Dori Barnes. On the right side are (guest) Chris Smith, Mike Williams, and Stan Milora, who is from ORNL.

IEEE Symposium

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Those who ran the Publications Office at the IEEE Symposium were (left to right) Norm Fromm, Jeanne Salerno, and Alex Nagy.

Williams Receives Fusion Technology Award at IEEE

PPPL Engineering Head Michael D. Williams was honored with the Fusion Technology Award at the Fifteenth Symposium on Fusion Engineering, held October 11-15 in Hyannis, Cape Cod, Massachusetts. *(See accompanying article on page 5.)*

The Fusion Technology Award is presented bi-annually in recognition of outstanding leadership and technical contributions which are widely recognized and have a major impact on fusion energy technology.

"The award aptly recognizes Mike's distinguished leadership in the design and successful operation of neutral-beam-heating systems on the Poloidal Divertor Experiment (PDX) and the Tokamak Fusion Test Reactor (TFTR) at Princeton," noted PPPL Director Ron Davidson.

"The neutral-beam systems have enabled us to attain world record plasma temperatures and are essential to the achievement of record fusion power levels from TFTR during deuterium-tritium experiments. In addition, as Head of the PPPL Engineering Department, Mike has done an outstanding job managing the preparation of TFTR facilities for these historic experiments," Davidson continued.

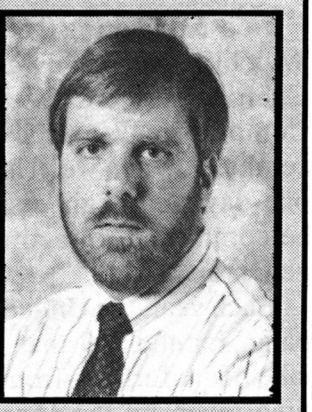


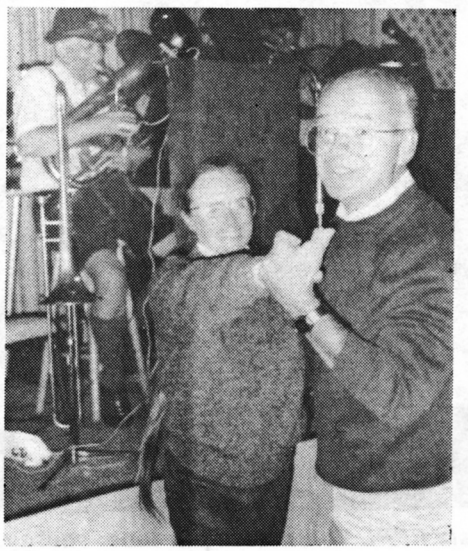
Photo: Dietmar Krause

Michael D. Williams

Mike Williams joined PPPL in 1976 as a design engineer for the PDX Project. In 1978 he was appointed Project Engineer for PDX neutral-beam-heating systems. He joined the TFTR Project in 1981 as Branch Head for neutral-beam-heating systems engineering. Williams was named Division Head of TFTR Heating Systems in 1988.

In addition to serving as Head of the PPPL Engineering Department, starting in 1991, he is presently Deputy Project Head of TFTR. Williams also has managerial responsibility for technology transfer at PPPL—an area of increasing national importance.❖

Golf tournament organizers Dave Schlatka of Stone & Webber, which sponsored the tournament, and Dori Barnes of PPPL were the only two-person team. Congratulations on tying for third place!



Marilee Thompson and husband Jim Bialek kick up their heels to the sounds of the OOMPAH band at the Octoberfest dance.

Head of the IEEE/NPSS Standing Committee Richard Callis of GA congratulates PPPL Engineering Head Mike Williams after presenting him with the Fusion Techology Award. Conference Chair Alberta Dawson of MIT, (seated) looks on.

United Way Campaign Plans Set

Gift Incentives Now Being Gathered!

"We're planning the best United Way blitz yet," said Scott Larson, Chair of this year's United Way Committee. "We hope that by December 9, when we'll have our big one-day campaign, everyone will be committed to record-breaking generosity!"

Each year, the United Way campaign reminds us that giving can take many forms—from the gift of time given by the Day of Caring volunteers *(see photo)*, to financial gifts, great and small. One of the ingenious ways PPPL supports giving, and at the same time adding a lighthearted side to our United Way campaign, is through gift incentives—to be offered as door prizes during the Campaign here.

Lab staff members have contributed some truly useful and intriguing gifts in the past, from hand-crafted handiwork and sculpture to free lessons in a sport or skill. Now's the time to brainstorm about what you could contribute!

Do you have a special skill or hobby you could share with someone? Could you provide a lesson or service in something you're skilled at? When you're out holiday shopping could you pick up an interesting, inexpensive gift to delight a fellow employee?

Says Mary Ann Brown, who heads the Incentives Committee, "Already several Lab employees have added their gifts to those given by local businesses. Those who would like to contribute can call me at 3045 or stop by my office, B354."❖

Errata

Thanks to Ellen Webster for taking the photographs of the Women's Breakfast shown in the last HOTLINE (Oct. 18, 1993); they were mistakenly attributed to Dietmar Krause.❖

For the United Way Day of Caring, six PPPL Volunteers put time, energy, enthusiasm, and elbow grease into cleaning up the University NOW Day Care Center grounds in Princeton on September 18. Thanks to Pat Terlitz, (who was working too hard to take time out for the photo), and to (left to right), Harry Mynick, Scott Parker, Jim Strachan, Dianne Nunes, and Hiro Takahashi for bringing the good will of the Lab into the community. Joining them in their work was Clement Nouko (far right) of the University NOW staff.