PPPL
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HOTLINE

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TPX Design Gets High Marks

The Tokamak Physics Experiment (TPX) has come through the Conceptual Design Review (CDR) with flying colors. During four days of intensive work at PPPL March 29 to April 1, a review committee of 32 deliberated over every aspect of the Conceptual Design. Also present were 16 Department of Energy (DOE) observers.

Ron Davidson, PPPL Director, commented, "Developing the conceptual design of TPX has been an extraordinary national effort involving engineers and scientists from several institutions. The TPX team and project management are to be commended for an outstanding job."

Jeffrey Hoy, TPX Program Manager, Office of Fusion Energy, in the DOE Office of Energy Research, was very pleased with the CDR. He said, "We were quite impressed with the work of the TPX team. Reviewers provided excellent feedback to the team and in general were very supportive. In addition, when CDR Committee Chairman James D. Callen gave his briefing on TPX to FEAC (Fusion Energy Advisory Committee for DOE) on April 16, it was well received."

Commented TPX Program Director Keith Thomassen, "I think you could say we got at least an A, and some of us would like to think we got an A+."

Rob Goldston, Chief Scientist for TPX said, "We are pleased that we were able to communicate both the importance of the mission of TPX and also the quality of design work that has been done on the project."

Photo: Denise Applewhite

The TPX organization (see organization chart on page 8) includes (front row, left to right): Keith I. Thomassen, Program Director, LLNL; Wayne Reiersen, Deputy Project Engineer, PPPL; James C. Sinnis, Project Engineer, PPPL; and Robert J. Goldston, Chief Scientist. Second row, left to right, includes: Robert T. Simmons, Project Control Manager, PPPL; John A. Schmidt, Project Director, PPPL; George "Hutch" Neilson, Deputy Project Director and Physics Manager, ORNL; and William M. Nevins, Deputy Physics Manager, LLNL. Not shown are PPPL Director Ronald C. Davidson and Senior Engineer D. Bruce Montgomery, MIT.

The Conceptual Design Review is not only a DOE checkpoint, but also provides important input to the design process from experienced fusion physicists and engineers, according to TPX Project Engineer Jim Sinnis. Said Sinnis, "The CDR served both these purposes very well. DOE will soon have a review committee report that will allow us to proceed with the project. We will use this report as valuable input to the next phase of the design process."

CDR Committee Findings

The CDR committee included fusion experts from the United States, Japan, Russia, France, Great Britain, and Germany. During the wrap-up meeting, N. Anne Davies, Associate Director, Office of Fusion Energy in the DOE Office of Energy Research, described the accomplishments of the TPX team as "an amazing effort," referring to the fact that the project went from selection of concept to CDR in just one year.

In their general findings, the review committee remarked that, "This is truly a national magnetic fusion project. TPX is an excellent vehicle for developing advanced tokamak concepts, which together with burning plasma results from the International Thermonuclear Experimental Reactor (ITER), should lead to a compact, efficient DEMO and fusion reactor."

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TPX High Marks

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They also noted that the TPX project "has done a remarkable job in a short time and approximately fits the $500 million cost envelope." Both physics and engineering were found to be sound, although there were of course some adjustments recommended. Reviewers indicated that the Total Project Cost estimate was very accurate, suggesting an increase of only three percent. The project was commended for developing a design that should meet the goals of the TPX mission within the cost ceiling.

The physics subcommittee reported that it found "the physics objectives to be important for fusion research and that the global parameters of the device allow these advanced physics regimes to be explored."

The physics subcommittee report also noted that the unique contributions the TPX will be able to make relate to "its ability to explore conventional as well as advanced tokamak regimes in long-pulses and steady-state discharges. High-aspect-ratio physics, controllability of steady-state plasmas, and particle handling comprise other unique features."

Engineering efforts also received high marks. In his summary remarks, Callen reported that the TPX "engineering conceptual design is sound and should be able to achieve its engineering performance objectives after some project adjustments."

The Environment, Safety and Health (ES&H) subcommittee found the ES&H foundation of the TPX project to be sound, and reported that "TPX has done an appropriate level of ES&H planning for a project at this stage."❖

Photo: Denise Applewhite

Conceptual Design Review Committee (with asterisk)—US Department of Energy Observers (no asterisk).

First Row: Stanley Staten, US DOE*; William Cooper, LBL*; Heinrich Boenig, LANL*; James Callen, U of WI*, CDR Committee Chairman; Jeffrey Hoy, US DOE/OFE*; Alexander Kostenko, Efremov Institute*; Victor Karpenko, consultant*; Ian Hutchinson, MIT*; Jean Jacquinot, JET*.

Second Row: Sylvester Sims, US DOE*; Philip Thompson, ORNL*; Peter Ritzcovan, US DOE*; Michiya Shimada, JAERI*; Alan Rolfe, JET*; Clarence Hickey, DOE; Robert Wunderlich, US DOE/Chicago*; Stephen Eckstrand, US DOE/OFE*; Jeffrey Freidberg, MIT*; (not identified).

Third Row: Anthony Chargin, LLNL*; Kristine Forsberg, US DOE*; F. Loray Schwartz, US DOE*; Robert McGrath, Sandia National Laboratory*; Osamu Motojima, National Institute for Fusion Science*; David Clark, US DOE/PAO*; K. Jay Jayakumar, SSC Laboratory*; Antoine Torossian, CEA-Cadarache*; Matthew Moffitt, TPX Project Engineer/PAO; (not identified).

Fourth Row: Daniel Lehman, US DOE*; (not identified); Ronald McKnight, US DOE/APT; Edward Koch, DOE Office of Procurement & Project Assistance; Farrokh Najmabadi, UCLA*; John Willis, Director, Division of Confinement Systems, OFE; Milton Johnson, Area Manager, Princeton Area Office; Gregory Pitonek, TPX Project Manager, PAO; Ado Adami, US DOE*; Kenneth Gentle, U of Texas*.

CDR Committee Members not pictured: Hans Conrads, Universität Greifswald; Vyacheslav Strelkov, Kurchatov Institute.

TPX High Marks

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Photo: Denise Applewhite

Through the efforts of (left to right) Lance Korbner, Gail Marshall, Sallie Young, and Janet Hergenhan, over 400,000 pages of documentation were compiled for the TPX Conceptual Design Review. Thanks for assistance and support during the meeting were forthcoming both from the TPX team and from Jeffrey Hoy, TPX Program Director in the Office of Fusion Energy.

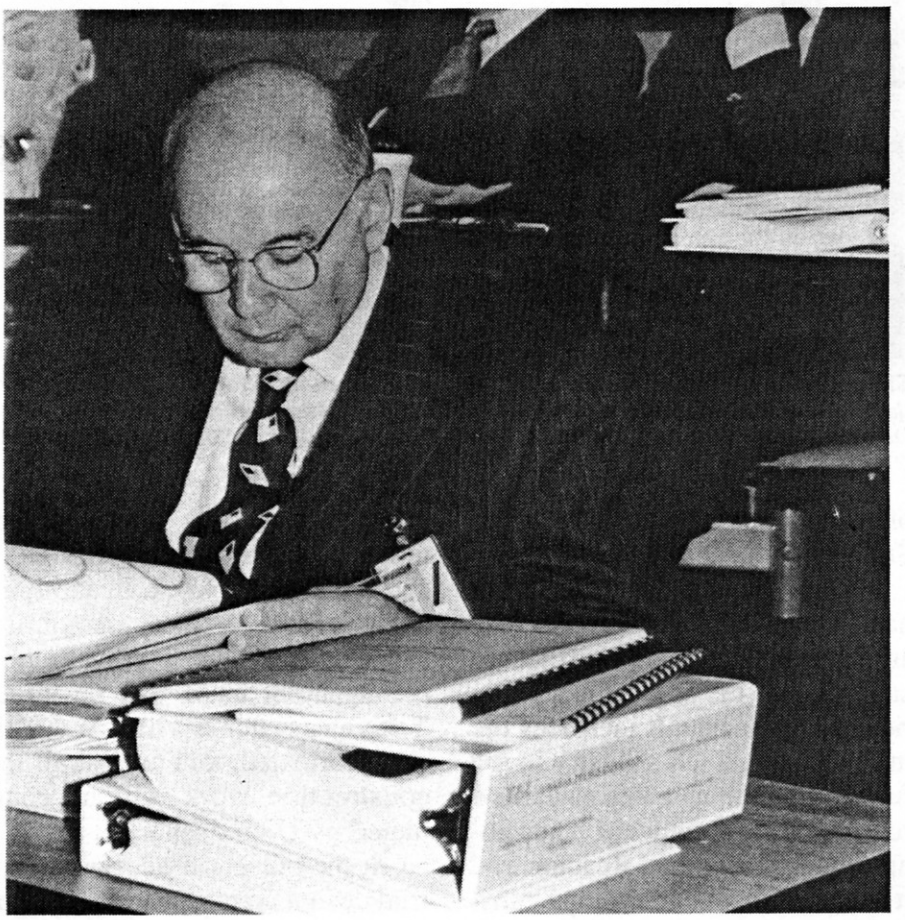

Photo: Denise Applewhite

CDR Committee member Antoine Torossian, CEA-Cadarache, pores over the mountain of documentation reproduced by the Laboratory's Duplication Center for the TPX Conceptual Design Review.

A National Project

Among the findings of the Conceptual Design Review Committee is the point that "TPX is truly a national magnetic fusion project." Noted TPX Program Director Keith Thomassen of Lawrence Livermore National Laboratory (LLNL), "The word *truly* is the key word in this statement. For TPX, several laboratories, universities, and industry all play a major ongoing role."

Explained Thomassen, "While TPX will be built at PPPL using the Test Cell that presently houses TFTR, the project is using a 'teaming model' that includes a national project team, multi-institutional research, and major roles for industry. For example, LLNL, Oak Ridge National Laboratory (ORNL), and PPPL will be responsible for having major subsystems built by industry."

Focusing on the contributions of the Laboratory, Director Ron Davidson said, "PPPL can take great pride in both its technical contributions to the TPX design and the leadership role it has played in coordinating this national activity."

Advantages

The national character of the project is crucial to maintaining US national strength in fusion research in an era when most tokamaks across the country have completed their missions.

The national approach has several advantages. Thomassen emphasizes the importance of drawing on the resources of team members' home institutions and encouraging ownership by all Labs that are collaborators or contributing central team members.

Thomassen notes that "Because the project is nationally based, we

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National TPX

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can draw on the best expertise from around the nation. Theory and experimental groups across the country, for example, will be able to make contributions without necessarily leaving their institutions or devoting themselves full time to TPX."

Says Chief Scientist Rob Goldston, "TPX is designed to be a magnet for activities of all the fusion groups around the country. Not only is this approach practical during a period when fusion funding is limited, but also working with people from other institutions is exciting and enjoyable. PPPL staff are mixed together with scientists and engineers who bring with them new ideas and new institutional resources."

Budget Reflects National Character of TPX Project

TPX FY94 funding is $20 million, according to the Clinton administration budget. Budget distribution reflects the fact that the TPX machine itself will be built by a consortium of national laboratories working with industry. For example, this money will be divided among PPPL, LLNL, ORNL, MIT, Argonne National Laboratory (ANL), and Los Alamos National Laboratory (LANL) and four universities—Columbia, Illinois, UCLA, and Wisconsin.

Major Role of Industry

Design responsibilities have been assigned to fusion laboratories based on their existing technical strengths. However, approximately 76 percent of TPX funding will actually be spent by the industries with which they work. For this reason, much attention has already been given to the logistics of the industrial role, including a review of the plan by the DOE Business Strategy group.

Major industrial involvement has several advantages. For example, it allows the TPX project to capitalize on the past project experience of industry. It increases the involvement of US industry in the fusion program as a step towards a role in the International Thermonuclear Experimental Reactor, and it enhances fusion technology transfer.

Therefore, several important roles will be played by industry. For example, they will complete much of the tokamak preliminary and final design work. In addition, an industrial systems integration support team and a construction management team will be hired. Tokamak systems will be industrially fabricated, and almost all the construction work will be completed by US industry.

At the present time, two industrial design teams, headed by General Atomics and Ebasco, are part of the conceptual design team. The

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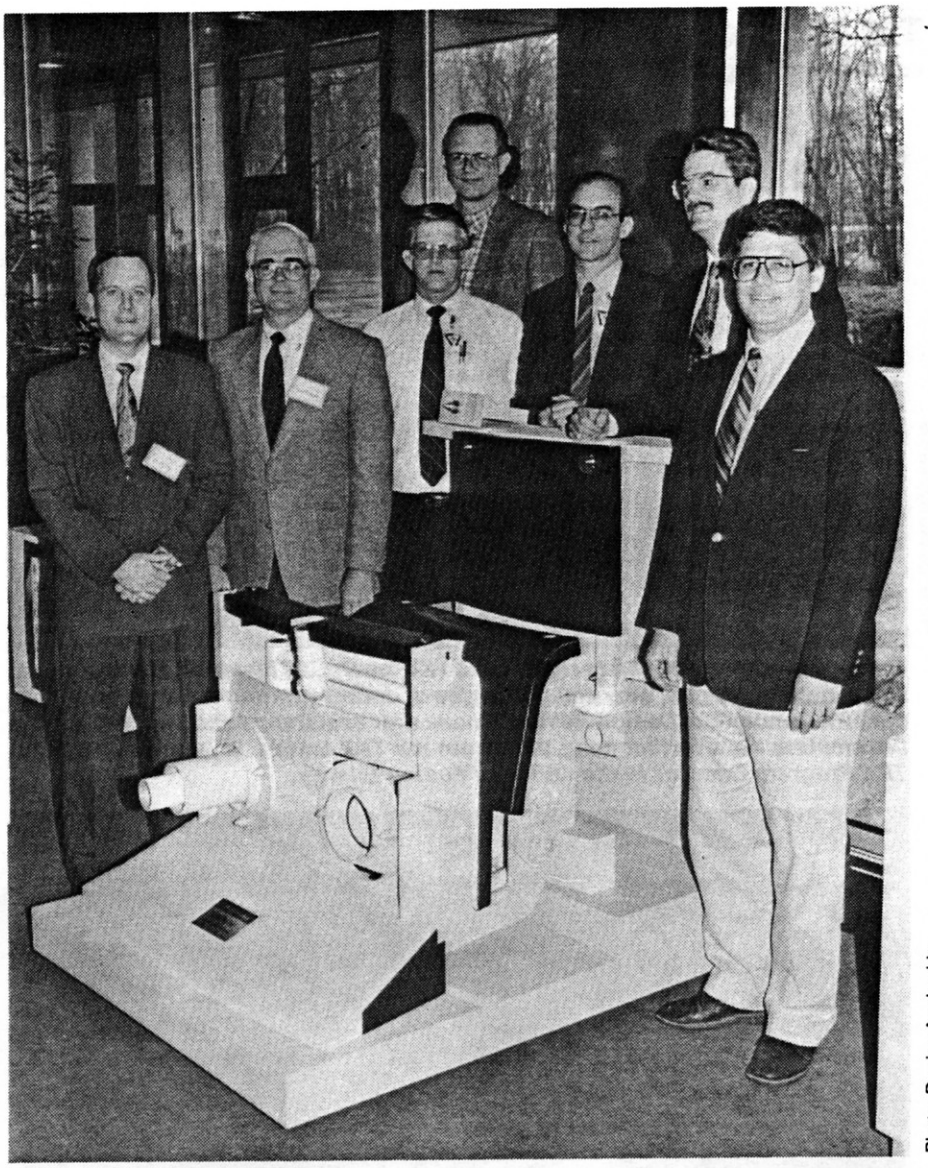

Photo: Denise Applewhite

Shown is a full-size mock-up of a 1/16th segment of the TPX divertor. With it are design team members (left to right): John Haines and Harold Mantz, McDonnell Douglas; Paul Anderson, GA; Alan Hyatt (behind Anderson), LLNL; Leigh Sevier, GA; Mike Ulrickson, PPPL; and David Hill, GA.

National TPX

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General Atomics team includes McDonnell Douglas and is responsible for the plasma facing components. The Ebasco team includes Rockwell International and McDonnell Douglas and is responsible for the vacuum vessel system. These contracts will be re-bid for preliminary design and beyond, along with the magnet systems, systems integration, and construction management contracts.

In addition, General Dynamics, Westinghouse, and Grumman were asked to evaluate project design work on the superconducting magnets and the support structure in regard to their feasibility, manufacturability, and cost.

New contracts for preliminary and final design will be developed this year to replace the conceptual design contracts.

Outreach and Communications

TPX Physics Manager George (Hutch) Neilson of ORNL has moved to Princeton to be more directly available for the project, yet he still maintains strong ties with Oak Ridge—so he is particularly sensitive to the ongoing need for good communications.

Says Neilson, "We're very fortunate to have senior physicists and specialists of many kinds working together to make TPX a success. For this national team to work well together, we must continue to promote a sense of ownership and to develop effective methods of communication."

According to Neilson, to bring the fusion community up to speed on TPX, an outreach program has been under way. It has consisted of a series of TPX briefings that have been given to senior science and policy advisors, and seminars that have been held at major fusion centers and within industry.

These briefings and seminars are two examples of the many communications approaches being employed to counter the tendency of a national project to be too diffuse. In addition, teleconferences, electronic mail, and fax machines make the national approach much more feasible than in the past.

Another aspect of communication for the TPX project concerns systems integration. During design, manufacture, and construction, the role of systems integration will be crucial, because, as Thomassen observes, "All parts must fit together like a fine-tuned Swiss watch." Therefore, much attention is being given to developing effective systems integration approaches.

The *TPX Press* newsletter, first published this February, is designed to keep everyone current on what's happening and will be available to the entire national fusion community. Copies are available through Tony De Meo at PPPL's Information Services Office (B380).❖

Photo: Denise Applewhite

Enjoying a light moment during the January International Workshop on Steady-State Tokamaks are, left to right: George "Hutch" Neilson, John Schmidt, Keith Thomassen, Rob Goldston, Jeff Hoy, DOE Program Manager for TPX, Gerald Navratil of Columbia University, and Milt Johnson, Manager of the DOE Princeton Area Office. The workshop, held at PPPL, included 105 fusion experts from the US, Japan, Russia, France, the United Kingdom, Germany, and Italy and was called to encourage a working-level exchange of ideas on next-generation steady-state tokamaks.

HOTLINE

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The TPX Mission

The mission of TPX is *to develop the scientific basis for a compact and continuously operating tokamak fusion reactor*. This mission must be seen in context with the current U.S. magnetic fusion strategy and the international fusion program. As shown in the flow chart, several essential parallel tasks in fusion power development are in progress with the ultimate goal of a demonstration power reactor (DEMO.)

One major task is to push the frontiers of high performance and to explore deuterium-tritium (D-T) operation in tokamaks. TFTR, JET, and JT-60U are presently pursuing these goals with the International Thermonuclear Reactor (ITER) in the planning stages.

Another crucial task is the development of programs and facilities to carry out nuclear engineering and materials aspects of the program.

At the same time, tokamaks such as PBX-M at PPPL, and other smaller-scale machines including stellarators are pursuing "concept improvement."

It is to advance this work that TPX is planned. TPX would be the first new major US fusion research facility built since the present generation of tokamaks, which were designed in the mid-1970s.

Program Director Keith Thomassen explained why product improvements are needed, saying, "Because tokamaks are now so large, and projected to be expensive as reactors, the public isn't convinced we have a feasible product. They have seen how large fission reactor projects have threatened to bankrupt utility companies, so they're highly suspicious of big nuclear complexes. Therefore, one of our goals for product improvement is to show with TPX that we can run tokamaks in ways that will allow for smaller and less expensive fusion reactors."

Mission Statement

The mission of the Tokamak Physics Experiment (TPX) is to develop the scientific basis for a compact and continuously operating tokamak fusion reactor.

Supporting objectives are to:

- **Optimize plasma performance through active control of the current profile and of plasma-wall interactions, and by advanced plasma shaping—leading to a compact tokamak fusion reactor.**
- **Achieve this optimization using techniques for non-inductive current drive and profile control that are consistent with efficient continuous operation of a tokamak fusion reactor.**
- **Demonstrate the integration of optimized plasma performance and efficient continuous operation in fully steady-state plasmas.**

Scientific Goals

Explains TPX Chief Scientist Rob Goldston, "The mission of TPX is to develop advanced operating regimes with higher confinement and plasma pressure, that will permit a more compact or lower-field tokamak reactor. At the same time, the TPX operating regimes will incorporate steady-state, noninductive current drive."

Goldston notes that these two fundamental aspects of the mission are highly complementary, in that recent results from TFTR and DIII-D (at General Atomics) show current profile control to be key to achieving higher plasma performance—and current profile control is a natural feature of the multiple current-drive schemes planned for testing on TPX. At the same time, the high self-generated bootstrap current that will be available at high plasma pressure in TPX makes the current drive problem much more tractable.

"Thus," says Goldston, "the key scientific goal of TPX is to improve the efficiency of the tokamak by improving its plasma physics performance. Both higher confinement and higher plasma pressure limits are needed to allow tokamak reactors with less daunting engineering parameters than a machine like ITER—which has a major radius of eight meters and a plasma current of 25 million amperes. A high fraction of self-generated bootstrap current will allow efficient, fully continuous operation."

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Mission

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Observes Goldston, "Some of the most exciting new results presented at the TPX CDR were theoretical calculations by the TPX Advanced Plasma Configurations group, headed by Steve Jardin, which showed stable equilibria for TPX with very high plasma pressure, potentially very good confinement, and nearly full bootstrap current drive."

Goldston points out that in addition to the scientific goal of TPX, the project will also push forward capabilities of US industry in a number of areas of fusion technology. Among these are: large superconducting coils, cryogenic systems, steady-state plasma-facing components, low activation materials, and remote maintenance equipment.

"It is worth noting that while the TPX is focused on improving the tokamak concept in parallel with activities on ITER, the TPX will also be a flexible test-bed for new concepts in divertors, current drive, and disruption control," observes Goldston.

"Once successful new concepts have been qualified in high-performance steady-state plasmas on TPX, they can be transferred to ITER. Similarly, the technology development of TPX will strengthen the ability of US industry to contribute to ITER design and construction," Goldston concludes.❖

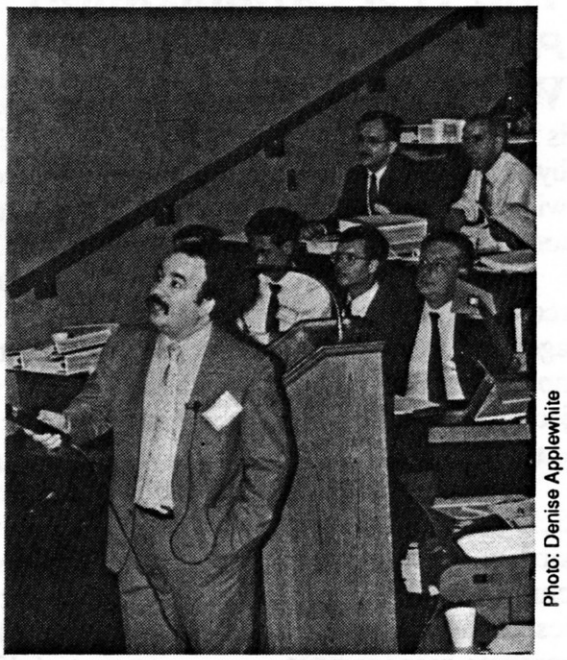
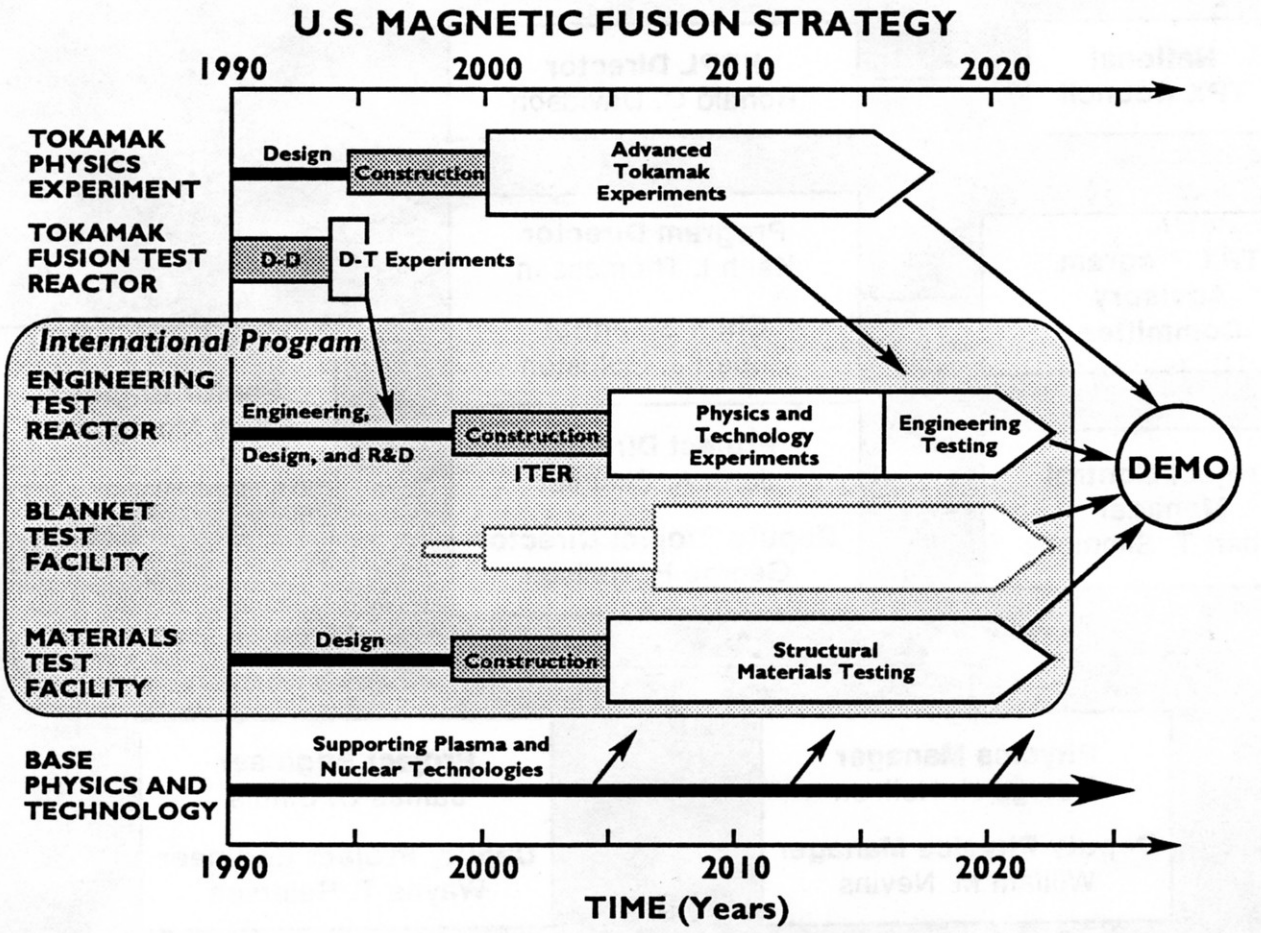


Photo: Denise Applewhite

Rob Goldston points out details of the physics basis for the TPX design to the CDR Committee.



Several parallel and essential paths of research and development are being pursued in the international fusion program with the goal of a demonstration power reactor demo by the year 2025.

The TPX Organization

PPPL is Lead Lab

While the scope of the TPX project is national, PPPL is lead laboratory by virtue of the fact that the machine will be located here. As PPPL Director, Ron Davidson heads the project.

In his role as TPX Program Director, Keith Thomassen has management responsibility for developing the mission, the technical objectives, and the program requirements of TPX.

TPX Project Director John Schmidt has management responsibility for project execution, including engineering design, physics and engineering interface, and resource management.

As TPX Chief Scientist, Rob Goldston is a senior advisor on scientific issues and participates in technical and management decisions related to the mission, objectives, physics requirements, and design.

D. Bruce Montgomery, as Senior Engineer, advises both the TPX Program Director and the TPX Project Director on engineering matters.

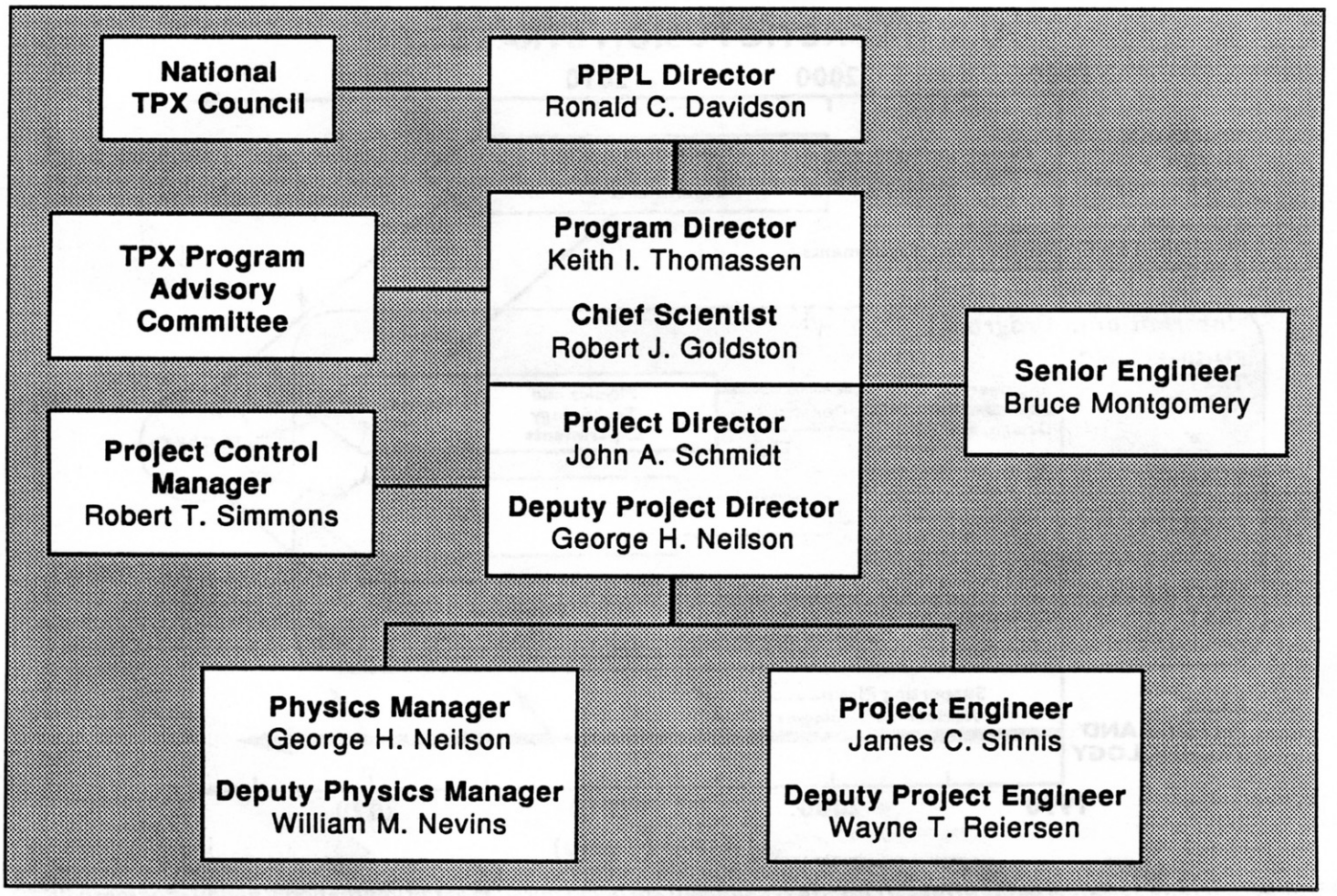
Deputy Project Director George "Hutch" Neilson is also the Physics Manager and is responsible for the development of the physics design requirements and analysis activities in support of TPX design and construction. Deputy Physics Manager Bill Nevins works with Neilson to fulfill these responsibilities.

Project Engineer Jim Sinnis is responsible for developing the engineering design of TPX with support from Deputy Project Engineer Wayne Reiersen.

Project Control Manager Bob Simmons and his organization are responsible for project control and administrative functions in support of the TPX project.

Environment, Safety, and Health (ES&H) functions are central to the TPX Project, with the PPPL ES&H Office providing support to the WBS (work breakdown structure) Managers and acting as ultimate authority on ES&H matters.

The Quality Assurance and Reliability Program for TPX is handled through a representative from the PPPL Quality Assurance office.❖



The TPX Organization Chart.

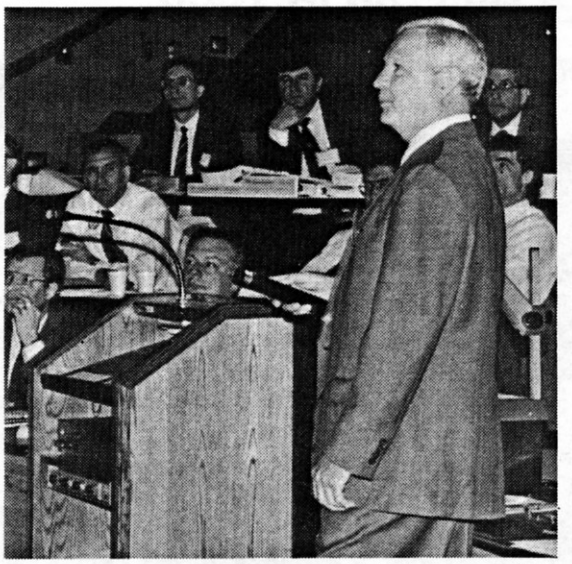


Photo: Denise Applewhite

Keith Thomassen describes the TPX mission and its role within the larger fusion program to the CDR Committee.

Introducing Keith Thomassen

TPX Program Director Keith Thomassen of LLNL has been involved in the project since its inception and has a strong commitment to its realization. Says Thomassen "I believe that developing the data base for advanced fusion reactors is one of the most important tasks in the fusion program at this time."

Thomassen led the joint LLNL-PPPL-MIT "advocate group" for the Steady-State Advanced Tokamak (SSAT), one of several alternative projects proposed to the National Task Force headed by John Sheffield of ORNL after the Burning Plasma Experiment (BPX) was cancelled. When the SSAT was chosen, it was renamed the TPX.

Thomassen's education and career have focused on fusion energy research and development. Before accepting the TPX position, Thomassen headed the LLNL magnetic fusion program. He is the Principle Deputy to David Baldwin, who heads Energy Programs at LLNL, and is also a professor in residence at the University of California at Berkeley.

Thomassen received his Ph.D. in Plasma Physics from Stanford University in 1962 and then spent a year doing post doctoral fusion research in Paris, France, at the Saclay Center for Nuclear Studies.

Back at Stanford, Thomassen spent the next four years in teaching and research. From 1968 to 1973 he was an Associate Professor of Electrical Engineering at MIT. Continuing his research and teaching in plasma physics, he authored the textbook *Introduction to Microwave Fields* and Circuits. He next served as the Head of Magnetic Fusion Technology and Development Programs at Los Alamos National Laboratory.

In 1977, Thomassen joined LLNL as the Program Leader for of MFTF-B (Mirror Fusion Test Facility)—a facility with superconducting magnets storing as much energy as the TPX magnets are designed to store.

Thomassen brought the Alcator-C tokamak to LLNL from MIT in 1987 for FEL (free-electron laser) experiments and led the program on the renamed facility, MTX (Microwave Tokamak Experiment), which completed its mission last October.

In summarizing the contributions TPX can make, Thomassen said, "This project is not only critical for the fusion program at this time, serving to improve the outlook for fusion reactors, but is also critical in that we are making an important transition to nationalized facilities and programs. We must learn to cooperate, communicate, and mutually support such activities. If we do, I'm certain that we will bring to bear the best talent the US has to offer in making fusion a success."

Advisory Committees

Two advisory committees provide broad fusion community participation in TPX.

TPX National Council

The TPX National Council reports to the Director of PPPL.

Members:

Stewart Prager, University of Wisconsin (Chair)
David Baldwin, LLNL
John Dawson, UCLA
Ronald Davidson, PPPL (ex-officio)
Stephen Dean, Fusion Power Associates
Gerald Navratil, Columbia University
Miklos Porkolab, MIT
Paul Rutherford, PPPL
John Sheffield, ORNL
Richard Siemon, LANL

TPX Program Advisory Committee

The TPX Program Advisory Committee advises the TPX Program Director on physics-related matters pertaining to the TPX program.

Charter Members:

Gerald Navratil, Columbia University, Chair
Steven Allen, LLNL
Daniel D'Ippolito, Lodestar Research
James Drake, University of Maryland
Raymond Fonk, University of Wisconsin
Bruce Lipschultz, MIT
Tak Kuen Mau, UCLA
Masanori Murakami, ORNL
George "Hutch" Neilson, TPX (ex-officio)
Kurt Schoenberg, LANL
Tony Taylor, GA
Alan Todd, Grumman
James Van Dam, University of Texas at Austin
Michael Zarnstorff, PPPL

TPX Schedule Calls for First Plasma in 1999

"The TPX schedule is ambitious but attainable based on past experience with fusion machines," according to the CDR Committee's judgement.

An integrated schedule including over 2000 activities has been developed for project planning and control, according to John Schmidt, Project Director. Says Schmidt, "Given the yearly funding profile requested by the TPX project, a completion date of 1999 could be expected. (See TPX Milestones chart.)

"However," notes Schmidt, "Clinton administration guidelines for fusion funding during the period 1994-98 fall somewhat short of the funding needs of TPX during this period. Efforts are underway to increase those funding guidelines. Otherwise, the funding shortfall could delay plasma operation by at least one year."

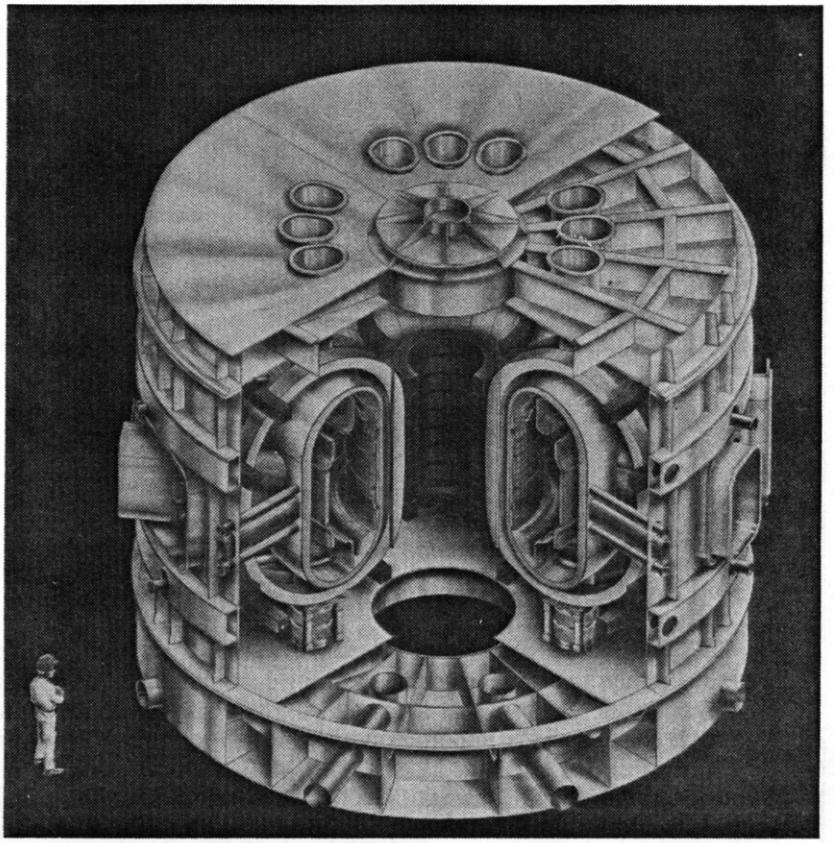
The $20 million in funding for TPX is a visible element in the Administration budget for fiscal year 1994, according to Schmidt. This includes Construction (Plant and Capitol Equipment—PACE) Funding. During this spring and summer, the Administration, with the help of fusion proponents, will be working hard to assure that Congress appropriates this funding.

Upcoming Activities

An Environmental Assessment has been completed and was recently submitted for DOE approval, according to TPX Project Director John Schmidt. At the same time, the Independent Cost Estimate (ICE) review is being done by DOE subcontractor Foster Wheeler and is to be completed in June.

Responses to the CDR recommendations are being developed, and a number of small workshops are being planned to deal with specific issues. Presentations on TPX are scheduled for large fusion-related meetings both internationally and in the US to describe the project and respond to questions.

Everyone on the TPX staff will be busy with these activities, but as Schmidt notes, "Our biggest goal now is to have funding approved so that we can begin Preliminary Design on October 1."❖



Artist's Rendition of the Tokamak Physics Experiment (TPX).

TPX Milestones

November 1992	Mission Need Determined
April 1993	Conceptual Design Review
June 1993	Independent Cost Estimate Review
August 1993	Project Start
July 1994	Detailed Design
June 1995	Construction Start
March 1999	Start of Operations
September 1999	First Plasma