

PPPL NEWS

The Princeton Plasma Physics Laboratory is a United States Department of Energy Facility

New Stellarator Project Underway

An Interview with Hutch Neilson

On April 1, the National Compact Stellarator Experiment (NCSX) was officially granted Project status by the U.S. Department of Energy. A successful Conceptual Design Review, which focused on physics, was held in May, 2002. A Preliminary Design Review, which will examine engineering design, as well as cost and schedule issues, is scheduled for this October. Contracts have been awarded for the fabrication of prototype components to begin in January. The new machine will be built at PPPL's C-Site, with first plasma scheduled for June of 2007. Recently, *Hotline* staff interviewed NCSX Project Head Hutch Neilson to learn about this exciting new venture.

How did you first become interested in stellarators?

I became interested in stellarators in the early 1980's when I was at Oak Ridge National Laboratory (ORNL). We built a stellarator called the Advanced Toroidal Facility (ATF). I was responsible for preparing the ancillary systems, the

power supplies, diagnostics, plasma heating systems, and so on, and pulling everything together to achieve the first plasma milestone.

What interested me about stellarator physics was the three-dimensional structure of the magnetic field and the plasma shape. The cross-sectional shape of a 3-D plasma depends on where the torus is sliced, while the cross-sectional shape of a tokamak, a 2-D torus, is always the same. Consequently, stellarator physicists have three degrees of freedom to tailor the plasma shape for good performance. There are only two degrees of freedom in a tokamak.

I had worked on tokamak magnetic diagnostic data analysis. I became fascinated with the idea that stellarator coils could generate a spiraling magnetic field without the plasma current needed in a tokamak. I began trying to understand high pressure stellarator equilibria and how to infer their properties from magnetic data. It was a much more difficult task than I expected, and I didn't get very far. Today there is a national team, led by some of our best researchers, working on the 3-D magnetic data analysis problem. So I don't feel so bad about my lack of progress working on it part-time back in the 1980's.

Can you reflect on how it feels to return to a concept on which PPPL was founded?



Hutch Neilson

Continued on page 2

Stellarator

Continued from page 1

Lyman Spitzer believed that we would make a lot of progress in plasma physics and performance with tokamaks, but that the stellarator would make the better reactor because it is more straightforward to make it run steady-state. I think it is fitting that the Laboratory, after making historic advances with tokamaks, has turned to the task of expanding our understanding of toroidal configurations to find the best solution for magnetic fusion reactors. For instance, just as we are using the National Spherical Torus Experiment (NSTX) to push into new physics regimes, we will use NCSX to understand how to use 3-D fields and plasma shaping to optimize performance. We are encouraging and supporting other institutions that are tackling different aspects of this difficult challenge. It is a challenge that is worthy of PPPL's talents. This is what attracted me to join the Laboratory staff in the mid-1990's. But more importantly, I believe Professor Spitzer would approve and be proud of us for taking on these important problems.

What are the advantages of a stellarator compared to other magnetic confinement configurations?

The basic conditions for good magnetic confinement are a toroidal geometry and a magnetic field that twists around helically on magnetic surfaces. A stellarator can create those conditions with coils alone. It doesn't require a plasma current. That means it is easy to make a stellarator steady-state. Also, stellarator plasmas typically don't disrupt. These advantages result from the three-dimensional nature of the stellarator. Its coils and vacuum vessel have more complex shapes than those of tokamaks and this carries a cost. However, it also carries enormous opportunity for improved performance. As I noted earlier, a stellarator gives designers three degrees of freedom to tailor the plasma shape for good performance. We now have good enough physics models and computer power to do this, and this is

how modern stellarators, such as NCSX, are designed. With these experiments, we can test physics solutions that will lead to practical reactors. We can study 3-D physics effects that are important for all magnetic configurations, but should be much easier to see in a configuration that is itself 3-D. A goal of our research is to quantify both the benefits and the costs, giving the designers the information they need to optimize future devices.

Where are the major existing stellarators located?

Japan and Germany both have long histories of stellarator research and are the leaders in the field. Japan has a TFTR-scale superconducting stellarator, the Large Helical Device (LHD). The Germans are building a large superconducting stellarator, the Wendelstein 7-X, the next step in their stellarator line. This follows the recent closure of their W7-AS stellarator experiment in Garching after a successful run of almost 15 years. The W7-X is being built in Greifswald in the former East Germany. Spain, Australia, and the United States also have operating stellarators. Our new stellarators, the NCSX here and the Quasi Poloidal Stellarator (QPS) to be built at the Oak Ridge National Laboratory (ORNL), will not be among the world's largest, but they will develop physics ideas that will lead to more compact stellarator power plant designs. The U.S. compact stellarator designs have much lower aspect ratios than previous stellarators. They are closer to tokamaks in that respect. Moreover, they have strong physics ties to tokamaks, so they can take advantage of, and build on, all the progress we have made with tokamaks — nothing is thrown away.

How did the idea of a compact stellarator evolve? Will NCSX be the first compact stellarator in the world?

The seminal ideas originated with theorists, many of them at PPPL, who in the early 1980's explained how the confinement properties of a stellarator depended on the details of the

Continued on page 3

PPPL NEWS

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magnetic-field structure. By incorporating that understanding into computer codes, we have been able to design stellarator configurations to meet physics specifications. Those designs can then be built and tested to validate the physics models. The W7-AS and the University of Wisconsin's Helically Symmetric Experiment (HSX) are the first examples of this new approach. It is a dramatic departure from the cut-and-try approach to experiment design that we used to take. It came about because both our physics understanding and our design capabilities matured to the point where we can target the characteristics we want in our designs. That allows us to design better experiments that are more precisely targeted to the questions we want answered, to take larger steps, and consequently to make faster progress.

The compact stellarator strategy actually combines several ideas. One is magnetic quasi-symmetry, which means that even though the plasma shape is three-dimensional, the magnetic field has a symmetry direction, just as a tokamak or a spherical torus does. HSX is now testing this idea on a small scale, and it is working very well. As a quasi-axisymmetric stellarator, the NCSX has a strong physics overlap with the tokamak. In fact, a charged particle following a magnetic field line around in NCSX would think it was in a tokamak. That is, the charged-particle orbit confinement is the same as in a tokamak, so we believe that some of the tokamak's good performance features will carry over to NCSX. Unlike previous stellarator designs, the NCSX is optimized to be both quasi-axisymmetric and stable at finite pressure in a compact configuration. The result is a passively stable configuration that relies on the shape of the coils rather than active feedback and current drive to maintain a high-performance stable plasma. A fusion power reactor based on this approach would have power densities as high as a tokamak, but would operate with a higher overall efficiency, because it would not need to recycle any power to drive current and plasma rotation. It would have more complex coil geometries than a tokamak, but would be a simpler and more reliable system overall.

The QPS experiment proposed by ORNL is a smaller, higher-risk experiment designed to push stellarators to aspect ratios less than 3.0. Auburn University is building a small stellarator, the Compact Toroidal Hybrid (CTH), to explore plasma physics issues in support of NCSX. As you can see, NCSX is not an isolated experiment but part of a national program that includes theory and multiple experiments to develop the knowledge base needed to assess the attractiveness of the compact stellarator concept and decide on a major next step by 2011 or 2012.

What was the genesis of the National Compact Stellarator Experiment?

In 1996-1997, several working groups were formed at PPPL to come up with new initiatives for the Laboratory. There was one on stellarators looking at quasi-axisymmetric configurations. At the same time, other groups around the country, including the ORNL stellarator group, were also interested in modern optimized stellarators. A national program planning committee drafted a blueprint for a national stellarator proof-of-principle program, with NCSX as its central element, to develop the compact stellarator. In 1998 PPPL and ORNL formed a partnership to propose and carry out the NCSX project by pooling our talents in stellarator physics and engineering. A national advisory committee was formed about the same time and has guided the project ever since. The project has been debated in many forums and passed several major peer reviews, including a physics validation review in 2001 and a conceptual design review in 2002. The fabrication project was approved by DOE last fall and officially started on April 1.

What is the overall timeframe for the design, construction, and operation of NCSX?

This year we are continuing with the design and are starting R&D to determine exactly how the modular coils and vacuum vessel, the most challenging components, will be manufactured. We recently placed contracts with industry to develop the manufacturing processes and build prototypes for the winding forms and the vacuum vessel. We are developing the coil winding methods here at PPPL, and are planning to wind the NCSX coils at the former Tokamak Fusion Test Reactor test cell. Most of the machine subassembly also will be performed here. Next year we will start building the vacuum vessel and the 18 modular coils that will be the heart of the machine itself. We will start building the three field-period subassemblies in 2005. Each will consist of six coils and one-third of the vacuum vessel. Final assembly will begin in 2006, with first plasma scheduled for June of 2007. We expect NCSX to operate for about 10 years.

What are the roles of other U.S. fusion laboratories in the NCSX program? Which labs are involved? Foreign labs?

ORNL is our partner in the project. They have key leadership roles including responsibility for the design of the stellarator core itself. When the project moves into operation, ORNL will have significant responsibilities for management and

Continued on page 4

Continued from page 3

research. Other laboratories and universities, including foreign ones, will collaborate with us on NCSX research. Several have already expressed interest. It is too early to know exactly who will do what, but certainly diagnostics, divertors, plasma heating, and theoretical tools will be fruitful areas for collaboration.

Starting next year, we will hold a series of national research forums, like those so successful for NSTX, for open discussions of the NCSX research program with the larger community. The input from these meetings will help determine what tools are needed and will enable our potential collaborators to plan for participation in the program.

A program advisory committee composed of fusion physicists from several U.S. and foreign institutions has served the project very well through the planning and design phases. It includes experts in all branches of plasma physics, both stellarator and non-stellarator people. It will focus on research planning issues when we get closer to operation to help guide the research program.

Tell us about the site preparations that are now underway at PPPL and about the space that will be dedicated to NCSX and its support systems.

NCSX will be located in the former PLT/PBX-M test cells, and the NCSX control room will be constructed in the area once occupied by the PLT and PBX-M control rooms. So there will be a significant modernization and upgrade of the C-Site area of PPPL, which in the 1960's was the site of the Model-C Stellarator.

Currently, a crew led by PPPL's Erik Perry is orchestrating the removal and preparation of the PLT/PBX-M areas. The old control rooms have been cleared out. Power supplies have been disconnected from PBX-M, and a decommissioning contractor has purchased PBX-M for scrap. Four of the old PBX-M poloidal field coils will be shipped to our NCSX partner, ORNL, for use on QPS. We expect that the test cell will be cleared by August. In 2006, following their fabrication in the TFTR test cell, NCSX's three field-period subassemblies will be transported to C-Site, and assembly of the stellarator core will begin. ●



The group attending the NCSX Conceptual Design Review are, from left, Alex Pletzer, Art Grossman (UCSD), Don Monticello, Phil Heitzenroeder, Guoyong Fu, Mike Kalish, Ron Strykowski, Long-Poe Ku, Gary Oliaro, Ed Lazarus (ORNL), Jim Lyon (ORNL), Martha Redi, Jim Chrzanowski, Hutch Neilson, Jerry Levine, Greg Pitonak (DOE), Brad Nelson (ORNL), Judy Malsbury, Dave Johnson, Neil Pomphrey, Raki Ramakrishnan, Chuck Finfgeld (DOE), Bob Simmons, Allan Reiman, Wayne Reiersen, Harry Mynick, John Schmidt, Rob Goldston, Warren Marton (DOE), Mike Zarnstorff, Rich Hawryluk, and Irving Zatz.

The team members participating in the NCSX project are: (from PPPL) Bill Blanchard, Art Brooks, Tom Brown, Fred Dahlgren, Larry Dudek, H. M. Fan, Russ Feder, Eric Fredrickson, Guoyong Fu, Charlie Gentile, Geoff Gettelfinger, Rob Goldston, Pamela Hampton, Ron Hatcher, Rich Hawryluk, Phil Heitzenroeder, Stuart Hudson, Dave Johnson, Chang Jun, Mike Kalish, Long-Poe Ku, Henry Kugel, Doug Loesser, Jerry Levine, Frank Malinowski, Judy Malsbury, Dick Majeski, David Mikkelsen, Don Monticello, Lew Morris, Harry Mynick, Hutch Neilson, Gary Oliaro, Erik Perry, Alex Pletzer, Neil Pomphrey, Raki Ramakrishnan, Martha Redi, Wayne Reiersen, Allan Reiman, Joe Rushinski, Paul Rutherford, John Schmidt, Bob Simmons, Tim Stevenson, Brent Stratton, Ron Strykowski, Hiro Takahashi, Al von Halle, Mike Viola, Mike Williams, Mike Zarnstorff, Irving Zatz; (From ORNL) Bob Benson, Lee Berry, Mike Cole, Paul Goranson, Steve Hirshman, Ed Lazarus, Jim Lyon, Stan Milora, Peter Mioduszewski, Brad Nelson, Larry Owen, Don Spong, Dennis Strickler, David Williamson; (Others) Allen Boozer (Columbia U.), Alexander Georgiyevskiy (consultant), Art Grossman (UCSD), Dave Hill (LLNL). ●

Budding Young Scientists Exhibit Projects at PPPL



Area students, toting their winning science experiments, came to PPPL on April 25 for the Lab's annual Science Day Fair. The Science Fair honors the winners of PPPL's Corporate Awards, who were chosen among student exhibitors in March at the North Jersey Regional Science Fair at Raritan Valley Community College, and at the Greater Mercer Science and Engineering Fair at Rider University. The young scientists exhibited their work in the Lobby, which included topics such as the effect of temperature on the speed of light, creating static electricity, and robotic surveillance using appearance-based obstacle detection. Above, PPPL physicist Doug Darrow (left) talks to student exhibitor Meghan Kara McNulty about her project, "The Laser: Light, Optics, and Purity."



PPPL physicist and Nobel Laureate Russell Hulse (at right) hears about Cassandra Barone's project, "Bendhams Disks."

PPPL Hosts Area Students for Science Bowl



On March 1, PPPL hosted the U.S. Department of Energy's Regional Science Bowl competition that drew 29 teams from area high schools. At left, PPPL Deputy Director Rich Hawryluk (standing) serves as a science judge while two teams vie. At right, U.S. Congressman Rush Holt (far left) stands with the winning team, the Academy for the Advancement of Science and Technology in Bergen County.

Awards

DeLooper Honored for Outreach



John DeLooper, Associate Director of External Affairs at PPPL, recently received the Department of Energy Distinguished Associate Award. DeLooper was honored for his “valuable coordination of countless education outreach activities and special events.”

In particular, DeLooper was cited for his efforts in coordinating the Snowmass Fusion Summer Study Workshops, which took place in Snowmass, Colorado, in 2002 and 1999. At the most recent, about 300 leading scientists from the U.S. and international fusion community attended the two-week forum that assessed the major next steps in fusion energy science research.

Above, N. Anne Davies, DOE’s Associate Director of Science for Fusion Energy Sciences, presents the award to DeLooper during a March DOE meeting in Maryland. ●

Ritter Awarded

On June 26, PPPL’s Chris Ritter received a Service Award as President and Trustee of the Education Fund of Trenton, Inc., from the Trenton School District. The Education Fund is a non-profit corporation whose mission is to enhance the quality of educational programs in the Trenton Public Schools. ●

Simmons Named Engineering Fellow

In recognition of his exceptional engineering achievements and contributions to the engineering profession, PPPL’s Robert Simmons was recently elected a Fellow of the American Society of Mechanical Engineers (ASME) International.

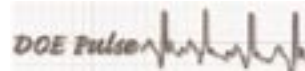
Simmons, the Systems Engineering Support Manager at PPPL for the National Compact Stellarator Experiment



Robert Simmons

(NCSX), joined the Laboratory’s staff in 1989 as a project control manager. He has been actively involved in the operation and management of complex engineering projects and the development and implementation of project management systems for more than 35 years.

Simmons received a bachelor’s degree from the Naval Academy in 1966 and a master’s in business administration from Ohio State University in 1975. Before coming to PPPL, he worked in private industry as a project manager for nuclear power plant services and served nine years on U.S. Navy nuclear submarines in various capacities, including as a supply officer, operations officer, and navigator. He retired from the Navy as a reserve captain in 1991. Last year, Simmons received the first ASME Engineering and Technology Leadership Award, which has been named the Robert T. Simmons Leadership Award in his honor. ●



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Local Officials Have Breakfast with Lab Director



PPPPL Director Rob Goldston hosted a breakfast briefing for local government and school officials on June 27. Sixteen state, county, municipal, and school representatives from the area attended. Goldston gave a talk about fusion and PPPL Deputy Director Rich Hawryluk guided a tour of some of the Lab's experimental areas. At top, Goldston (standing) gives the presentation. At right, Hawryluk (far left) leads a tour of the National Spherical Torus Experiment (NSTX). ●



Summer Students Abound at PPPL



Students from around the nation are at PPPL this summer — many to assist in the development of fusion energy — to conduct research and develop science curricula. The students are here through the National Undergraduate Fellowship Program (NUF), Science Undergraduate Laboratory Internships (SULI), and Pre-service Teachers (PST) programs. All programs are funded by the U.S. Department of Energy (DOE).

The NUF program in Plasma Physics and Fusion Energy Sciences, administered by PPPL staff, provides a summer research experience to outstanding junior undergraduates at laboratories and universities nationwide. Twenty students were selected this year to conduct research in the disciplines that comprise the plasma sciences, in general, and fusion research, in particular. This year, six of the NUF students work with mentors at PPPL, while the remaining 14 students conduct their research at other laboratories.

Through SULI, college students are placed in paid internships in science and engineering at any of several DOE facilities, with students working with scientists or engineers on projects related to the laboratories' research programs. Seven SULI students chose PPPL to do their research this summer.

Two students, one an undergraduate and the other a graduate student, are at PPPL this summer to develop science curricula through the PST program. The students are dedicated to teaching in the sciences. ●



At top, outside PPPL's Lyman Spitzer Building, are many of this year's summer students. Above, PST participant Riley O'Brien works at PPPL on her summer project, which includes writing a curriculum module with improved methods for teaching science. The module is for elementary and secondary teachers. O'Brien is also in the middle of the group picture.