STATEMENT BY THE ENERGY POLICY COMMITTEE, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS-UNITED STATES ACTIVITIES, ON THE FY1993 DEPARTMENT OF ENERGY BUDGET REQUEST FOR FUSION ENERGY

The following is the written statement of the Institute of Electrical and Electronics Engineers-United States Activities (IEEE-USA) Energy Policy Committee concerning the FY1993 U.S. Department of Energy budget request for fusion. These views were presented to the Energy Subcommittee of the House Committee on Science, Space, and Technology on February 20, 1992.

Major portions of the statement were written by a subcommittee of the Plasma Science and Applications Committee (PSAC) of the IEEE Nuclear and Plasma Sciences Society (NPSS) at the request of Ned Sauthoff (Princeton Plasma Physics Laboratory), the NPSS liaison representative to the IEEE-USA Energy Policy Committee. The PSAC subcommittee was chaired by Mary Ann Sweeney of Sandia National Laboratories. Her subcommittee members were Igor Alexeff (University of Tennessee), Ian Brown (Lawrence Berkeley Laboratory), John Glowienka (Oak Ridge National Laboratory), Steve Gold (Naval Research Laboratory), John Maenchen (Sandia National Laboratories), J. Reece Roth (University of Tennessee), Nikos Salingaros (Southern Methodist University), Loren Steinhauer (STI Optronics), and Linda Sugiyama (Massachusetts Institute of Technology). The final statement was approved by the IEEE-USA Energy Policy Committee prior to release. The views expressed in the statement represent a consensus of the PSAC Subcommittee on Fusion Energy Funding Policy and of the IEEE-USA Energy Policy Committee. These views do not necessarily represent the opinion of any particular individual, laboratory, university, or place of work.

The Energy Policy Committee of the Institute of Electrical and Electronics Engineers – United States Activities (IEEE-USA) is pleased to submit its views on the U.S. Department of Energy (DOE) FY1993 budget request for fusion energy.

The Energy Policy Committee supports research aimed at a timely demonstration of fusion as a viable power source for base-load electrical power generation. An adequate supply of energy is vital to the economic growth and security of the nation and the world and to the nation's international competitiveness. Of chief concern are the reliability and continuity of the nation's electricity supply system and the related global climate change and environmental issues associated with electric power production. Extensive research and development (R&D) will be required to achieve improvements in present energy sources and to develop new ones.

The Energy Policy Committee's support of DOE-funded research in fusion is coupled with strong support for an overall package of energy technologies that includes energy conservation and efficiency, electric power generation and storage systems, photovoltaics and renewable energy, and advanced nuclear fission power as well as fusion power technologies. We believe that improvements in both efficiency and increased energy production are essential to ensure adequate supplies of reliable, low-cost, and environmentally acceptable energy in the future. Fusion should be considered as one critical component of a future energy technology mix that could supplement and eventually reduce the need for burning of fossil fuels. This statement documents our position on fusion energy R&D within the context of this overall energy package.

The Energy Policy Committee regards fusion power as a highly desirable goal because of its potential advantages: abundant, geographically dispersed deuterium fuel and reduced radioactive hazards and environmental impacts. A fusion reactor would produce no atmospheric emissions that could contribute to acid rain or greenhouse warming.

In addition, we support government funding of fusion R&D because of its potential contributions to the fields of science and engineering.

FUSION PROGRAM OVERVIEW

In its most easily attainable form, fusion consists of the nuclear burning of deuterium and tritium. Fusion is a potential source of electrical energy and process heat for industry that is characterized by the availability of a tremendous amount of natural raw fuel and the potential for reduced environmental impacts. While the potential for electrical energy and process heat from fusion is immense, its development has proved difficult, and fusion has not yet been demonstrated at a commercial level. Indeed, the next technical challenge is the demonstration of fusion power production equal to the power invested in heating the plasma, and fusion is not expected to play a major role in producing commercial power until well into the next century. Thus, fusion is a long-range solution to a long-range problem. Unless fundamental research on fusion is pursued now, there is a significant danger that mankind will suffer severe energy shortages or severe environmental damage before fusion can be developed as an alternative energy source. Because of its long lead time and precompetitive status, fusion research must be funded by the government almost exclusively.

In recent years, the United States has had fusion research programs in two distinct areas: low-intensity, long-duration magnetic confinement fusion energy (MFE) and high-intensity, short-duration inertial confinement fusion (ICF). Magnetic confinement fusion research in the United States has been carried out at a number of laboratories, with the largest device located at the Princeton Plasma Physics Laboratory. Research has focused on the tokamak concept, although several alternative magnetic topologies (stellarator, tandem mirror, bumpy torus, field-reversed configurations) have been investigated. Inertial confinement fusion research using lasers, light ions, and heavy ions is centered at the national weapons laboratories (Livermore, Los Alamos, and Sandia), chiefly because of classification restrictions that derive from similarities between an imploding fusion pellet and a nuclear weapon. All fusion research is funded through the DOE, with MFE and a small amount of ICF under Energy Research (ER) and ICF mostly under Defense Programs. While ICF research has military relevance in simulating the effects of nuclear weapons, it remains a long-term energy technology along with MFE. Current funding is focused on devices that will allow demonstration of scientific, as opposed to engineering, feasibility: the tokamak for MFE and the glass laser for ICF, with only lesser support for alternative magnetic configurations and alternative inertial drivers.

Two recent program reviews, commissioned by DOE and Congress and performed by the Fusion Policy Advisory Committee (FPAC) and the National Academy of Sciences (NAS), were completed in 1990. These reviews concluded that the U.S. fusion program is well directed toward critical goals and that a commitment to a sustained and somewhat higher level of funding is needed to ensure the timely development of fusion energy. These committees recommended a near-term MFE focus on the deuterium-tritium (D-T) tokamak reactor concept and a near-term ICF focus on the glass laser. Both committees recommended that research on alternative fusion fuels, alternative fusion confinement concepts, and basic physics and engineering issues receive steady and adequate funding to ensure that economic and environmental feasibility, as well as scientific and engineering feasibility, can be demonstrated. However, in late 1990, budgetary constraints forced the Office of Fusion Energy to focus the MFE program on the development of the D-T tokamak; research on all alternative fusion fuel approaches and alternative confinement approaches was severely reduced, even though advanced fuels and configurations may provide environmental and safety advantages in the long term.

FUSION PROGRAM PROGRESS

The production of 2 MW of fusion power for a duration of 1 s by the burning of a mixture of deuterium and tritium fuels in the Joint European Torus (JET) in November 1991 was a milestone in the fusion program. This event, the first burning of a significant amount of the more reactive tritium fuel in a tokamak, marked a milestone in magnetic fusion research. It is regrettable that the 1985 schedule delay of the burning of tritium in the U.S.'s Tokamak Fusion Test Reactor (TFTR) prevented an even earlier demonstration of fusion power at significantly higher levels.

Recent progress in U.S. magnetic fusion included the achievement of an even more enhanced mode of confinement in the Doublet III-D (DIII-D) tokamak at General Atomics, observation of modes driven by energetic particles (simulating the products of fusion reactions) in TFTR, and improved understanding of fluctuations and transport in both these tokamaks and in the Advanced Toroidal Facility (ATF) stellarator at Oak Ridge National Laboratory. In the past year, progress in the ICF program included ablative stabilization and gradient scale-length stabilization of Rayleigh-Taylor modes in radiatively driven and direct-drive targets in agreement with computational models, diagnosis of the mixing of fuel and pusher material, increased compression by pulse shaping, improved laser beam smoothing, and theoretical understanding of how ion beam divergence can be controlled.

Recent fusion research has also made contributions to fundamental plasma science and technology. For example, theoretical methods have been developed to treat the interaction of a dilute high-energy particle population with magnetohydrodynamic modes of a background plasma. Applications to the earth's magnetosphere as well as to tokamaks have enjoyed quantitative successes. Magnetic reconnection in toroidal fusion geometries is at the forefront of exploring the mutual interaction of magnetic reconnection (which changes magnetic topology) with the nonlinear dynamics of ergodic particle orbits that arise because of the topological changes. Picosecond-pulse lasers, developed from ICF technology, have been used to generate extraordinarily high coherent harmonics ($n \approx 100$) in a plasma—a phenomenon yet to be understood theoretically. Microwave tube technology is being extended to continuous-wave powers approaching the megawatt level at millimetre wavelengths via development of gyrotron tubes for heating fusion plasmas. In addition, the pursuit of physics issues in fusion is driving the development of state-of-the-art numerical computations.

DOE'S MFE DIRECTION

The MFE program is being redirected in reaction to the budgetary constraints within the DOE Office of Energy Research. The production of 10 to 20 MW of fusion power by the burning of a D-T fuel mixture in TFTR is expected to be achieved in the FY1993-1994 time frame and will be the next step in the progression toward the understanding of the physics of burning plasmas and in the demonstration of fusion power production in the laboratory.

Unfortunately, the expected flatness of the funding profile imposed on the DOE Office of Energy Research has forced the Secretary of Energy Advisory Board (SEAB) Task Force on Energy Research Priorities to recommend that the fusion program not take the previously planned step, the Burning Plasma Experiment (BPX). The task force stated that this action on fusion device construction (and others within the Office of Energy Research) was driven by the budgetary constraints and not the quality of the proposed program. The Fusion Energy Advisory Committee is now engaged in an intense process of program review and development, targeted at the proposal of a $400 million device that would be affordable if the fusion program's real rate of growth is the 5%/yr recommended by the SEAB Task Force.

DOE'S ICF DIRECTION

The DOE now considers ICF as an energy program and has acted on the recommendation by the NAS by establishing an ICF program within the Office of Energy Research. The ICF program will complement the target physics supported by Defense Programs by addressing the critical problem areas of efficient, high-power heavy-ion drivers and the production of cheap, high-gain pellet targets and the design of appropriate reactor chambers and systems.

The DOE program plan includes the device upgrades and research leading to the demonstration of ignition and modest gain in the laboratory and the understanding of the physics of high-current, heavy-ion beam accelerators and direct drive, as recommended by the NAS.

DISCUSSION AND RECOMMENDATION

The SEAB Task Force stated that ". . . increased investment in scientific research is critically important to the welfare and competitiveness of the nation." The task force warned that the "scientific and technical effort in support of the goals and objectives of the Department of Energy" will be "seriously inadequate" if "the current ER budgetary caps and out-year allowances" are not reversed. It also recommended that "every effort should be made to secure a future ER budgetary profile that is more in keeping with the outstanding scientific opportunities before the nation and traditional role of the DOE as a major source of support for fundamental science and engineering research." For these reasons, the IEEE-USA Energy Policy Committee encourages increased investment in energy-related R&D with strong science and technology content.

The committee believes that fusion must play a role in long-term electrical energy production because of its potential as an inexhaustible and environmentally attractive technology. We encourage Congress to support DOE's intent to establish fusion as an energy program with a strong emphasis on scientific and technological content.

The IEEE-USA Energy Policy Committee therefore supports DOE's proposed restoration and increase of fusion funding and its intent to fund fusion research in the context of an energy program. The committee regrets, however, the departure of the MFE program from the preferred plan described in the National Energy Strategy. This recommended strategy is consistent with the recommendations of the FPAC, which outlined a schedule for the demonstration of a fusion power plant by 2025 and an operating commercial fusion power plant by 2040.

The committee believes that an international collaboration on large-scale projects such as the International Thermonuclear Experimental Reactor (ITER) is vital to advance the fusion research effort and demonstrate scientific and commercial feasibility. Nevertheless, we believe that the role of the United States in ITER development must be carefully defined and that a strong, complementary domestic program is necessary to ensure competitiveness in the production of future fusion power systems. In addition, smaller scale international collaborations should also be encouraged.

The development of fusion energy has significant environmental, foreign policy, and national security implications. Government funding of precompetitive energy research is an essential requirement for the emergence of significant private investment in innovative energy technologies, including fusion. A stable, committed federal investment in energy R&D is essential. If the present budgetary constraints cannot be reduced to the extent of restoring the preferred plan described in the National Energy Strategy, then the IEEE-USA Energy Policy Committee recommends that DOE carefully tailor the fusion program to include the following elements:

1. Commit to the steady, long-term development of fusion power. This requires stable funding of fusion R&D efforts, in spite of periods of temporary economic and political change. Stable funding to pursue innovative ideas and to do basic physics experiments should exist in parallel with stable funding for large engineering demonstration devices such as ITER.

2. Participate as a major partner in international efforts to develop fusion as a viable future energy source even though the U.S. fusion budget is currently considerably smaller than those of Europe and Japan.

3. Maintain a strong domestic research program to complement international programs. For example, the domestic program might emphasize broad-based research on basic plasma science and new and improved concepts to complement the international focus on complex, integrated engineering as in ITER. A strong domestic program requires fusion devices, located in the United States, on which significant scientific research can be done.

4. Create new funding sources for university-based research in both MFE and ICF to provide the intellectual stimulus, objective criticism, and innovative thinking that universities foster and to train future scientists and engineers. The recent U.S. Nuclear Regulatory Commission Research Briefing on Contemporary Problems in Plasma Science highlighted many exciting opportunities for university research, including innovative uses of fusion facilities, which are not being exploited because funding sources for basic plasma sciences are extraordinarily limited. This has been one of the traditional strengths of the U.S. scientific effort in MFE, and universities will be able to play a larger role in the ICF effort once changes in classification guidelines recommended by the NAS are completed.

5. Maintain a broad focus, so that the shortcomings of one approach do not preclude the development of an ultimate fusion program that combines economic attractiveness with significant environmental and safety advantages. This area of research should include development of advanced configurations and materials and alternative confinement configurations, as well as the use of advanced low-activation fusion fuels. This breadth is essential because it is too early to select the optimum fusion energy system for ultimate commercial development.

6. Enhance the U.S. fundamental scientific and engineering base in the sphere of energy research to ensure that the nation gains the necessary technological expertise to establish U.S. industry as a major developer and supplier of fusion power systems in the future.

The IEEE-USA Energy Policy Committee thanks you for this opportunity to comment on the FY1993 budget request for fusion energy. IEEE-USA and its committees stand ready to assist Congress as a resource for technical advice and policy perspectives on a wide range of issues that affect the career and technology policy interests of the nearly 250 000 electrical and electronics engineers and computer scientists comprising our U.S. membership.

This policy statement was contributed by Mary Ann Sweeney. Dr. Sweeney is a Fellow of IEEE and a past chairman of the IEEE Plasma Science and Applications Committee. She has served as secretary and vice president of the IEEE Nuclear and Plasma Sciences Society and is currently chairman of the Nominating Committee of the IEEE Nuclear and Plasma Sciences Society. She is a senior member of the technical staff in the Beam, Plasma, and Electromagnetic Theory Department at Sandia National Laboratories (SNL) and has been involved in particle beam research for the inertial confinement fusion program at SNL for the last 18 years.