DEPARTMENT OF ENERGY
FY 1996 CONGRESSIONAL BUDGET REQUEST
ENERGY SUPPLY, RESEARCH AND DEVELOPMENT

OVERVIEW

FUSION ENERGY

THE ENERGY CONTEXT

For the long-term, the Department of Energy is seeking to provide a portfolio of diverse energy sources. Fusion energy plays an important role in the Department's long-term energy strategy.

Because fusion energy is a long-range option, what the world might be like, how energy might be delivered, and the geopolitical stresses and opportunities must be considered in planning the program.

A growing world population is one factor to be considered. In the 1950's, when the possibility of fusion energy was first raised, the world population was 2.7 billion; in 1990 it was 5.3 billion. The United Nations projects that, by 2025, it will be 8.5 billion. Of this 8.5 billion, 84 percent, or a little over 7 billion people, will live in what are now the less developed nations.

If the people of the less developed countries are to raise their standard of living to that of the more developed countries, their use of energy must grow in all sectors. If the entire world consumed energy at the per capita rate of the inhabitants of the nations belonging to the Organization for Economic Cooperation and Development (OECD), total demand would increase by a factor of three. Without major investments in a diverse portfolio of clean technologies for electrical power generation, developing countries will be forced by economics to use energy and transportation technologies with negative national and global long-term environmental consequences. A mix of clean energy technologies, which may include fusion as well as renewable energy technologies, will be required to meet future national and world-wide environmental, energy and energy security needs. If electric vehicles become a major form of urban transport, this will only exacerbate the requirements for electric power generation. The issue of providing for energy demands in the third world is a matter of environmental stewardship, as well as social justice and equity. Without this recognition, major geopolitical imbalances that can affect the security of the developed world may occur. Striking the right balance offers an opportunity for trade for those nations which have developed clean, efficient technologies to provide electric power.

Domestically, the future is different. U.S. demand for energy has been reduced and significant continued reductions from conservation and renewables can be foreseen through the middle of the next century. Historically in the U.S., growth in electricity demand has been tied to the rate of economic growth. Until the 1970-80's, it outpaced the economy -- when the average annual growth in the Gross Domestic Product (GDP) was 2.7 percent, a 3.4 percent per year growth of electricity demand was seen. The most recent near-term forecasts of the Energy Information Administration show growth in electricity demand well below the projected annual GDP growth rates. This slower growth is due to energy efficiency, in both the supply and consumption sectors.

However, the need for new technology for domestic electrical power generation cannot be ignored. The development of electric vehicles may well contribute to increased demand for electricity in the next century. Replacement of existing electricity generation also offers opportunity for environmentally beneficial technology. Replacement of fossil fuel is environmentally appropriate and eventually required. The timing of the needs and the size of the demand are uncertain and depend on such things as population growth, economic activity, and legislative and regulatory changes.

WHY DEVELOP FUSION ENERGY TO MEET THE NEED?

Fusion energy is a virtually inexhaustible energy source. Fusion will produce the most energy per amount of fuel input of any known option, with only helium gas as a releasable byproduct. A pound of fusion fuel contains the energy equivalent of 12 million pounds of coal, 25 thousand barrels of oil, 142 million cubic feet of natural gas, or 4.5 pounds of fission fuel. Fusion will not release greenhouse gases associated with global warming or chemicals associated with acid rain, nor does it contribute to other forms of atmospheric pollution.

Fusion has the potential to ensure the safety of the public by limiting radioactive materials, that could be dispersed, and by assuring safe power plant shutdown under accident conditions without the need for active safety systems. No "runaway" nuclear accidents are possible in fusion power plants.

The fusion process does produce radioactivity in the structural materials in the power plant, but this environmental impact can be greatly reduced by using structural materials that minimize the long-term radioactive waste when they are subjected to the fusion process. The development of these "low-activation" materials" is becoming a priority in the fusion energy long-range development program.

PROGRAM SUCCESSES

The progress made by the fusion program toward the goal of developing fusion as a source of electricity has been steady since the beginning of the program in 1951. The results from the program are at the cutting edge of science and technology. The scientific discipline of plasma physics has been established by the fusion program because it forms the basis for fusion development. Plasma physics is now used in a variety of areas in addition to fusion. For example, the principles of plasma physics are used in understanding the near-earth space environment and its effects on communication. Plasma physics has made contributions to the establishment of many small businesses that have increased the base of highly skilled jobs in such diverse areas as the transmutation of toxic wastes, and manufacturing of computer chips.

The most recent success for the fusion program is the achievement of a scientific breakthrough at the Princeton Plasma Physics Laboratory's Tokamak Fusion Test Reactor (TFTR). Beginning about one year ago and continuing up to the present, a series of world records have been achieved for the release of energy from fusion reactions using fuels that will be used in commercial fusion power plants. The most recent record is the release of 10,700,000 watts of fusion power for a short time. This amount of energy, if produced continuously, could supply about 3,500 homes with electricity. The TFTR will continue to operate through most of 1995 before being shutdown in order for the fusion program to move ahead with other program priorities.

The inherent attributes of fusion energy and its unbroken string of successes have led the Department of Energy to consider fusion energy as an important potential source of electricity-generating capacity in the middle of the 21st century.

FUSION PROGRAM GOALS

The present program goal is to have an operating demonstration plant by about 2025, and an operating commercial power plant by about 2040. An intermediate objective of the program is to produce, by the year 2010, a technology demonstration which verifies the practicability of commercial electric power production, as stated in the Energy Policy Act of 1992 (EPACT). However, budgetary constraints over the past few years may mean that the schedule for meeting such objectives is delayed. Therefore, we are reevaluating the program goals, including those in EPACT, with the objective of making whatever changes are necessary to bring the goals in line with anticipated funding levels in the outyears.

Meeting the fusion program goals requires a broadly based fusion energy program with a long-term perspective, one that carefully defines the crucial scientific and technology issues and deploys the resources needed to resolve those issues in an era of stringent national budgets.

The Administration recognizes that significant budgetary commitments will be required to meet the programmatic objectives and milestones identified above. The Administration will conduct a review of the fusion energy program, under the auspices of the President's Commission of Advisors on Science and Technology (PCAST) and the Office of Science and Technology Policy.

This review, which will include an examination of U.S. participation in the ITER construction and the role of the planned TPX project, is intended to be completed by summer 1995. When the final results of this study are available, the President will review the PCAST recommendations and make a determination on the appropriate future strategy for the U.S. fusion program. Start of construction of the TPX project will await that determination.

APPROACHES TO FUSION

The present fusion program includes development of two approaches to fusion, namely, magnetic confinement fusion and inertial confinement fusion.

The magnetic approach uses magnetic fields to contain the fusion fuel, allowing the fuel nuclei to remain close together long enough for fusion reactions to occur. In inertial confinement fusion small pellets of fusion fuel are imploded by high energy beams, allowing the fuel atoms to fuse together to release energy.

The Office of Fusion Energy is responsible for the entire program of research and development directed at magnetic fusion, while the majority of the effort in inertial fusion is funded by the Office of Defense Programs. Only the development of the energy-specific high energy beams and fuel pellet production for inertial fusion energy are currently pursued by the Office of Fusion Energy.

FUSION PROGRAM STRATEGY - MAGNETIC FUSION

The fusion development program is in a period of major transition. It is evolving from a program focussed on physics research to one including engineering development, from a laboratory and university base to include an industry base, and from a domestic program to an international program.

Budget realities have made it imperative that a specific type of fusion concept be selected and vigorously pursued. The magnetic fusion program is, therefore, focussed on the development of a donut-shaped device called a tokamak to generate the fusion energy. This focussing has occurred for several reasons. First and foremost is the objective evaluation of research done on many alternatives to the tokamak over the years. This evaluation has been done independently by all of the world's major fusion programs, and each program has concluded that the tokamak stands the best chance of being developed into a successful power producing system. The need to collaborate with international partners has also contributed to focussing the U.S. program on the tokamak.

The magnetic fusion program strategy is focused on developing the information that is necessary for the design, construction, and operation of a tokamak magnetic fusion power plant for the purpose of demonstrating that fusion can be an economically competitive source of electricity. Four major activities have been identified as necessary to accomplish this objective.

The first activity involves the need to understand the physics of igniting and maintaining a "burning" plasma in a fusion power plant. In addition, a data base for the design and operation of the components needed in a fusion power plant must be developed. Each of the world's major fusion programs have independently reached the conclusion that a facility to address these issues should be the next step in fusion development. To this end, the European Union, Japan, the Russian Federation, and the United States have signed an agreement to conduct engineering design and supporting research and development for the International Thermonuclear Experimental Reactor (ITER). Decisions on whether and where to construct ITER could be made as early as mid-1996, with a more likely date being 1997-1998.

The second activity involves the development of advanced structural materials that will not become highly radioactive in the fusion power plant environment. The international community has agreed that the development of advanced materials requires the building of a materials testing facility that will operate at conditions that are prototypic of those in a fusion power plant.

The third activity is the development and testing of the components needed to extract the energy after the fusion reactions occur so that it can be used to generate electricity. These components, generally referred to as the "blanket," also contain materials that, when exposed to the products of fusion reactions, become fusion fuel. The fuel is then cycled back into the power plant to keep it operating. The several different types of blankets will be tested in ITER after the completion of the work required for the first activity.

The fourth activity addresses the need to improve the power plant embodiment of fusion. The Tokamak Physics Experiment will offer a unique opportunity to improve the economics of a demonstration power plant by making it smaller, more efficient, and thus, less expensive to build and operate than would otherwise be possible. The TPX, which should be operating before the ITER, would also contribute information to the later design phase of ITER components and to how to operate ITER continuously during its second phase as an engineering test bed for blanket development. TPX would also help maintain a strong domestic program so that the United States is able to take advantage of its participation in ITER. In building the TPX, United States' industry will gain valuable experience that will allow them to successfully compete with industry abroad for the large contracts that will be available for the construction of ITER.

Within magnetic fusion, various alternatives have been evaluated on the basis of extensive objective data collected after many years of government-supported research. Development of the tandem mirror, the reversed field pinch, and the field-reversed compact toroid devices, has been stopped. Prior to that time, as many as thirty concepts were evaluated and their support was terminated for objective technical reasons. Support for exploration of several alternates is included in the current budget request. When the Inertial Fusion Energy program is included, the amount devoted to alternate concepts is approximately 4% of the fusion budget. While budget realities have forced the U.S. program to concentrate on tokamaks, both the European Union and Japan have continued research on non-tokamak fusion concepts. The U.S. program maintains contacts with those parts of the European Union and Japanese programs.

FUSION PROGRAM STRATEGY - INERTIAL FUSION

The strategic plan for the development of inertial fusion as an energy source requires specific underpinning technical information before development details can be implemented. First, the amount and nature of energy required to initiate thermonuclear burn of laboratory targets should be determined. An important part of this information is how much gain, or energy multiplication, can be obtained from laboratory inertial fusion. This ignition and gain information is expected to come from the target physics program and the National Ignition Facility carried out under Defense Programs within DOE. Second, a high intensity energy source (driver) that has high efficiency and can be reliably pulsed several times per second must be developed in order to use laboratory ignition in energy applications. A heavy ion accelerator has been consistently identified as the best candidate driver. The inertial fusion energy program will conduct the physics tests of the heavy ion beam concept. When thermonuclear burn of laboratory targets is established and an energy-specific driver has been developed, then a detailed development approach for inertial fusion energy can be implemented. The growth and evolution of this IFE activity into a full development program is also predicated on success in the inertial fusion confinement effort that is being pursued by the Department's Office of Defense Programs.

The Energy Policy Act of 1992 requires that the Department establish "... a broad based fusion energy program." To the extent possible within budgetary resources, several alternatives to tokamak-based fusion are being explored. This exploration includes not only alternatives in magnetic fusion, but also in inertial fusion. In 1990 the Fusion Policy Advisory Committee recommended to the Department that both the magnetic and inertial paths to fusion be carried on in parallel, at independent paces that are technically justifiable until sufficient information is available to make a choice between them. It is our current judgement that this information will not be available until the second decade of the next century.

PROGRAM PARTICIPANTS

The fusion energy program is conducted at many institutions located throughout the U.S. In addition, the program has ties to various institutions throughout the world by virtue of an extensive network of collaborative agreements. The major participants in the fusion program are:

National Laboratories, which can bring together multidisciplinary teams of scientists and engineers to solve specific technical problems and to design and construct the increasingly complex experimental devices which we require to make progress.

U.S. Industry, which will provide the design and manufacturing expertise required to build our new facilities and will eventually produce and market fusion power plants. Also, General Atomics, an industrial firm, operates the D-III-D tokamak device, participates in the base science and technology programs, and is active in both the Tokamak Physics Experiment and the International Thermonuclear Experimental Reactor program.

Universities, which will train the next generation of our program's scientists and engineers while providing the basic theoretical and experimental underpinnings of the fusion program.

International Partners, with whom we jointly plan and execute our fusion research programs and with whom we are now conducting the engineering design of the ITER.

ELEMENTS OF THE PROGRAM

The Tokamak Fusion Test Reactor has been conducting deuterium-tritium experiments for the past year and has recently achieved a record 10.7 million watts of fusion power. The research on TFTR has made a significant step toward demonstrating the scientific feasibility of fusion power and has provided key elements of the physics basis for ITER.

The International Thermonuclear Experimental Reactor (ITER) is a prime example of cooperation with international partners. The President has called ITER "the centerpiece of the research effort in magnetic fusion energy....." The objective of ITER is to demonstrate the scientific and technological feasibility of using magnetic fusion energy for the production of electricity. ITER, in reaching its goal, will address the ignition and burn issue by becoming the first fusion device to reach ignition, the condition under which the fusion reaction is self-sustaining. ITER will also address the issue of component development for the extraction of the energy from the fusion reactions by providing a test environment in which scale models of these components of future fusion power plants can be tested under conditions similar to those that will be found in the power plants.

The Tokamak Physics Experiment (TPX) will be built on the site of the Tokamak Fusion Test Reactor at the Princeton Plesma Physics Laboratory in New Jersey. The TPX will be an advanced tokamak device that offers a unique opportunity to move fusion science and technology down the path toward an economically attractive demonstration fusion power plant by addressing the issue of fusion concept optimization. TPX will do this by exploring advanced modes of operating a tokamak, such as continuous operation, allowing future tokamaks to be smaller, more efficient, and thus, cheaper to build and operate. The mission of TPX is complementary to the mission of the ITER, and together these projects represent the future of the U.S. fusion program. Construction of the TPX will allow the U.S. to remain a strong partner in the ITER program both scientifically and in terms of our industrial base.

While ITER and TPX play a central role in the strategy for moving toward a fusion economics demonstration power plant, a continuing commitment is required to conduct a strong domestic program to support the ITER and TPX project, and to put the U.S. in a position to use the information gained for the demonstration plant, and ultimately for commercialization. Important elements in the U.S. domestic program include the D-III-D experiment at General Atomics, and the Alcator C-Mod experiment at the Massachusetts Institute of Technology. These and other groups conduct physics research to support ITER, to improve the tokamak concept, and to maintain competencies in experimental, theoretical, and computational plasma physics.

The base program must also contain the engineering and technology developments needed to support ITER and TPX and to lead the fusion program into the demonstration power plant phase. Large superconducting magnet design and construction, very high power and high frequency microwave heating devices, and means of fueling the fusion plasma are some of the necessary technologies that must be developed.

The Materials Test Facility (MTF), which is necessary for the development of advanced, low-activation materials, is also being pursued. At the present time the U.S. is collaborating on a conceptual design for this facility along with the EU, Japan, and the Russian Federation. There has been no commitment by any of the Parties to a Materials Test Facility beyond the current design activity.

THE ROLE OF INDUSTRY

Successful results from the activities directed at the four development issues will lead to the final phase of fusion development: commercialization. We have already begun early preparations for a transition of expertise to industry to support this, particularly in the TPX program. The private sector is expected to play the principal role in developing new commercial technologies. The government's role in fusion energy is necessary because fusion is such a long-term program and the technical and economic risks are too high to expect the private sector to fund the work for at least the next two decades. However, the ultimate technology transfer of fusion to the private sector will be most efficiently accomplished if there is timely introduction and continued involvement of industry in the U.S. fusion program. Thus, the need for sustained involvement of the industrial sector as an important step toward developing the fusion energy option and meeting the Department's goals in the area of technology transfer is recognized. To this end, we are developing partnerships between national laboratories and private industry in order to successfully accomplish both the TPX and the ITER activities.

It is anticipated that an increasing share of the funds expended on fusion energy research will be spent in industry, with a substantial majority of the total funds going to industry by the time the design of a demonstration power plant begins.

The following sections contain a brief description of the accomplishments of the program in FY 1994, the work ongoing in FY 1995, and the work proposed for FY 1996 in each of the three subprograms of the Fusion Energy Program.

DEPARTMENT OF ENERGY
FY 1996 CONGRESSIONAL BUDGET REQUEST
ENERGY SUPPLY, RESEARCH AND DEVELOPMENT

(Tabular dollars in thousands. Narrative in whole dollars.)

LEAD TABLE

Fusion Energy

Activity	FY 1994 Adjusted	FY 1995 Appropriation	FY 1995 Adjustment	FY 1995 Adjusted	FY 1996 Request
Operating Expenses					
Confinement Systems	$163,156	$150,506	$37,351	$187,857	$131,492
Applied Plasma Physics	57,250	54,275	0	54,275	48,821
Development & Technology	77,950	89,026	0	89,026	100,400
Planning & Projects	38 a/	5,857	1,507	7,364	6,053
Inertial Fusion Energy	3,859	6,000	2,000	8,000	3,100
Program Direction	8,926	9,600	0	9,600	9,600
Subtotal Operating Expenses	311,179	315,264	40,858	356,122	299,466
Capital Equipment	15,519	10,299	0	10,299	12,479
Construction	1,940	47,000	-45,000	2,000	54,100
Subtotal Program	$328,638	$372,563	-$4,142	$368,421	$366,045
Adjustment	-6,361 b/	-2,065 b/	-----	-2,065 b/	-------
Total Program	$322,277	$370,498	-$4,142	$366,356	$366,045

a/ Excludes $4,711,000 which was transferred to the SBIR ($4,559,000) and STTR ($152,000) programs.

b/ Share of Energy Supply, Research and Development general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

	FY 1994 Adjusted	FY 1995 Appropriation	FY 1995 Adjustment	FY 1995 Adjusted	FY 1996 Request
Operating Expenses	$311,179	$315,264	$40,858	$356,122	$299,466
Capital Equipment	15,519	10,299	0	10,299	12,479
Construction	1,940	47,000	–45,000	2,000	54,100
Subtotal Program	$328,638	$372,563	–$4,142	$368,421	$366,045
Adjustment	–6,361	–2,065	-----	–2,065	-------
Total Program	$322,277	$370,498	–$4,142	$366,356	$366,045
Staffing (FTEs)					
Headquarters	61	61	0	61	61
Field Office	21	21	0	21	21
Total	82	82	0	82	82

Authorization: Section 209, P.L. 95–91, "Department of Energy Organization Act"

DEPARTMENT NERGY
FY 1996 CONGRESSIONAL BUDGET REQUEST
ENERGY SUPPLY RESEARCH AND DEVELOPMENT
(dollars in thousands)

SUMMARY OF CHANGES

Fusion Energy

FY 1995 Appropriation	$ 372,563
- Adjustments	- 4,142
FY 1995 Adjusted	$ 368,421

Operating Expenses

Confinement Systems .... - 56,365

Supports continued operation of DIII-D and Alcator C-Mod. PBX will be shutdown indefinitely. TFTR decontamination and decommissioning will be initiated. Princeton scientific and technical staff will be involved in data analysis of D-T experiments as well as off-site collaborations. R&D in support of the Tokamak Physics Experiment (TPX) project continues at a reduced level as construction is initiated. The start of TPX construction will await completion of the PCAST review and a determination by the President as to the appropriate future strategy for the U.S. Fusion Program.

Applied Plasma Physics .... - 5,454

Diagnostic development and computer facility support are funded at slightly below the FY 1995 level with the primary focus on supporting ITER and TPX. Significant reduction in small tokamak support will occur.

Development and Technology .... + 11,374

This increase provides for the support of U.S. share of the ITER Engineering Design Activities including the engineering design and technology development tasks required to validate the ITER design and for development of low activation materials.

Planning and Projects .... - 1,311

Provides primarily for SBIR obligations.

Inertial Fusion Energy... - 4,900
Activities are reduced as a consequence of the decision to focus the effort on initiation of construction of ELISE.

Program Direction... 0
Funds are provided to support the staffing resources associated with the Fusion Energy Program.

Capital Equipment... + 2,180
An increase in capital equipment funds is primarily associated with a decision to proceed with a significantly descoped version of the equipment upgrades on the D-III-D facility.

Construction... + 52,100
The increase is primarily associated with the initiation of the ELISE project and construction of TPX.

FY 1996 Congressional Budget Request... $366,045

KEY ACTIVITY SUMMARY

FUSION ENERGY

I. Preface: Magnetic Fusion Energy - Confinement Systems

The mission of the Confinement Systems subprogram is to investigate the magnetic confinement of hot plasmas in experimental devices of a size and scale relevant to the International Thermonuclear Experimental Reactor (ITER) or a fusion power plant. This requires exploratory research on both the ignition and burn physics and concept improvement issues. The Confinement Systems subprogram will investigate these subjects in FY 1996: completing the analysis of the deuterium-tritium (D-T) experiments in the Tokamak Fusion Test Reactor (TFTR) ~~at~~ the Princeton plasma Physics Laboratory (PPPL); conducting research to resolve the major scientific issues of magnetic fusion on both U.S. and foreign devices; designing the Tokamak Physics Experiment (TPX) to study improvements of the tokamak concept; and carrying out physics R&D for the TPX and the ITER designs.

The major scientific topics within the ignition and burn and the concept improvement issues are: energy confinement; plasma heating; equilibrium and stability; power exhaust and particle control; current drive; and physics of the energetic helium ions or alpha particles, that are the products of D&T fusion reactions.

Energy confinement is an important physics issue for future fusion devices, such as ITER, because it determines whether they can achieve a self-sustaining fusion reaction (ignition). In a fusion power plant, the deuterium-tritium fuel must be heated to a temperature of about 100,000,000 degrees Celsius to initiate the fusion reactions. Then, the thermal energy of the hot fuel mixture (plasma) must be sufficiently well confined that the heat generated by the fusion reaction sustains the required temperature. Research on energy confinement and plasma heating involves developing and using powerful heating systems, such as neutral beams and/or radio-frequency (RF) waves to heat the plasma, studying the plasma to understand its behavior, and determining how to improve energy confinement. Experimental energy confinement research is carried out in close cooperation with the diagnostics and theory activities supported by the Advanced Physics and Technology subprogram.

The issue of equilibrium and stability affects the reliability and economic attractiveness of fusion power. In a fusion power plant, the temperature and density of the plasma (i.e. the pressure of the plasma) must be high enough to produce sufficient fusion power to be practical. In a tokamak, the external magnetic field must apply a pressure about 10 times larger than the pressure of the plasma to provide stable containment of the plasma. Research on equilibrium and stability is concentrated on developing designs and operating conditions that theory predicts will maximize the plasma pressure confined by practical magnets. Research to date has shown that D-shaped plasmas can achieve a sufficiently high pressure to meet the design objectives of ITER. Future work will focus on the study of advanced operating regimes, which could permit even higher pressures. If successful, this work could lead to more compact and cheaper fusion power plants.

The most critical design issue for next generation devices such as ITER and TPX is power exhaust/particle control, which is closely coupled to both physics and technology issues. Both alpha particles (helium nuclei) and large amounts of heat (thermal power), generated by the fusion reactions, must be exhausted from the vacuum vessel of a fusion power plant, and the deuterium-tritium fuel has to be replenished. High power on material surfaces surrounding a plasma can dislodge impurities, which migrate to the center of the plasma and both dilute the fuel and cool the plasma by radiation. Therefore, physics and technology research is needed to develop methods to carry away both the plasma power and the leftover alpha particles with minimal impurity generation. Studies are being conducted to develop better power exhaust and particle control systems (such as magnetic divertors), to understand impurity migration to the plasma core, and to develop plasma fueling systems (such as high-velocity hydrogen or deuterium pellet injectors).

In a tokamak device, a magnetic field provided by external coils and a magnetic field provided by driving a current in the plasma are required. The current drive issue addresses the need to create this current in a continuous or steady-state mode, as opposed to the present short-pulses. Continuous operation will reduce the problems of thermal and mechanical fatigue of the components of a power plant. In a tokamak it is possible to drive the required currents continuously by several techniques including radio-frequency waves and optimization of a current generated by the plasma itself. Planned current drive experiments will concentrate on improving the efficiencies of radio-frequency wave current drive and optimizing the self-generated current. These experiments are important to ITER, which will require improved current drive in its technology phase, and to TPX, which will use current drive to achieve advanced tokamak configurations.

The behavior of the alpha particles generated by the fusion reactions in the plasma is the least explored and potentially most important physics issue. First, the impact of alpha particles on energy confinement and plasma stability could affect the basic feasibility of a fusion power plant. Further, understanding alpha particle heating is necessary to control a burning plasma. Work on this issue is presently being addressed in TFTR, which recently achieved a world record 10.7 million watts of fusion power.

The goal of the U.S. Magnetic Fusion Energy program is to develop fusion power plants as a technically and economically credible energy source for the 21st century. Improvements in tokamak performance could lead to more economical tokamak power plants. The Tokamak Physics Experiment, is currently being designed by a national team of experts to study such improvements and demonstrate the techniques required for continuous operation. Construction of TPX will enable U.S. industry to participate fully in the construction of ITER, while operation of the TPX for long pulse lengths will also provide valuable information for the nuclear technology testing phase of ITER.

Because of their unique capabilities, several existing devices are being used to investigate the scientific issues discussed above and to prepare for the burning plasma physics experiment on ITER. Analysis of the data from the D-T experiments on TFTR is providing information on the behavior of D-T plasmas and alpha particle physics. Experiments on confinement, pressure limits, power and particle control, and current drive will be carried out on the DIII-D tokamak at General Atomics (GA). Research at the Alcator C-Mod tokamak at the Massachusetts Institute of Technology will be focused on the power and particle control with an ITER-like configuration, radio-frequency wave heating, and confinement in a high-field, high-density plasma.

Budget priorities necessitate eliminating research on some of the existing major toroidal devices in Confinement Systems. The Princeton Beta Experiment at PPPL will not operate in FY 1995 or FY 1996. Also, the TFTR will be shutdown at the end of FY 1995 in order to begin preparation for the Tokamak Physics Experiment. The Advanced Toroidal Facility at the Oak Ridge National Laboratory (ORNL), an alternate configuration to a tokamak, was shut down at the end of FY 1994. The U.S., however, will collaborate with large alternate concept programs (stellerators) in Japan and Germany in order to obtain first hand knowledge on progress in this area. Stellerators provide an alternate path to tokamaks in developing a continuously operating fusion power plant.

As the number of fusion facilities diminishes and the U.S. fusion program consolidates its focus on ITER, TPX, and other high priority issues, a consolidated group of the scientific personnel at universities and laboratories with no operating research devices will collaborate on the remaining tokamak devices and stellarators. Lawrence Livermore National Laboratory and Oak Ridge National Laboratory scientists and engineers will continue major collaborations on DIII-D at General Atomic and support of the national effort on TPX. Scientists from the TFTR program at PPPL will begin collaborative activities on other tokamaks in the U.S. and abroad. Joint tokamak experiments will continue on TEXTOR and ASDEX-Upgrade in Germany, TORE SUPRA in France, the Joint European Torus (JET) in England, JFT-2M and JT-60-Upgrade in Japan.

The following table summarizes the operating expense funding for the Confinement Systems subprogram:

II. A. Summary Table: Magnetic Fusion Energy - Confinement Systems

Program Activity	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
Tokamak Fusion Test Reactor (TFTR)...............	$ 74,832	$ 66,230	$ 38,000	$ -28,230
Base Toroidal.....................................	61,341	71,808	81,300	9,492
Advanced Toroidal.................................	7,804	7,819	0	-7,819
Tokamak Physics Experiment (TPX).................	19,179	42,000	12,192	-29,808
Total, Magnetic Fusion Energy - Confinement Systems	$ 163,156	$ 187,857	$ 131,492	$ -56,365

II. B. Laboratory and Facility Funding Table: Magnetic Fusion Energy - Confinement Systems

Lawrence Livermore National Lab	4,469	4,950 ✓	4,500	-450
Oak Ridge National Lab	10,363	~~8,541~~ 8,981	7,345	-1,196
Princeton Plasma Physics Lab	95,573	~~106,945~~ 112,449	65,092	-41,853
All Other	52,751	~~67,421~~ 61,477	54,555	-12,866
Total, Magnetic Fusion Energy - Confinement Systems	$ 163,156	$ 187,857	$ 131,492	$ -56,365

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1994	FY 1995	FY 1996
Magnetic Fusion Energy - Confinement Systems			
Tokamak Fusion Test Reactor (TFTR)	During FY 1994, TFTR achieved a record 9 million watts of fusion power and made a significant step toward demonstrating the scientific feasibility of fusion power. TFTR provided specific information on confinement in deuterium-tritium (D-T) plasmas, radio frequency heating of D-T plasmas, and the behavior of the fusion-produced alpha particles to the ITER design team.	TFTR scientists recently achieved their goal of 10 million watts of fusion power. They will continue D-T experiments in FY 1995 to gain additional information on the effects of alpha particles on the plasma and to test alpha particle diagnostics for ITER. They will complete the D-T experiments by the end of the year and begin final analysis of the data.	TFTR scientists will complete the analysis of the TFTR data. Then they will begin collaborative experiments on DIII-D and Alcator C-MOD in the U.S., JET, ASDEX-Upgrade, and Tore Supra in Europe, and JT-60U in Japan. These experiments will be focused on confinement, plasma heating, current drive, power handling and studies of the edge plasma, and D-T experiments on JET. These collaborations will use the TFTR group's expertise to carry out physics R&D for ITER and TPX and will also maintain the experienced team needed to operate the TPX. TFTR engineers and technicians will complete the safe shutdown of all TFTR systems and begin preparations for the removal of the tokamak. They will also prepare many of the TFTR facilities for transfer to TPX.
	$ 74,832	$ 66,230	$ 38,000
Base Toroidal	DIII-D was operated at the beginning of the fiscal year and increased its world record high beta (efficiency of magnetic field utilization) to 12%. It was shut down for about 7 months for improvements to heating and power exhaust systems, and for the installation of a new pellet fueling system. Experimental operations resumed in May 1994 with a focus on heating and current drive experiments with the new power system, power and particle exhaust studies, and confinement experiments, all in support of the design of ITER and TPX.	The DIII-D program will increase operations and continue with current drive experiments using the upgraded radio frequency power system and pellet fueling experiments. The engineering design of a radiative divertor for heat and particle exhaust will be initiated, and the 2 MW microwave heating system will be completed. DIII-D will also investigate long-pulse operating techniques that could be extrapolated to the operation of ITER and TPX, which will both have significantly longer operating pulses (approximately 1000 seconds).	The DIII-D program will continue with heating and current drive experiments using combined microwave and lower frequency radio waves. Fabrication of major components of the radiative divertor will be completed. DIII-D will also explore new methods of tokamak operation to improve the attractiveness of fusion power plants.

Program Activity	FY 1994	FY 1995	FY 1996
Base Toroidal (Cont'd)	Alcator C-MOD successfully completed its first phase of physics operation. Divertor and edge physics studies along with detailed measurements of the scrape-off layer were performed. Additional heating and diagnostic systems were added during a five-month shutdown, and the second phase of operations begun in May.	C-MOD scientists will undertake an evaluation of power handling, heating efficiency and impurity generation using a flexible particle removal scheme that is relevant to ITER and will compare results with other existing schemes.	The Alcator C-Mod program will extend its heating and power handling program to new regimes with the addition of an additional 2 MW of heating power. In addition, C-Mod will begin experiments on radio wave current drive at high plasma densities.
	Scientists from ORNL, GA, and a few universities continued collaborations with the tokamaks in Germany (TEXTOR and ASDEX), France (Tore Supra), England (JET), Japan (JFT-2M and JT-60U), and Russia (T-10) in the areas of power and particle exhaust, long pulse operation, and radio frequency heating. These collaborative programs provide important physics R&D for ITER and TPX.	International collaborative programs will continue with an emphasis on the needs of the ITER and TPX physics design activities.	International collaborative programs will continue with an emphasis on the needs of the ITER and TPX physics design activities.
			Funding in the amount of $269,000 has been budgeted for the STTR program.
	$ 61,341	$ 71,808	$ 81,300
Advanced Toroidal	PBX-M was operated briefly in the early part of the fiscal year to complete experiments in progress and then it was mothballed for the remainder of the year. These experiments produced useful results on plasma profile control with radio frequency heating in support of the TPX design. Several subsystems were refurbished and modified in preparation for future operations.	PBX-M will remain mothballed in FY 1995 and the PBX-M group will participate in the experiments on TFTR.	PBX-M will be shut down in FY 1996, and the remainder of the PBX-M group will participate in collaborative experiments.

III. Magnetic Fusion Energy - Confinement Systems (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
Advanced Toroidal (Cont'd)	The re-assembly of the ATF facility was completed in the middle of fiscal year. About one month of long-pulse experiments in support of power and particle exhaust requirements for TPX and ITER were carried out before ATF was permanently shut down in the summer of 1994.	The remaining ATF scientific staff will collaborate on the U.S. and foreign tokamaks to support the ITER and TPX design and on international stellarators to keep abreast with the developments in this alternate concept.	ORNL scientific staff will continue to keep abreast of the developments in alternate concepts and will collaborate on international stellarators.
	$ 7,804	$ 7,819	$ 0
Tokamak Physics Experiment (TPX)	The national TPX project team began preliminary design of major tokamak systems and carried out supporting R&D. This R&D is being coordinated with that for ITER in order to maximize cost efficiency. A DOE Management Systems Review of TPX was successfully conducted which judged the project's management systems and business practices to be fundamentally sound. Industrial subcontracts under PPPL and LLNL were established for hardware design of the vacuum vessel, plasma facing components, and magnets. RFP's for systems integration support and construction management were also released. The Preliminary Safety Analysis Report was initiated.	The TPX lab-industry team will continue preliminary design of major tokamak systems in preparation for starting final design work on most systems in FY 1996. The design effort will be expanded to encompass some auxiliary systems. Prototype superconductor material for the magnets will be produced by industry to demonstrate manufacturing techniques and qualify vendors for future procurements. In addition, mock-ups of the internal tokamak components will be built to develop and demonstrate design concepts for remote (robotic) maintenance equipment. Industrial contracts for systems integration and tokamak construction management will be placed. The Preliminary Safety Analysis Report will be completed and submitted to DOE.	The project's highest priority R&D will be carried out on schedule to support design work on the magnets, plasma facing components, remote maintenance equipment, and vacuum vessel. Physics R&D will also continue in support of the design effort. Final design activities will be limited to critical tokamak subsystems. The industrial management support staff located at Princeton will be fully established.
	$ 19,179	$ 42,000	$ 12,192
Magnetic Fusion Energy - Confinement Systems	$ 163,156	$ 187,857	$ 131,492

KEY ACTIVITY SUMMARY

FUSION ENERGY

I. Preface: Magnetic Fusion Energy - Applied Plasma Physics

The Applied Plasma Physics subprogram plays a crucial role in the development of the fundamental understanding of plasma behavior in magnetic confinement devices, and therefore, funds work that addresses the ignition and burn and the concept optimization issues. To achieve its mission, the subprogram funds:

1. efforts in the development of theories and models of plasma behavior in various confinement geometries with emphasis on the tokamak,

2. experimental confinement physics including diagnostics development,

3. computing resources for the entire fusion program,

4. the development of new approaches in the design and operation of toroidal devices, as well as with the development of novel concepts and geometries for possible future power plants,

5. the use of development tools in the analysis and interpretation of data from experiments funded by the Confinement Systems subprogram, and

6. people to participate in the design of experiments on existing devices and in the design of future devices. Particular emphasis is presently placed on support of the design of ITER and TPX.

This subprogram includes three separate subactivities: Plasma Theory, Experimental Plasma Research, and Magnetic Fusion Energy Computing.

Recently, in Plasma Theory activity, there has been significant improvement in the understanding of the physics of tokamaks. These advances, coupled with a steady increase in computational capabilities, have led to an effort to develop models to simulate what is happening inside a tokamak. Improvement and evaluation of these models will continue in FY 1996. The capabilities of these models to predict how plasmas will behave will be tested by comparing results from the models to actual plasma performance observed in various tokamaks including DIII-D, C-MOD and TEXT. When the models are verified they will be used as tools to aid in the design of fusion experiments such as TPX and ITER, and eventually, in the design of a demonstration power plant.

The Experimental Plasma Physics effort develops and extends the scientific basis for fundamental fusion concepts. Most tasks are carried out at universities, with lesser involvement by national laboratories and industry. This approach exploits the ability of university programs to economically obtain the information necessary to justify investment in large experimental machines. The emphasis of this part of the subprogram is shifting from the "conventional" tokamaks to innovations in tokamaks and to non-tokamak concepts. This shift will be accelerated by planned restructuring in FY 1996.

The diagnostic development activity will continue to develop advanced diagnostics for present and future devices, most specifically ITER. This activity will become more costly, as developmental diagnostic devices are deployed on larger fusion facilities like TPX. International collaborations will be increased where appropriate.

The Office of Energy Research's Office of Scientific Computing provides access to state of the art computing hardware for the fusion energy program. The Energy Sciences Network, supported by the Office of Scientific Computing, and related computing facilities, supported by the Office of Fusion Energy, provide the infrastructure for the development of codes, storage and analysis of experimental data and the means of maintaining cooperative projects with the world fusion community.

II. A. Summary Table: Magnetic Fusion Energy - Applied Plasma Physics

Program Activity	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
Fusion Plasma Theory	$ 18,231	$ 17,100	$ 18,000	$ 900
Experimental Plasma Research	24,882	24,025	20,821	-3,204
MFE Computing	14,137	13,150	10,000	-3,150
Total, Magnetic Fusion Energy - Applied Plasma Physics	$ 57,250	$ 54,275	$ 48,821	$ -5,454

II. B. Laboratory and Facility Funding Table: Magnetic Fusion Energy - Applied Plasma Physics

	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
Lawrence Livermore National Lab	12,740	11,784	10,211	-1,573
Los Alamos National Laboratory	2,380	1,585	2,013	428
Oak Ridge National Lab	4,058	4,043	3,578	-465
Princeton Plasma Physics Lab	3,361	3,399	3,054	-345
All Other	34,711	33,464	29,965	-3,499
Total, Magnetic Fusion Energy - Applied Plasma Physics	$ 57,250	$ 54,275	$ 48,821	$ -5,454

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1994	FY 1995	FY 1996
Magnetic Fusion Energy - Applied Plasma Physics			
Fusion Plasma Theory	Maintain emphasis on improved understanding of how energy and particles are lost from the plasma in toroidal devices. Provide codes to interpret the Deuterium-Tritium experiments on TFTR. Make use of massively parallel computers to increase the detail and realism of codes for the prediction of plasma stability and losses from the plasma under self-sustaining fusion conditions.	Maintain emphasis on improved understanding of plasma losses in toroidal devices. Make use of this improved understanding to advance the capabilities of predicting ITER performance. Make these capabilities available to increase the range of possible design alternatives for fusion power plant concepts.	Begin using tools developed under the Numerical Tokamak Initiative to model transport, i.e., loss of particles and energy, in fusion grade plasmas. Incorporate the effect of fluctuations in the plasma on the loss of particles and energy from tokamaks in the presence of significant alpha particle populations. Deploy codes that contain the effects of stabilization of plasma magnetic activity by shear and plasma rotation. Develop models to characterize plasma transients and ways of controlling plasma magnetic activity.
	Continue development and application of fusion physics models for ITER, with particular emphasis on plasma stability, disruptions and heat and particle control in the divertor in ITER.	In continuing support of ITER design, develop and validate more realistic models of plasma edge and divertor; develop models of how to stabilize plasmas by causing the plasma to rotate; develop models to predict and control plasma disruptions in TPX and ITER; and develop new ways of designing plasma control systems.	Deploy realistic plasma edge codes to predict ITER performance in controlling particle and energy fluxes and initiate efforts to develop optimum designs for an ITER divertor. Develop codes to characterize and provide optimization of control system parameters. Develop codes to study the use of synergistic effects of external current drive, internally generated currents and power deposition within the plasma to achieve plasma stability for enhanced plasma operating conditions.
	Maintain meaningful contacts with domestic and foreign alternate concept experiments and apply the ideas and results coming from these experiments to the improvement of tokamak operations.	Continue cooperating with foreign alternate concepts programs and apply the special insights gained in these geometries to point to improved tokamak operations.	Initiate steps to participate in modeling efforts for the Large Helical Device (LHD) being constructed in Japan which is scheduled to have first plasma in 1998. Continue the transfer of models and tools developed in the study of alternate concepts to the development of advanced tokamak scenarios with particular emphasis on plasma stability and fueling.

Program Activity	FY 1994	FY 1995	FY 1996
Fusion Plasma Theory (Cont'd)	$ 18,231	$ 17,100	$ 18,000
Experimental Plasma Research	Physics studies of tokamaks at aspect ratios significantly different from the mainline tokamaks are continuing at Columbia and PPPL. Investigating the physics of injecting small plasma bodies (called compact toroids) into magnetic fields will be completed at UC Davis and collaborations with Tokamak de Varennes in Canada on using compact toroids to fuel tokamaks will continue. Current drive using radio frequencies below the ion cyclotron frequency is being evaluated at the University of Wisconsin.	Continue physics studies of tokamaks at high and low aspect ratios at Columbia and PPPL to improve physics understanding of the tokamak. Participate in international collaboration on low aspect ratio tokamak research. Complete small scale evaluation of radio frequency current sustainment at the University of Wisconsin.	There will be some restructuring of a reduced toroidal plasma program beginning in FY 1996 with the intent of providing innovation in toroidal experiments and increasing the breadth of the small scale experimental program. Existing tokamak programs will complete conceptual physics studies of high and low aspect ratio configurations to improve physics understanding of the tokamak. There will be continued participation in international collaboration on low aspect ratio tokamak research. Several university experiments will be phased out to accommodate the reduced budget level.
	Continue developing physics basis of non-tokamak devices at several laboratories. At the University of Wisconsin, evaluation of the physics for transition of the plasma magnetic structure from tokamak to reversed field pinch configuration is being initiated with emphasis on understanding changes in particle and energy losses. Also at the University of Wisconsin, fabrication will continue on the helically symmetric plasma system which, when completed, will provide a small scale physics study of an alternate to both the tokamak and presently used stellarators. The field reversed configuration device to be used in compact toroid acceleration experiments at the University of Washington will be on line. Small scale experiments will be carried out on new concepts for more attractive fusion cores.	Investigate means for improving containment of energy and particles in reverse field pinches at the University of Wisconsin. Evaluate accelerated compact toroid plasma configurations as fusion core fueling concept at the University of Washington. Continue fabrication of the helically symmetric plasma system at the University of Wisconsin for physics test of a non-tokamak reactor concept. Evaluate accelerated compact toroid configurations as reactor fueling concept at the University of Texas on the TEXT tokamak. Provide critical evaluation of small scale exploration of new concepts to provide basis for determining continued funding.	There will be continuing emphasis on non-conventional plasma devices. Critical evaluations of the future role of the reverse field pinch as a confinement device will be carried out at the University of Wisconsin. The helically symmetric plasma system will be in the final stages of fabrication. If progress is satisfactory, funding for continuation of one or more of the new concepts completed in FY 1995 will be considered.

III. Magnetic Fusion Energy - Applied Plasma Physics (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
Experimental Plasma Research (Cont'd)	Proof-of-principle experiments for different alpha diagnostics are being carried out during the deuterium-tritium operation of TFTR. Advanced diagnostic development of techniques applicable to ITER and other future devices will continue. Participate in planning for advanced diagnostics for ITER at a pace consistent with ITER management. Continue implementation of fluctuation diagnostics including participation in physics experimenta on confinement devices.	Continue international collaboration for proof-of-principle tests for alpha diagnostic. Evaluate results obtained from alpha diagnostics deployed on TFTR. Actively participate in research and development consistent with ITER diagnostics requirements.	Diagnostics efforts will increase the emphasis on new approaches particularly with application to divertor measurements. The development of alpha diagnostics for future devices will involve collaboration with the JET tokamak. Based on projected ITER needs, selected ITER relevant diagnostic research will be initiated. The total diagnostics effort, however, will be reduced due to the lower budget level.
	Text upgrade is operating with microwave heated plasmas to observe transitions between low and high plasma confinement modes and to characterize these transitions using a heavy ion beam probe for measurements of internal plasma parameters as well as other diagnostics. Lack of a higher frequency power source at this time will limit the scale of experiments.	Operate TEXT upgrade experiment with restrictions in heating power and operation time due to budget constraints. Use full capability of heavy ion beam probe to characterize the internal parameters of the plasma which affect particle and energy movement within and out of the plasma for different plasma modes.	Continue operation at a reduced level of TEXT-Upgrade with microwave heating and with fully operational enhanced diagnostics. Emphasis will be on understanding internal plasma parameters and on the transport of energy and particles within and out of the plasma.
	An atomic data compilation and distribution, with increased emphasis on data for divertor and edge physics, is continuing.	Continue support of main stream fusion experiments including ITER by producing, compiling and distributing atomic data.	A reduced atomic physics program will place more emphasis on providing detailed information for divertor and edge modeling. International cooperation and collaboration will become more important and on line services will be further refined.
	$ 24,882	$ 24,025	$ 20,821

III. Magnetic Fusion Energy - Applied Plasma Physics (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
MFE Computing	Support access to Energy Sciences Network and primary Energy Research computers. Provide local computers at fusion sites. Support specific computer code developments using new high performance computers for tokamak simulation.	Continue supporting access to Energy Research computing facilities. Prototype the implementation of distributed computing to gain experience in running experiments and theory support at remote sites. Support the development of codes optimized for massively parallel computers to advance the realism of codes that simulate tokamak operations.	Access to Energy Research computers and services will be supported by the programs. Computer services and purchase of computers will be funded out of individual programs as required.
	$ 14,137	$ 13,150	$ 10,000
Magnetic Fusion Energy - Applied Plasma Physics	$ 57,250	$ 54,275	$ 48,821

DEPARTMENT OF ENERGY
FY 1996 CONGRESSIONAL BUDGET REQUEST
ENERGY SUPPLY, RESEARCH AND DEVELOPMENT
(dollars in thousands)

KEY ACTIVITY SUMMARY

FUSION ENERGY

I. Preface: Magnetic Fusion Energy - Development and Technology

The Development and Technology subprogram addresses the technology aspects of all of the fusion program issues: ignition and burn, concept optimization, fusion nuclear technology, and materials development. The work supported by this subprogram includes: the design and technology development for the International Thermonuclear Experimental Reactor; the development of the technologies needed for the Tokamak Physics Experiment, D-III-D and other fusion experiments; and studies of future fusion power plant designs. The work is divided into five main technical areas: ITER, Plasma Technologies, Fusion Technologies, Advanced Materials and Fusion Systems Studies.

The U.S. has committed to be an equal partner with the European Union, Japan and the Russian Federation in a 6-year program to prepare an engineering design and conduct related R&D for the ITER project. These tasks are referred to as the Engineering Design Activities or the EDA. The current agreement among the four ITER Parties is limited to the EDA phase of the program. While no decision has been made to construct the facility, the Parties will be initiating discussions on possible construction and the issue of facility siting. The overall objectives of ITER are to demonstrate the scientific and technological feasibility of fusion power, to demonstrate controlled ignition and extended burn, and to validate design concepts and qualify engineering components for a fusion power plant. The EDA began on July 21, 1992 with the signing of a formal agreement by the four Parties.

The Development and Technology subprogram funds the U.S. share of ITER design and technology R&D work. Theory and diagnostics support for ITER are funded by the Applied Plasma Physics subprogram, and experimental tokamak physics support is provided by the Confinement Systems subprogram.

One of the goals of the EDA effort is to involve U.S. industrial firms, enabling them to compete for contracts to fabricate components and systems for ITER. U.S. industrial firms have been integrated into the U.S. effort in order to provide expertise in large project management, systems design and integration, scale-model components and specific technology development tasks. The technology development tasks selected for emphasis in FY 1996 will be a continuation of those assigned by and negotiated with the ITER Director and approved by the ITER Council, the project's governing body, in FY 1995.

The second technical area, Plasma Technologies, supports the technologies needed to form, confine, heat, and sustain a fusion plasma. These technologies include magnetic systems, plasma heating systems, fueling systems and the materials that will be used in the plasma environment. While the principal focus of these activities is ITER, development in support of existing and near term devices, such as D-III-D and TPX, is also supported.

The magnetic systems program is developing reliable pulsed and steady state superconducting magnets that provide the magnetic fields required to confine the plasma. The heating program focuses on developing the technologies required to heat the plasma and to sustain it. The plasma fueling program develops high-speed deuterium and tritium pellet injectors not only to supply fuel to the plasma chamber, but also to control the plasma density for optimum performance. The development of heating and fueling systems directly supports the operating magnetic confinement experiments such as D-III-D and TFTR in the U.S. and the Joint European Torus in England, and has enabled the production of record plasma conditions in the D-III-D at General Atomics in San Diego. Research continues for materials that will withstand high heat and erosion in power plant components located near the plasma.

Future experiments in TPX and ITER of extended duration in higher density and higher temperature plasmas will necessitate continued development in each of these areas. The U.S. is participating in bilateral and multi-lateral international collaborations on these topics.

The third area, Fusion Technologies, focuses on long-term waste issues, safety and environmental considerations, component reliability, fuel breeding and processing, and removing the energy released during the fusion reactions from the plasma. These elements are important for future fusion power plants, as well as ITER and TPX.

The fusion systems studies team shifts effort to prepare for the commercial application of fusion power. Utility and industrial participation is strengthened, and the conceptual design of a DEMO, the major program step after ITER, is undertaken.

The advanced materials program includes three elements: low activation structural materials; insulating ceramics; and planning for a Materials Test Facility. All three are directed at development of the materials that will result in an economically competitive, environmentally attractive fusion power system. In all areas the work is closely connected to the international fusion program, through IEA and bilateral collaboration programs.

Some of the facilities used in the Development and Technology subprogram include: the FENIX Test Facility at the Lawrence Livermore National Laboratory for testing of superconducting magnets; the Plasma Materials Test Facility at Sandia National Laboratories; the RF Test Facility at Oak Ridge National Laboratory; and a test facility at VARIAN Corporation which tests high power microwave tubes. The Tritium Systems Test Assembly at Los Alamos National Laboratory (LANL) and the fusion materials work in the High Flux Isotopes Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) are also supported under collaborative agreements with Japan.

II. A. Summary Table: Magnetic Fusion Energy - Development and Technology

Program Activity	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
ITER	$ 60,776	$ 67,864	$ 80,100	$ 12,236
Plasma Technologies	5,516	6,040	3,300	-2,740
Fusion Technologies	3,461	3,337	4,600	1,263
Fusion Systems Studies	2,734	2,450	3,000	550
Advanced Materials	5,463	9,335	9,400	65
Total, Magnetic Fusion Energy - Development and Technology	$ 77,950	$ 89,026	$ 100,400	$ 11,374

II. B. Laboratory and Facility Funding Table: Magnetic Fusion Energy - Development and Technology

Argonne National Lab (East)	$ 5,943	$ 6,305	$ 8,100	$ 1,795
Lawrence Livermore National Lab	7,720	8,698	7,200	-1,498
Los Alamos National Laboratory	3,698	3,676	4,728	1,052
Oak Ridge National Lab	12,332	13,697	15,250	1,553
Pacific Northwest Lab	3,219	2,990	3,520	530
Sandia National Laboratories	5,475	7,297	6,780	-517
All Other	39,563	46,363	54,822	8,459
Total, Magnetic Fusion Energy - Development and Technology	$ 77,950	$ 89,026	$ 100,400	$ 11,374

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1994	FY 1995	FY 1996
Magnetic Fusion Energy - Development and Technology			
ITER	In the magnet area, design and development of ITER model coils and preparations for test of these coils will continue. Superconducting strand with ITER specifications for Stage 1 is being completed and delivered. Component testing in FENIX will be continued.	In the magnet area, design and development of ITER model coils and preparations for testing of coil components and fabrication techniques will continue. U.S. testing of superconducting strand will continue. U.S., Japanese, and Russian Federation superconducting cable for ITER will begin. Structural materials tests will continue.	In the magnet area, design and development of ITER model coils and components and fabrication techniques will continue. U.S. testing of superconducting strand will continue and cabling the strands in collaboration with the EU will begin. Testing of full size, short samples of U.S., Japanese and Russian Federation superconducting cable for ITER will continue. Structural material tests will continue.
	In the heating area, development of gyrotron tubes and radio frequency launchers will continue.	In the heating area, development of advanced radio frequency launchers and gyrotron tubes and components for ITER will continue.	In the heating area, development of 1 MW, advanced gyrotron tube and components for ITER will continue. Development of radio frequency system components will be initiated.
	In the fueling area, general development of a high speed pellet injector to meet ITER needs will occur.	In the fueling area, design of a high speed pellet injector to meet ITER needs will occur.	In the fueling area, fabrication of a high speed pellet injector to meet ITER needs will occur.
	In the area of plasma materials interaction, the reference ITER divertor concepts are being studied and evaluated; and tests will continue on beryllium, carbon and high Z materials. Erosion and redeposition and disruption simulation tests will continue.	In the area of plasma materials interaction, ITER divertor concepts will be refined and examined. Tests will continue on beryllium, erosion and high Z materials. Erosion, redeposition and disruption simulation tests will continue. ITER divertor-specific modelling will be continued. Disruption modelling will continue.	In the area of plasma materials interaction, ITER divertor concepts will be refined and examined. Tests will continue on beryllium, erosion and high Z materials. Erosion, redeposition and disruption simulation tests will continue. ITER divertor-specific modelling will be continued. Disruption modelling will continue.

III. Magnetic Fusion Energy - Development and Technology (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
ITER (Cont'd)	Continued as a full participant in the ITER design for the EDA by providing the U.S. staffing for the Joint Central Team (JCT) and providing design support of the U.S. Home Team for the JCT. An industrial contract was established with a conglomerate of industrial companies to provide this support. The U.S. provides ITER design support on magnets, blankets, divertors, remote maintenance, vacuum vessels as well as costing and work breakdown analysis.	Continue the U.S. support for the Four-Party design of the ITER by continuing the tasks begun in FY 1994 and adding other support requested by the JCT to the limit of the U.S. share as defined by the ITER Council and negotiated with the JCT.	Continue the U.S. support for the Four-Party design of the ITER by continuing the tasks begun in FY 1994 and adding other support requested by the JCT to the limit of the U.S. share as defined by the ITER Council and negotiated with the JCT.
	Provide for management of the U.S. ITER Home Team. Support Operation of the San Diego ITER Co-Center.	Provide for management of the U.S. ITER Home Team. Support operation of the San Diego Co-Center.	Provide for management of the U.S. ITER Home Team. Support operation of the San Diego Co-Center.
	Conduct U.S. task assignments in TSTA to provide data base for and validation of ITER fuel cycle design, performance validation and safety analysis.	Conduct U.S. task assignments in TSTA to provide data base for and validation of ITER fuel cycle design, performance validation and safety analysis.	Complete tritium testing of palladium membrane reactor (PMR) concept for fuel cleanup as a stand-alone system. Begin integration of PMR concept into the full TSTA processing loop. Conduct U.S. task assignment in TSTA to provide data base for validation of ITER fuel cycle design.
	The magnetic fusion program will continue to evaluate and support improving the safety of ITER with regard to activation products, confinement, and tritium safety. An integrated failure data base and design standards will also be developed.	The magnetic fusion program will continue to evaluate and support improving the safety of ITER with regard to activation products, confinement, and tritium safety. An integrated failure data base and design standards will also need to be developed.	Determine and evaluate activation products and tritium source terms based on ITER design for safety analysis purposes. Conduct experiments as necessary on potential release mechanisms and confinement barriers.

Program Activity	FY 1994	FY 1995	FY 1996
ITER (Cont'd)	U.S. task assignments for ITER first wall/blanket/shield (FW/B/S) R&D will be conducted on key issues for reference concept (water cooling and steel structure) and for the advanced concept (lithium cooling and vanadium structure). For the advanced concept, the U.S. will lead in development of an insulator coating to minimize magnetic effects of flowing lithium.	Under an industry contract, small-scale mockups of the water cooled FW/B/S concept will be fabricated and tested with heating loads that simulate ITER operating conditions. A small vanadium test section cooled with high-temperature lithium will be operated to demonstrate the performance of the insulator coating for the advanced FW/B/S. Mockups exposed to a small 14 MeV neutron source in Japan will be initiated.	Medium-scale mockups testing of both the water-cooled and lithium-cooled FW/B/S concepts for ITER will be initiated to establish normal thermalhydraulic and thermomechanical performance parameters and to determine responses to off-normal conditions. Initial nuclear testing with Japan's 14 MeV neutron source will be completed to establish the effectiveness of ITER radiation shielding and the distribution of nuclear heating.
	U.S. tasks for remote maintenance and vacuum vessel (VV) R&D will be conducted as assigned. In the remote maintenance area, concepts will be developed by industry for cutting/welding of coolant pipes and approaches will be evaluated for remotely operated electrical connectors and in-vessel mapping. In the VV area, an industrial activity will begin on fabricating a full-scale mockup of the in-board VV section and on techniques for VV cutting/welding.	Work will be initiated to procure welding/cutting equipment for coolant pipes and VV sections. The mockup of the in-board VV section will be tested for hydraulic and mechanical performance and a second full-scale VV section will be fabricated by industry for testing.	Prototype welding/cutting equipment will be tested under conditions simulating the remote handling requirements for ITER assembly and maintenance. The second VV section mockup will be tested for hydraulic and mechanical performance and work will be initiated on U.S. contribution toward fabrication of a complete VV sector mockup
	U.S. work on structural materials for the first wall/blanket/shield is being conducted on agreements approved by the JCT. The test program includes: a major task to validate vanadium-chromium-titanium alloys for an advanced blanket; the irradiation performance of candidate copper alloys; planning to produce copper/steel wall material for testing; and experimental evaluation of austenitic stainless steels.	The U.S. will continue the evaluation of vanadium alloys, copper, copper-steel, and austenitic stainless steels for ITER in-vessel components. Emphasis will be on the effects of irradiation, using U.S. and Russian Federation research reactors.	Evaluation of structural materials for ITER, including vanadium, copper, and steel will emphasize fracture properties and other conditions specified by the JCT designers. Irradiation effects evaluation will continue, supplemented by base property measurements for mechanical, physical, and chemical compatibility behavior.

III. Magnetic Fusion Energy - Development and Technology (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
ITER (Cont'd)	Experimental work to define the effects of irradiation and other service variables on the properties of insulating ceramics and optical materials are under way. Irradiations in U.S. experimental facilities are used to simulate the ITER environment, and include the in-situ measurement of critical electrical properties during irradiation. The program also evaluates the change in properties after the irradiation exposure.	Insulating ceramic materials and materials for optical component systems will be under test in both separate material and component forms. Testing conditions will emphasize the effects of irradiation and other environmental factors on these materials to qualify them for use in ITER components. Irradiations in U.S. test reactors will be used to simulate ITER conditions. In-situ measurement of critical electrical properties will be included.	Evaluation of insulating ceramic and optical materials under simulated ITER service conditions will continue. These test will be conducted to qualify available materials for use in diagnostic components in ITER.
	$ 60,776	$ 67,864	$ 80,100
Plasma Technologies	In the heating area, development of 110 GHz, 1 MW gyrotron tubes will be continued and design of internal coupler will be completed. ICRH antenna design and development work will proceed in support of existing and near term fusion devices.	In the heating area, fabrication of 1 MW, 110 GHz gyrotron tube with internal coupler will be completed. ICRH antenna design and development work will proceed in support of existing and near term fusion devices. Tests of a folded waveguide antenna on a tokamak will be considered. Studies to determine heating requirements for TPX will be initiated.	The 1 MW, 110 GHz gyrotron will be tested in FY 1996, and ICRH antenna design efforts in support of near term fusion research will be slowed down.
	Advanced two-stage pellet injectors will be developed and tested.	Two-stage high speed pellet injector development will be continued.	Pellet injector development will be slowed down.
	In the plasma materials interaction area, effort is focused to provide tritium inventory support for TFTR and international collaborations. Divertor modelling support for TPX is being provided.	In the plasma materials interaction area, effort will be focused on providing plasma facing component measurements of erosion in support of TPX and beryllium fabrication for international collaborations. Divertor modelling efforts will continue.	In the plasma materials interaction area, effort will be slowed to focus only on providing plasma facing component measurements of erosion in support of TPX.
	Superconducting wire characterization test and magnet analysis are being continued. Magnet insulator development will continue. Development support for TPX magnets is being provided.	New superconducting wire characterization tests, magnet analysis, and prototype fabrication will be examined. Development support for TPX magnets will be continued.	Development support for TPX magnets will be continued.

Program Activity	FY 1994	FY 1995	FY 1996
Plasma Technologies (Cont'd)	$ 5,516	$ 6,040	$ 3,300
Fusion Technologies	Continue BEATRIX II program under an IEA agreement to test the neutron irradiation performance of candidate ceramic materials that would breed tritium in a fusion power plant. Initiate concept definition study under an IEA agreement of a Volumetric Neutron Source (VNS) facility that would be dedicated to the testing, development, and verification of nuclear components for fusion power plants. Continue international cooperative programs on U.S.-Japan testing of tritium fuel cycle components and system in TSTA.	Complete post-irradiation examination studies of ceramic breeder materials tested under the BEATRIX-II program. Initiate a conceptual design activity of VNS under an IEA agreement. Initiate planning of a cooperative activity under an IEA agreement, for R&D needed to design and construct mockups of DEMO-relevant nuclear components that will be tested in ITER. Testing in TSTA will be reduced and focussed on critical fuel cycle issues.	Continue pre-conceptual design of VNS and complete preliminary evaluations of VNS technical issues, R&D requirements, and construction costs. Begin cooperative R&D programs for R&D to design and construct mockups of DEMO-relevant nuclear components that would be tested in ITER. Conduct the DOE-JAERI Collaborative Program on tritium safety and safety technology research. Complete decontamination and decommissioning of JAERI Fuel Cleanup System. Conduct experiments on behavior of tritium releases, develop technology for tritium waste handling, tritium confinement and detriation system and materials accountability.
	$ 3,461	$ 3,337	$ 4,600
Fusion Systems Studies	The pulsed tokamak power plant design will be completed and the PULSAR report issued. Technical work on the Stellarator power plant study will be finished and the project report issued in April 1995. The new project, Starlite, undertakes preparation for the fusion power plant design, DEMO, and roll-forward assessments of needed technology R&D is beginning. Close cooperation with utility advisors continues.	Starlite project continues. A team of university, laboratory, and industrial design engineers prepare demo requirements based on definitions and purpose of the demo that were established in FY 1994. Utility advisors review DEMO planning. Design concept of DEMO endorsed by fusion community and other stakeholders. Stellarator study is completed.	Pre-conceptual system design studies of fusion demonstration power plant begin. Industrial participation and responsibility are expanded.
	$ 2,734	$ 2,450	$ 3,000

III. Magnetic Fusion Energy - Development and Technology (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
Advanced Materials	Structural Materials for first wall/blanket/shield regions, divertor structures, and ceramics for insulating applications are under evaluation and development. Emphasis is on low activation materials meeting performance requirements, emphasizing resistance to degradation under irradiation. Evaluation of vanadium and silicon carbide are emphasized. Two active collaborations with Japan are included in the program.	Work will be expanded to develop low activation materials suitable for in-vessel structural applications in fusion power systems. Experimentation on insulating ceramics will also be continued. Low activation structural materials under study include vanadium alloys, silicon carbide composites and ferritic steels. Bilateral collaborations with Japan and Russia provide expertise and facilities to expand work in this program. Coordination of work with ITER and IEA partners is continuing.	Experimental, modeling, and theoretical work will be continued to develop low activation structural and special purpose materials for in-vessel use in fusion power systems. Planning will be completed to guide this program to the qualification of materials for a demonstration power system. Active collaborations will be continued and expanded with ITER and IEA partners.
	During 1994, the U.S. has led IEA partners and the Russian Federation in the initial stages of planning for an International Fusion Materials Irradiation Facility (IFMIF). In parallel, facility options have been evaluated and a preliminary outline of system requirements developed. A possible facility layout has been completed. The active participation of an industrial team has expanded the capabilities of a three-laboratory partnership in this work.	An active conceptual design activity will be underway to define a deuterium-lithium neutron source that will meet the needs of the ITER partners to develop materials for fusion power systems. The U.S. expects to participate in all phases of this activity, with emphasis on the accelerator technology and design integration.	Active support of the IEA led conceptual design activity of the Four ITER partners will allow completion of most of the conceptual design activity for a deuterium-lithium neutron source facility during this year. It is anticipated that some component development may also be underway, to answer the most important critical issues identified in the earlier phases of this design work.
	$ 5,463	$ 9,335	$ 9,400
Magnetic Fusion Energy - Development and Technology	$ 77,950	$ 89,026	$ 100,400

DEPARTMENT OF ENERGY
FY 1996 CONGRESSIONAL BUDGET REQUEST
ENERGY SUPPLY, RESEARCH AND DEVELOPMENT
(dollars in thousands)

KEY ACTIVITY SUMMARY

FUSION ENERGY

I. Preface: Planning and Projects

II. A. Summary Table: Planning and Projects

Program Activity	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
Planning and Projects	$ 38	$ 7,364	$ 6,053	$ -1,311
Total, Planning and Projects	$ 38	$ 7,364	$ 6,053	$ -1,311

II. B. Laboratory and Facility Funding Table: Planning and Projects

	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
All Other	$ 38	$ 7,364	$ 6,053	$ -1,311
Total, Planning and Projects	$ 38	$ 7,364	$ 6,053	$ -1,311

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1994	FY 1995	FY 1996
Planning and Projects	Funding in the amount of $4,559,000 and $152,000 has been transferred to the SBIR program and the STTR program, respectively.	Funding in the amount of $6,866,000 and $343,000 has been budgeted for the SBIR program and the STTR program, respectively.	Funding in the amount of $5,797,000 and $166,000 has been budgeted for the SBIR program and the STTR program, respectively.
	$ 38	$ 7,364	$ 6,053
Planning and Projects	$ 38	$ 7,364	$ 6,053

KEY ACTIVITY SUMMARY

FUSION ENERGY

I. Preface: Inertial Fusion Energy

Progress in inertial confinement fusion has provided confidence that net energy release in the laboratory is possible through compression, ignition, and burn of deuterium-tritium fuel microcapsules. With this background, the Department of Energy has established this Inertial Fusion Energy (IFE) subprogram to develop the potential of inertial fusion as an energy source. This activity is managed as a separate component of the Office of Fusion Energy within the Office of Energy Research.

This activity will rely on coordination with the Inertial Confinement Fusion Program in the Office of Defense Programs and has extended the Heavy Ion Fusion Accelerator Research that previously was undertaken within the Basic Energy Sciences subprogram of the Office of Energy Research. Inertial fusion is under development as a component of nuclear weapons research because it can test basic concepts of fusion explosions. The same basic concepts have the potential for commercial energy applications. The target compression and ignition physics are central to the energy concept, but will be developed under Defense Programs' activities. The heavy ion driver is specifically needed for energy applications and is supported here.

For commercial energy, a number of requirements must be met to deliver compression driving energy to the target at high efficiency and high repetition rate. For significant net energy production, the ignition and burn of a microcapsule is required to produce many times the energy required to compress the capsule. The compression driving source must have sufficient energy efficiency to allow net energy release from the system. For a reasonable energy source, the compression, ignition, and energy gain should be repeated several times each second. Thus, energy applications of inertial fusion require: high-efficiency, high-repetition-rate drivers; targets that can reliably yield useful net energy gain that can be cheaply produced; and reactor chambers to contain the micro-explosions and convert energetic fusion products to electricity.

The development of a heavy-ion driver has been the primary activity under the Inertial Fusion Energy program and a research accelerator for Induction Linac System Experiments (ILSE) was proposed, with conceptual design prepared and reviewed. Construction of that accelerator was not initiated. The FY 1996 budget supports continued heavy ion beam transport theory and experiments and the beginning of construction of Elise, the electric focus induction accelerator. The Elise accelerator will provide the capability to investigate some of the issues of the induction linac system experiments program. If those experiments are successful, the Elise accelerator can be extended to address all of the issues of this heavy-ion driver physics program.

II. A. Summary Table: Inertial Fusion Energy

Program Activity	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
Heavy Ion Beams................................	$ 2,348	$ 6,660	$ 2,550	$ -4,110
Reactors and Materials.........................	0	0	0	0
Driver Concept Development.....................	934	1,190	550	-640
Targets for IFE................................	577	150	0	-150
Total, Inertial Fusion Energy	$ 3,859	$ 8,000	$ 3,100	$ -4,900

II. B. Laboratory and Facility Funding Table: Inertial Fusion Energy

	FY 1994 Adjusted	FY 1995 Estimate	FY 1996 Request	$ Change
Lawrence Berkeley Lab	$ 2,562	$ 5,470	$ 2,200	$ -3,270
Lawrence Livermore National Lab	837	1,600	550	-1,050
All Other	460	930	350	-580
Total, Inertial Fusion Energy	$ 3,859	$ 8,000	$ 3,100	$ -4,900

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1994	FY 1995	FY 1996
Inertial Fusion Energy			
Heavy Ion Beams	Efforts are directed toward technology improvements, testing of accelerator modules and pulsed power systems, and development of a full-scale alkali ion source and injector.	A decision has been made to proceed with Elise, the electric focus section of the Induction Linac Systems Experiments (ILSE) accelerator. Efforts are increased in basic technology improvements and testing of accelerator modules and pulsed power systems with improvements in the design of Elise components as one goal. Begin construction of magnetic quadrupole channel for studies of transport of full-scale alkali ion beams at low energy. Step up preconstruction R&D activities in preparation for a more optimum start of Elise accelerator construction.	Fabrication support begins on the Elise accelerator in FY 1996. Low-energy magnetic transport studies with a full-scale ion beam will be concluded. Beam theory and simulation studies continue. Research and Development Associated with Construction will continue.
	$ 2,348	$ 6,660	$ 2,550
Reactors and Materials	No activity.	No activity.	No activity.
	$ 0	$ 0	$ 0

III. Inertial Fusion Energy (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
Driver Concept Development	For heavy ions, the induction linac concept is improved through use of new materials, advanced ion beam stability control, and high precision focusing. Initiate improved codes with new high performance computers to predict detailed ion beam performance, with advances in simulation of magnetic bending and focusing expected. Begin scaled experiment in ion beam recirculation.	Continue induction linac concept improvements in preparation for experiments following Elise construction and to maintain physics base during construction. High performance computers and improved codes will predict detailed ion beam performance. Scaled recirculation studies continue, including initial test of bending space-charge dominated beams. Scope out needed chamber transport experiments.	Induction linac concept improvements continue. Recirculation acceleration studies continue. Increase support for fabrication of small-scale ion ring.
	$ 934	$ 1,190	$ 550
Targets for IFE	Conceive and study inertial fusion targets tailored for energy application in collaboration with ongoing U.S. studies for defense applications. Energy specific heavy-ion target studies may begin in cooperation with European researchers.	Energy specific heavy-ion target studies can continue in cooperation with European researchers.	No activity.
	$ 577	$ 150	$ 0
Inertial Fusion Energy	$ 3,859	$ 8,000	$ 3,100

DEPARTMENT OF ENERGY
FY 1996 CONGRESSIONAL BUDGET REQUEST
ENERGY SUPPLY, RESEARCH AND DEVELOPMENT
(dollars in thousands)

KEY ACTIVITY SUMMARY

FUSION ENERGY

I. Preface: Program Direction

This subprogram provides the Federal staffing resources and associated funding needed to plan, direct, manage, and administer the highly complex scientific and technical research and development program in fusion energy. The Fusion Energy program is developing the magnetic and inertial approaches to attaining fusion energy as two separate and distinct programs, coordinating, in the latter case, with the Office of Defense Programs. International collaboration and increasing industrial involvement are essential elements of the program strategy and require extensive coordination efforts.

II. A. Summary Table: Program Direction

Program Activity	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
Personnel Compensation	$ 5,782	$ 6,162	$ 6,333	$ 171
Personnel Benefits	1,144	1,353	1,419	66
Travel	685	735	735	0
Contractual Services	1,315	1,350	1,113	-237
Total, Program Direction	$ 8,926	$ 9,600	$ 9,600	$ 0

II. B. Laboratory and Facility Funding Table: Program Direction

All Other	$ 8,926	$ 9,600	$ 9,600	$ 0
Total, Program Direction	$ 8,926	$ 9,600	$ 9,600	$ 0

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1994	FY 1995	FY 1996
Program Direction			
Personnel Compensation	Provided funds for personnel compensation for 82 full-time equivalents (FTEs) in the Office of Fusion Energy and related program and management support staff at Headquarters and in the field. Includes, for example: regular salaries; lump sum payments for unused annual leave; premium pay; and employee incentive awards.	Provide funds for personnel compensation for 82 FTEs. Includes, for example: regular salaries; lump sum payments for unused annual leave; premium pay; and employee incentive awards.	Provide funds for personnel compensation for 82 FTEs. Includes, for example: regular salaries; lump sum payments for unused annual leave; premium pay; and employee incentive awards. Provide for pay increases resulting, for example, from normal within-grade increases, locality and/or general pay raises.
	Funded staff for the Office of Fusion Energy activities including: policy development; preparation of technical research and development plans; assessment of scientific needs and priorities; development and defense of budgets; review, evaluation, and funding of research proposals; monitoring, evaluation, and direction of laboratory work and allocation of resources; oversight of university and industrial research programs; and oversight of construction, ES&H, and operation of scientific R&D facilities. Supported ITER materials development, two new testing facilities, and international collaboration on ITER design activities. Continued to support TPX project coordination and strong industry involvement, TFTR D-T, and efforts to improve the tokamak concept and ensure continuing development of inertial fusion energy. Continued physics experiments and establishment of ES&H criteria for ITER. Supported and managed other ongoing program activities consistent with program missions, the Energy Policy Act of 1992, departmental priorities, and improved contractor oversight. Joined with foreign partners in planning for a	Continue program management activities as in FY 1994 with particular emphasis on the ITER and TPX projects and the research and development activities that support the program's missions. Support development of the various technologies necessary for future tokamak reactors and power plants and the development of advanced materials. Manage basic physics research activities and identify promising advanced concepts. Manage design and R&D tasks for the ITER, including ES&H. Manage other ongoing program activities including TPX activities, the D-III-D and Alcator C-Mod facilities consistent with program missions, the Energy Policy Act of 1992, departmental priorities, and improved contractor oversight, including continued development of reactor technologies for ongoing and planned facilities. Continue international collaboration on ITER particularly regarding research and development tasks, design issues, construction decisions, and site selection. Intensify activities relating to a U.S. commitment concerning construction of ITER and the related site selection activities. Continue extensive planning for the U.S. program and with foreign partners	Continue program management activities with particular emphasis on the ITER and TPX projects and the research and development activities that support the program's missions. Support development of the various technologies necessary for future tokamak reactors and power plants and the development of advanced materials. Manage basic physics research activities and identify promising advanced concepts. Manage design and R&D tasks for the ITER, including ES&H. Manage other ongoing program activities including TPX activities, the D-III-D and Alcator C-Mod facilities consistent with program missions, the Energy Policy Act of 1992, departmental priorities, and improved contractor oversight, including continued development of reactor technologies for ongoing and planned facilities. Continue international collaboration on ITER, particularly regarding research and development tasks, design issues, construction decisions, and site selection. Intensify activities relating to a U.S. commitment concerning construction of ITER and the related site selection activities. Continue extensive planning for the U.S. program and planning with foreign

III. Program Direction (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
Personnel Compensation (Cont'd)	comprehensive program to develop fusion energy, particularly including materials development facilities and related R&D.	for a comprehensive program to develop fusion energy, particularly including materials development facilities and related R&D.	partners for a comprehensive program to develop fusion energy, particularly including materials development facilities and related R&D.
	Provided program and management support in the areas of budget and finance, personnel administration, acquisition and assistance, policy review and coordination, information resources management, and construction management support.	Continue to provide program and management support as in FY 1994.	Continue to provide program and management support as in FY 1995.
	Supported fusion energy activities carried out by the Chicago Operations Office, primarily at the Princeton Area Office. PAO is responsible for the operation of DOE's largest fusion laboratory, the Princeton Plasma Physics Laboratory, which operates the Tokamak Fusion Test Reactor facility. Provided increased support for the TPX activities.	Continue to support fusion energy activities carried out by the Chicago Operations Office at the FY 1994 level.	Continue to support fusion energy activities carried out by the Chicago Operations Office.
	Supported fusion energy activities at the Oakland Operations Office.	Continue to support fusion energy activities at the Oakland Operations Office.	Continue to support fusion energy activities at the Oakland Operations Office.
	$ 5,782	$ 6,162	$ 6,333
Personnel Benefits	Funded civilian personnel benefits to cover the Civil Service Retirement and Disability Funds, Federal Employees Retirement System, health benefits and life insurance funds, permanent change of station expenses, and unemployment compensation.	Fund civilian personnel benefits to cover the Civil Service Retirement and Disability Funds, Federal Employees Retirement System, health benefits and life insurance funds, permanent change of station expenses, and unemployment compensation.	Fund civilian personnel benefits to cover the Civil Service Retirement and Disability Funds, Federal Employees Retirement System, health benefits and life insurance funds, permanent change of station expenses, and unemployment compensation.
	$ 1,144	$ 1,353	$ 1,419

III. Program Direction (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
Travel	Provided funds for official domestic, international, and local travel. Funds transferee/new hire personnel for permanent change of station transportation.	Provide funds for official domestic, international, and local travel. Funds transferee/new hire personnel for permanent change of station transportation.	Provide funds for official domestic, international, and local travel. Funds transferee/new hire personnel for permanent change of station transportation.
	$ 685	$ 735	$ 735
Contractual Services	Provided a variety of program support such as printing and editing and contractual services, including, for example, ES&H support and timesharing on various information systems and communication networks; and Automated Office Support Systems (AOSS) workstations.	Provide a variety of program support such as printing and editing and contractual services, including, for example, ES&H support and timesharing on various information systems and communication networks; and Automated Office Support Systems (AOSS) workstations.	Provide a variety of program support such as printing and editing and contractual services, including, for example, ES&H support and timesharing on various information systems and communication networks; and Automated Office Support Systems (AOSS) workstations.
	$ 1,315	$ 1,350	$ 1,113
Program Direction	$ 8,926	$ 9,600	$ 9,600

DEPARTMENT OF ENERGY
FY 1996 CONGRESSIONAL BUDGET REQUEST
ENERGY SUPPLY, RESEARCH AND DEVELOPMENT
(dollars in thousands)

KEY ACTIVITY SUMMARY

FUSION ENERGY

I. Preface: Capital Equipment

The capital equipment revised request for FY 1996 of $12,479,000 supports the procurement of essential hardware for the experimental program. This permits the effective utilization of devices and people. Much of this equipment is used to support the operation of the fusion experimental devices or to make measurements and gather technical data. Some of this equipment replaces existing obsolete equipment while the remainder is new equipment. The principal equipment upgrade is for the DIII-D tokamak where the first phase of a longer term effort ~~will~~ be continued. When completed, DIII-D will be able to test prototype divertors for ITER and study current drive techniques relevant to ITER. Listed below is a summary of the specific capital equipment needs by sub-program.

II. A. Summary Table: Capital Equipment

Program Activity	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
Confinement Systems	$ 10,623	$ 5,300	$ 8,000	$ 2,700
Applied Plasma Physics	460	325	179	-146
Development and Technology	4,050	3,974	3,600	-374
Inertial Fusion Energy	386	700	700	0
Total, Capital Equipment	$ 15,519	$ 10,299	$ 12,479	$ 2,180

II. B. Laboratory and Facility Funding Table: Capital Equipment

	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
Lawrence Livermore National Lab	656	368	280	-88
Oak Ridge National Lab	1,597	1,005	1,000	-5
Princeton Plasma Physics Lab	226	437	2,037	1,600
All Other	13,040	8,489	9,162	673
Total, Capital Equipment	$ 15,519	$ 10,299	$ 12,479	$ 2,180

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1994	FY 1995	FY 1996
Capital Equipment			
Confinement Systems	Provide support for experimental operations of existing devices. Continue maintenance and modest upgrades to data acquisition systems by replacing/upgrading diagnostics hardware, analog to digital convertors, mass storage systems, etc., as needed for C-Mod, DIII-D, and TFTR. These funds will be used to upgrade the Fast Wave Current Drive system and to initiate the Radiative Divertor Equipment project, as a part of improvements to the DIII-D facility.	Provide support for experimental operations of existing devices. Continue maintenance and modest upgrades to data acquisition systems by replacing/upgrading diagnostics hardware, analog to digital convertors, mass storage systems, etc., as needed for C-Mod and DIII-D. A decision has been made to defer further work on the upgrade to the Fast Wave Current Drive system and to slow the pace of the Radiative Divertor hardware upgrade. Prototyping work on a long pulse microwave heating system will be initiated to upgrade the capabilities of the D-III-D facility.	Provide support for experimental operations of existing devices. Continue maintenance and modest upgrades to data acquisition systems by replacing/upgrading diagnostics hardware, analog to digital convertors, mass storage systems, etc., as needed for C-Mod and DIII-D. Fabrication of the radiative divertor will be continued. Work on a higher power upgrade of the long pulse microwave heating system will begin.
	$ 10,623	$ 5,300	$ 8,000
Applied Plasma Physics	Provide general laboratory equipment for experimental research at national laboratories including computing equipment.	Reduce general laboratory equipment at national laboratories.	Reduce general laboratory equipment at national laboratories.
	$ 460	$ 325	$ 179
Development and Technology	Special and general purpose equipment is purchased to increase the efficiency and productivity of the research and development efforts and technology test facilities.	Special and general purpose equipment is purchased to increase the efficiency and productivity of the research and development efforts and technology test facilities.	Special and general purpose equipment is purchased to increase the efficiency and productivity of the research and development efforts and technology test facilities.
	$ 4,050	$ 3,974	$ 3,600
Inertial Fusion Energy	Equipment funds are provided to support Heavy Ion Accelerator Physics Research.	Equipment funds are provided to support Heavy Ion Accelerator Physics Research.	Equipment funds are provided to support Heavy Ion Accelerator Physics Research.

III. Capital Equipment (Cont'd):

Program Activity	FY 1994	FY 1995	FY 1996
Inertial Fusion Energy (Cont'd)	$ 386	$ 700	$ 700
Capital Equipment	$ 15,519	$ 10,299	$ 12,479

DEPARTMENT OF ENERGY
FY 1996 CONGRESSIONAL BUDGET REQUEST
ENERGY SUPPLY, RESEARCH AND DEVELOPMENT
(dollars in thousands)

KEY ACTIVITY SUMMARY

FUSION ENERGY

I. Preface: Construction

II. A. Summary Table: Construction

Program Activity	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	$ Change
Construction	$ 1,940	$ 2,000	$ 54,100	$ 52,100
Total, Construction	$ 1,940	$ 2,000	$ 54,100	$ 52,100

II. B. Laboratory and Facility Funding Table: Construction

Lawrence Berkeley Lab	$ 0	$ 0	$ 3,200	$ 3,200
Princeton Plasma Physics Lab	1,940	2,000	50,900	48,900
Total, Construction	$ 1,940	$ 2,000	$ 54,100	$ 52,100

III. Activity Descriptions: (New BA in thousands of dollars)

Program Activity	FY 1994	FY 1995	FY 1996
Construction			
Construction	Support projects at PPPL to meet health, safety, and programmatic requirements and to provide miscellaneous modifications, additions, alterations, and non-major new construction items to meet programmatic goals.	Support projects at PPPL to meet health, safety, and programmatic requirements and to provide miscellaneous modifications, additions, alterations, and non-major new construction items to meet programmatic goals.	Support projects at PPPL to meet health, safety, and programmatic requirements and to provide miscellaneous modifications, additions, alterations, and non-major new construction items to meet programmatic goals.
	No activity.	No activity.	Carry out Title I design and begin Title II design and procurement of long-lead items for the Elise heavy ion accelerator.
	No activity.	No activity.	The future of the TPX program will be evaluated by PCAST as part of its review of the fusion program. Release of construction funding will await the completion of the review. At about half the planned level of funding, final design activities will be limited to critical tokamak subsystems. The industrial management support staff located at Princeton will be fully established. Schedule slippage will occur in other areas, causing significant delays in the hardware fabrication planned for FY 1997.
	$ 1,940	$ 2,000	$ 54,100
Construction	$ 1,940	$ 2,000	$ 54,100

ENERGY SUPPLY RESEARCH AND DEVELOPMENT
(Tabular dollars in thousands. Narrative dollars in whole dollars.)

IV. A. Construction Funded Project Summary

Project No.	Project Title	Previous Obligations	FY 1994 Adjusted	FY 1995 Adjusted	FY 1996 Request	Unappropriated Balance	TEC
GPE-900	General Plant Projects	$ XXX	$ 1,924	$ 2,000	$ 1,000	$ 0	$ 1,000
96-E-310	Elise Project	0	0	0	3,200	17,000	20,200
94-E-200	Tokamak Physics Experiment (TPX)	0	0	0	49,900	560,100	610,000
Total, Fusion Energy		$ 0	$ 1,924	$ 2,000	$54,100	$577,100	$631,200

IV. B. Construction Funded Project Descriptive Summary

1. Project Title and Location: GPE-900 General Plant Projects
Various locations

TEC: $ 1,000
TPC: $ 1,000

Start Date: 1st Qtr. FY 1996

Completion Date: 4th Qtr. FY 1997

2. Financial Schedule (Federal Funds):

Fiscal Year	Appropriated	Obligations	Costs
1996	$ 1,000	$ 1,000	$ 1,000

3. This project supports many small alterations, additions, modifications, replacements, and non-major new construction items required annually to provide continuity of operation, improvement in economy, road and structure improvements, elimination of health and safety hazards, minor changes in operating methods, and protection of the Government's significant investment in facilities. The FY 1996 General Plant Projects funding will also support high priority ES&H activities identified in the Department's ES&H Five Year Plan. Currently the estimated distribution for FY 1996 by laboratory is as follows:

Princeton Plasma Physics Laboratory................................	$ 1,000

4. Total Project Funding (BA):

	Prior Years	FY 1994	FY 1995	FY 1996 Request
Construction	$ 0	$ 1,940	$ 2,000	$ 1,000

IV. B. Construction Funded Project Descriptive Summary

1. Project Title and Location:

96-E-310 Elise Project
Lawrence Berkeley Laboratory
Berkeley, California

TEC: $20,200
TPC: $25,900

Start Date: 2nd Qtr. FY 1996

Completion Date: 3rd Qtr. FY 2000

2. Financial Schedule (Federal Funds):

Fiscal Year	Appropriated	Obligations	Costs
1996	$ 3,200	$ 3,200	$ 3,150

3. Narrative:

(a) The Elise Project, a linear heavy ion induction accelerator facility, will produce intense ion beams to test many of the features of a heavy-ion induction accelerator "driver" for inertial fusion energy (IFE) production.

(b) The Elise Project consists of the design, procurement and construction of a new heavy ion linear accelerator with its ancillary equipment and the modifications to the conventional facilities to house it.

(c) The Elise Project and its ensuing experimental program will be the main effort in the driver development plan during the next several years.

(d) The Elise accelerator will be capable of carrying out many, but not all, of the experiments proposed for the program of induction linac systems experiments, whose goal is to resolve the physics issues of heavy ion driver for Inertial Fusion Energy.

4. Total Project Funding (BA):

	Prior Years	FY 1994	FY 1995	FY 1996 Request	To Complete
Construction	$ 0	$ 0	$ 0	$ 3,200	$ 17,000
Capital Equipment	0	0	0	0	0
Operating Expenses	0	260	3,100	450	1,890

IV. B. Construction Funded Project Descriptive Summary

1. Project Title and Location:

94-E-200 Tokamak Physics Experiment
Princeton Plasma Physics Laboratory
Plainsboro, New Jersey

TEC: $610,000
TPC: $742,000

Start Date: 1st Qtr. FY 1994

Completion Date: 4th Qtr. FY 2001

2. Financial Schedule (Federal Funds):

Fiscal Year	Appropriated	Obligations	Costs
1996	$ 49,900	$ 49,900	$48,000

3. Narrative:

(a) TPX has a dual mission of steady state and advanced tokamak operation. It is designed to develop and demonstrate optimized steady state operation modes that would provide the basis for a more attractive DEMO.

(b) The TPX project also supports the schedule and technical objectives of the International Thermonuclear Experimental Reactor program and enables the U.S. to remain an important major participant and contributor to the international fusion program.

(c) The design of TPX will be based on a reconfiguration of the Tokamak Fusion Test Reactor (TFTR) facilities into a steady state advanced tokamak using many of the existing TFTR facilities, following the TFTR shutdown and decommissioning.

(d) The funding request in FY 1996 is for Title I Design activities to be completed and detailed Title II design to start.

(e) The start of TPX construction will await completion of the PCAST review and a determination by the President as to the appropriate future strategy for the U.S. Fusion Program.

4. Total Project Funding (BA):

	Prior Years	FY 1994	FY 1995	FY 1996 Request	To Complete
Construction	$ 0	$ 0	$ 0	$49,900	$ 560,100
Capital Equipment	0	0	0	0	0
Operating Expenses	12,800	19,200	42,000	12,192	45,808

ENERGY SUPPLY RESEARCH AND DEVELOPMENT
(Tabular dollars in thousands. Narrative material in whole dollars.)

Fusion Energy

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1. Title and Location of Project: General Plant Projects
Various Locations

2a. Project No. GPE-900
2b. Construction Funded

3a. Date A-E Work Initiated, (Title I Design Start Scheduled): 1st Qtr. FY 1996

5. Previous Cost Estimate: None

3b. A-E Work (Title I & II) Duration: Months vary per project

4a. Date Physical Construction Starts: 3rd Qtr. FY 1996

4b. Date Construction Ends: 4th Qtr. FY 1997

6. Current Cost Estimate:
TEC -- $ 1,000
TPC -- $ 1,000

7. Financial Schedule (Federal Funds):

		Costs			
Fiscal Year	Obligations	FY 1994	FY 1995	FY 1996	After FY 1996
Prior Year Projects	XXXXXXXXX	$ 2,250	$ 0	$ 0	$ 0
1994 Projects	1,924	1,774	150	0	0
1995 Projects	2,000	0	1,850	150	0
1996 Projects	1,000	0	0	850	150

8. Brief Physical Description of Project

These projects provide for the many miscellaneous alterations, additions, modifications, replacements, and non-major new construction items required annually to provide continuity of operation, improvement in economy, road and street improvements, elimination of health and safety hazards, minor changes in operating methods, and protection

1. Title and Location of Project: General Plant Projects

2a. Project No. GPE-900
2b. Construction Funded

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8. Brief Physical Description of Project (Continued)

of the Government's significant investment in facilities at the present time. The continuing review of our requirements will result in some of the projects being changed in scope; it will also result in other projects being added to the list with the necessary postponements of some now listed, all depending on conditions or situations not apparent at this time. The FY 1996 General Plant Projects funding will also support high priority ES&H activities identified in the Department's ES&H Five Year Plan.

The current estimated distribution of FY 1996 funds by location is as follows:

Princeton Plasma Physics Laboratory.. $ 1,000

9. Purpose, Justification of Need for, and Scope of Project

The following are tentative examples of the major items to be performed at PPPL:

Princeton Plasma Physics Laboratory*... $ 1,000

Miscellaneous Building and Facility Betterments and Modifications........... $1,000

These funds cover the Fusion Energy program's specific modifications for modernization and safety improvements to existing facilities.

10. Details of Cost Estimate

Not available at this time.

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* These projects will be constructed at the Princeton Plasma Physics Laboratory which is non-Government owned property.

11. Method of Performance

Design and engineering will be on the basis of negotiated subcontracts and construction work under fixed price subcontracts awarded on the basis of competitive bidding.

12. Funding Schedule of Project Funding and Other Related Funding Requirements

This item does not apply to general plant projects.

Since needs and priorities may change, other projects may be substituted for those listed, and some of these may be located on non-Government owned property.

13. Narrative Explanation of Total Project Funding and Other Related Funding Requirements

This item does not apply to general plant projects.

ENERGY SUPPLY RESEARCH AND DEVELOPMENT
(Tabular dollars in thousands. Narrative material in whole dollars.)

Fusion Energy

1. Title and Location of Project: Elise
Lawrence Berkeley Laboratory
Berkeley, California

2a. Project No. 96-E-310
2b. Construction Funded

3a. Date A-E Work Initiated, (Title I Design Start Scheduled): 2nd Qtr. FY 1996

3b. A-E Work (Title I & II) Duration: 10 Months

5. Previous Cost Estimate: None
Total Estimated Cost (TEC) -- None
Total Project Cost (TPC) -- None

4a. Date Physical Construction Starts: 2nd Qtr. FY 1997

4b. Date Construction Ends: 3rd Qtr. FY 2000

6. Current Cost Estimate:
TEC -- $20,200
TPC -- $25,900

7. Financial Schedule (Federal Funds):

Fiscal Year	Appropriation	Obligations	Costs
1996	3,200	3,200	3,150
1997	4,500	4,500	4,550
1998	4,700	4,700	4,550
1999	4,400	4,400	4,550
2000	3,400	3,400	3,400

8. Brief Physical Description of Project

The Elise Project consists of the design, procurement and construction of a new heavy ion linear accelerator with its ancillary equipment and the modifications to the conventional facilities to house it. The facility will be designed for a ten year life. The Elise accelerator will consist of an induction accelerator approximately 25 m long, with induction cells containing about 41 metric tons of magnetic material. The major accelerator subsystems are an ion injector and an electrostatically focused accelerator section. The injector already exists. In addition, the accelerator will have an alignment system, a high vacuum system, diagnostics, a data acquisition and control system, and special equipment to maintain the accelerator. The conventional facilities are based on a conceptual design that consists of modifications to and the construction of an accelerator enclosure in Building 51B. This will be of insulated steel frame construction and will include an energy management system, as well as standard lighting and fire protection systems. The Elise accelerator will be capable of carrying out many, but not all, of the experiments proposed for the program of induction linac systems experiments (ILSE), whose goal is to resolve the physics issues of a heavy ion driver for Inertial Fusion Energy. Elise is the electric focus portion of the previously conceived ILSE accelerator and is designed to be extendable to address the same key driver physics issues as ILSE.

These improvements to existing government-owned facilities will be located on land owned by the University of California and will serve or be operated in conjunction with other government-owned facilities at the Lawrence Berkeley Laboratory.

9. Purpose, Justification of Need For, and Scope of Project

The Elise Project, a linear heavy ion induction accelerator facility, will produce intense ion beams to test many of the features of a heavy-ion induction accelerator "driver" for inertial fusion energy (IFE) production. For credible results, Elise should be prototypical, at least in line charge density, of the front part of an accelerator for energy production. Research and development underway in FY 1994 and FY 1995 will build and evaluate key accelerator components. This work will resolve the required technology issues prior to the start of Elise project construction in FY 1996.

During the last 15 years nearly all high level reviews of inertial fusion have concluded that heavy ion accelerators are the leading driver candidate for inertial fusion energy. The review panels have consistently recommended a more vigorous heavy-ion driver development program. The National Energy Policy Act has also affirmed the need for heavy ion driver development. The Elise Project and its ensuing experimental program will be the main

9. Purpose, Justification of Need For, and Scope of Project (Continued)

effort in the driver development plan during the next several years. It has been designed to reconcile recommendations for a more ambitious development and the need for prudent financial management of limited resources.

Many of the beam parameters (e.g., ion kinetic energy and total beam energy) required to ignite a fusion target have already been demonstrated by existing high-energy accelerators. The main new feature required for a fusion driver is high instantaneous power (10^{14} - 10^{15} W). Since a driver is expected to accelerate ions to about 10 GeV, this high power corresponds to an ion current of 10^4 - 10^5 amperes. Currents greater than 10^4 amperes have been achieved in electron induction linacs, but no multi-gap ion accelerator has produced currents greater than one hundred amperes. Except for fusion energy application, there has been no compelling reason to produce such high ion currents. A new accelerator is required to probe this new accelerator physics regime with ions.

Ion current is the product of linac-charge density and ion velocity. The current itself is an important quantity in issues involving longitudinal dynamics. For most issues, line-charge density and beam radius are the important quantities since they determine the space-charge forces. For heavy-ion driver concepts, the line-charge density is large enough that the space-charge forces become comparable to the applied forces and much larger than the emmittance forces. Such beams are said to be space-charge-dominated. Several experiments with space-charge-dominated ion beams have been performed at LBL (e.g., Single-Beam Transport Experiment and the Multiple-Beam Experiment MBE-4) and elsewhere. These beams have shown good behavior in electrostatically focused channels, but the beams had lower line-charge density than full-scale driver beams. A principal purpose of Elise is to provide space-charge-dominated beams to perform scaled experiments in many subsystems found in a driver. The beam radius and line-charge density will be tested at values equal to those anticipated in a driver. However, for reasons of economy, the final ion kinetic energy from Elise will be approximately 5 MeV which is much less than required from a driver. The "as built" Elise accelerator will test induction acceleration with electrostatic transport, pulse compression and longitudinal beam control, and accelerator alignment effects. With ancillary additional experimental hardware, the Elise beam could be used to study magnetic transport and beam bending, drift compression, final focus, feedback-feed foreward beam control, and recirculation acceleration. Additional accelerator construction would be required to study multiple beam matching and transport, beam merging, and induction acceleration with magnetic transport.

1. T and Location of Project: Elise
Lawrence Berkeley Laboratory
Berkeley, California

2a. Project No. 96-E-310
2b. Construction Funded

9. Purpose, Justification of Need For, and Scope of Project (Continued)

Delay in funding or not authorizing this project will have the following effects:

(1) A delay in Elise translates directly into a delay in inertial fusion energy. Driver development is already a pacing item for inertial fusion energy.

(2) Other approaches to heavy ion acceleration are being studied in Europe and elsewhere. The results from Elise with the European results will lead to a sound choice of accelerator technology.

(3) A year-by-year delay will increase the cost of construction by the approximate escalation rate.

10. Details of Cost Estimate a/

		Item Cost	Total Cost
Elise			$ 20,200
(a) Engineering Design and Inspection		4,220	
(1) Conventional facilities	170		
(2) Special research facilities	4,050		
(b) Project Management		1,910	
Conventional facilities	70		
Special research facilities	1,840		
(c) Construction costs		9,180	
Conventional facilities	930		
Special research facilities	8,250		
(d) Standard equipment		0	
(e) Contingency (21.5% of above costs) b/		3,290	
(f) LBL Overhead (8.61% of above costs)		1,600	

a/ Cost estimates are based on a conceptual design completed in March FY 1994. Escalation calculations were based on published inflation estimates of August 1994: FY 1993 - 2.6%; FY 1994 - 3.1%; FY 1995 - 3.8%; FY 1996 - 3.8%; FY 1997 - 3.9%; FY 1998 - 4.1%; FY 1999 - 3.9%, FY 2000 - 3.7%.

b/ Contingencies were estimated separately for project management, special facilities (including associated ED&I), and conventional facilities.

1. Title and Location of Project: Elise
Lawrence Berkeley Laboratory
Berkeley, California

2a. Project No. 96-E-310
2b. Construction Funded

11. Method of Performance

Overall project management, including quality assurance, systems engineering and administration will be performed by LBL. This function will oversee both special research facilities and conventional facilities acquisitions.

Special research facilities engineering design and inspection will be done by LBL, LLNL, and appropriate industrial partners, as will construction and assembly of accelerator sections. Technical components for the facility will be procured by fixed-price subcontracts awarded on the basis of competitive bids.

Conventional facilities engineering, design and inspection will be performed under a negotiated architect-engineer subcontract. Construction and procurement shall be accomplished by fixed-price subcontracts awarded on the basis of competitive bidding.

12. Funding Schedule of Project Funding and Other Related Funding Requirements

	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	TOTAL
(a) Total project costs (TPC)								
(1) Total Estimated Construction Cost......................	$ 0	$ 0	$ 3,150	$ 4,550	$ 4,550	$ 4,550	$ 3,400	$ 20,200
(2) Other Project Costs								
(a) Research and development associated with construction........	200	3,000	350	250	250	250	150	4,450
(b) Conceptual design report and major documentation.......	60	100	100	0	0	0	0	260
(c) Start-up and preoperations.......	0	0	0	0	0	0	990	990
Total project cost............	$ 260	$ 3,100	$ 3,600	$ 4,800	$ 4,800	$ 4,800	$ 4,540	$ 25,900

12. Funding Schedule of Project Funding and Other Related Funding Requirements (Continued)

(2) Other related funding requirements (estimated annual costs) starting in FY 2000

(1) Facility operating costs	$ 610
(2) Programmatic operating expenses directly related to the facility	5,200
(3) Capital Equipment not related to construction, but related to the programmatic effort in the facility	2,080
(4) Maintenance, report, GPP or other construction related to programmatic effort tin the facility	$ 410
Total related annual costs	$ 8,300

13. Narrative Explanation of Total Project Funding and Other Related Funding Requirements

a. Total Project Cost - consists of the Elise facility, research and development associated with construction, conceptual design report, project documentation, and start-up/preoperations. The TPC funding profile was determined from analysis of the project schedule and considers the anticipated date of funding for both special research facilities and the time required for conventional facilities A/E selection. The major elements of the Elise construction project are briefly described in item 8.

1. Total Facility - Consists of the heavy ion linear accelerator and the conventional facility modifications and construction.

2. Other Project Costs
   - (a) Research and development associated with construction - consists of the development of accelerator cells, beam transport quadrupoles, and ancillary subsystems. Most of this effort is planned for completion prior to the start of the Elise project construction.
   - (b) Conceptual design report, project management plan, project plan, NEPA and associated reviews anticipated prior to the start of the Elise construction project are also included.
   - (c) The costs of start-up and preoperations necessary to prepare for the first of the anticipated scaled driver experiments is included. This would support staffing and other preoperational activities in preparation for full operation in FY 1999.

13. Narrative Explanation of Total Project Funding and Other Related Funding Requirements (Continued)

b. Related annual funding

(1) Facility operating costs - the cost of technical effort and materials to maintain the new Elise facility prorated over a ten year life starting in FY 2001; 35 staff years is estimated for this effort.

(2) Programmatic operating expenses directly related to the facility - the average cost of developing and conducting the Elise experiments prorated over a ten year period starting in FY 2001; includes effort such as experimental physicists, engineers and technical personnel to design, build, install and operate the Elise experiments.

(3) Capital equipment not related to construction, but related to programmatic efforts in the facility - the average capital cost of both developed and purchased equipment for experiments; consists of the hardware cost of a beam combining experiment, feed-forward experiment, bending experiment, drift compression and final focus experiment.

(4) Maintenance, repair, GPP or other construction related to programmatic effort in the facility - includes the cost of regulatory compliance, inspection, waste disposal, electricity and other utilities.

Fusion Energy

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1. Title and Location of Project: Tokamak Physics Experiment (TPX)
Princeton Plasma Physics Laboratory (PPPL)
Plainsboro, New Jersey*

2a. Project No. 94-E-200
2b. Construction Funded

3a. Date A-E Work Initiated, (Title I Design Start Scheduled): 1st Qtr. FY 1994

3b. A-E Work (Title I & II) Duration: 50 Months

5. Previous Cost Estimate:
Total Estimated Cost (TEC) -- $597,000
Total Project Cost (TPC) -- $694,000

4a. Date Physical Construction Starts: 3rd Qtr. FY 1996

4b. Date Construction Ends: 4th Qtr. FY 2001

6. Current Cost Estimate:
TEC -- $610,000
TPC -- $742,000

7. Financial Schedule (Federal Funds):

Fiscal Year	Appropriation	Adjustments	Obligations	Costs
1996	49,900	0	49,900	48,000
1997	124,100	0	124,100	122,000
1998	133,000	0	133,000	130,000
1999	128,000	0	128,000	129,000
2000	121,000	0	121,000	125,000
2001	54,000	0	54,000	56,000

This project will be located on non-Government owned land. The U.S. Government has leased this land from Princeton University for a 40-year period beginning in October, 1986.

The start of TPX construction will await completion of the PCAST review and a determination by the President as to the appropriate future strategy for the U.S. Fusion Program.

8. Brief Physical Description of Project

The design of TPX will be based on the reconfiguration of the Tokamak Fusion Test Reactor (TFTR) facilities into an advanced tokamak experimental facility to carry out research that extrapolates to steady-state. Many of the TFTR facilities, including buildings, auxiliary plasma heating systems, power supplies, motor generators, vacuum pumping systems, computer control systems, instrumentation systems, a water cooling system, utilities, and diagnostics are reusable for TPX. In addition, existing MFTF-B cryogenic equipment at Lawrence Livermore National Laboratory (LLNL) will be relocated to PPPL for use on TPX.

Construction of the TPX facility will include the following new facilities: 1) a high-aspect ratio, advanced tokamak with support structure, vacuum vessel, cryostat, vacuum pumping system, superconducting magnet coils, support systems; and 2) an on-site helium refrigeration plant that utilizes the above mentioned LLNL cryogenic equipment.

9. Purpose, Justification of Need For, and Scope of Project

The mission of the U.S. Magnetic Fusion program is to develop fusion as an environmentally attractive, commercially viable and sustainable energy source for the Nation and the world. Two key science issues in developing an attractive fusion demonstration power plant (DEMO) are extending the tokamak concept to the steady-state regime and pursuing advances in tokamak physics. TPX will address both issues and play a unique role in the world fusion program by developing stable plasma conditions with improved reactor characteristics (e.g., higher pressures, better confinement, lower input energy requirements). The aim would be to maintain these conditions for a sufficiently long period to demonstrate their utility in a power reactor. The central role of TPX then, is to point the way to a more efficient and economically attractive DEMO rather than relying on conservative extrapolation to a DEMO sized device from the present scientific data base.

The TPX project also complements the technical objectives of the International Thermonuclear Experimental Reactor (ITER) program and enables the U.S. to remain an important major participant and contributor to the international fusion program. Both the Secretary of Energy Advisory Board Task Force on Energy Research Priorities and the Fusion Energy Advisory Committee, as well as the heads of the major foreign fusion programs, have endorsed the unique role of the TPX mission in the world fusion effort. Failure to build and operate TPX would seriously impede development of an attractive DEMO, and also impair the future ability of the U.S. fusion program to retain an adequate level of scientific expertise until such time that ITER is constructed and operated.

9. Purpose, Justification of Need For, and Scope of Project (Continued)

The TPX would move tokamak and fusion development into a new era. For the first time, it would incorporate the main features of presently envisioned tokamak reactors, except for the use of tritium fuel. It would seek to significantly improve the physics of tokamaks in long pulse operation by exploring advanced regimes with the potential for better confinement, higher pressure limits, and a high fraction of internally-driven steady-state current, leading to an attractive DEMO concept. It would also advance reactor technologies including superconducting magnets, heat resistant internal components, steady-state plasma heating and current drive systems, and remote maintenance. In summary, the TPX would be an important and exciting experiment to advance fusion energy development in the U.S. and in the world.

The funding request of $49,900,000 in FY 1996 is for continuation of the preliminary design started in FY 1994 (in accordance with Congressional direction contained in the Energy and Water Development Conference Reports 103-305 dated October 22, 1993, and 103-672 dated August 4, 1994) and start of final design. Additionally, major procurements for the conductor to be used in the superconducting magnets and long-lead materials will be made during this fiscal year.

1. Title and Location of Project:	Tokamak Physics Experiment (TPX) Princeton Plasma Physics Laboratory (PPPL) Plainsboro, New Jersey*	2a. Project No. 94-E-200 2b. Construction Funded

10. Details of Cost Estimate a/b/

	Item Cost	Total Cost
(a) EDI and Construction Management/Systems Integration Costs		198,000
(1) Engineering Design, and Inspection (EDI) at 53% c/d/ of construction costs b/	$150,000	
(2) Construction Management at 6% of construction costs b/	17,000	
(3) Project Management and Systems Integration	31,000	
(b) Construction costs		284,000
(1) Improvements to land and utilities	100	
(2) Buildings and building modifications	3,200	
(3) Special features		
(a) Tokamak systems	165,000	
(b) Other systems	115,700	
Subtotal		$ 482,000
(f) Contingencies at approximately 27% of the above costs		$ 128,000
Total line costs (Section 12.a.i)		$ 610,000

11. Method of Performance

A fusion program objective is for TPX to be a National project with broad U.S. fusion program involvement in order to make full use of the technical and scientific capabilities that exist throughout the U.S. program. Consequently, the design and engineering for TPX will be an effort involving the participation of several national laboratories, other DOE research centers, and private industry. All program participants will benefit from the TPX technical and scientific challenges and progress. Industrial subcontracts for the design and fabrication for special facilities will be accomplished by cost-type contracts for the design and research and development phases and by negotiated cost-type or fixed price contracts for the fabrication phase. Negotiated cost-type industrial subcontracts will be awarded for Systems Integration Support and Tokamak Construction Management.

a/ These estimates are based on the Conceptual Design Review completed in March, 1993; conceptual design of tokamak systems and other major ancillary systems is 100% complete.

b/ All costs have been escalated using the DOE-ER escalation rates published for DOE Construction Projects in February, 1994.

c/ EDI as a percentage of construction cost is much lower (35%) if the replacement construction cost (over $150 million) of reusable PPPL/LLNL facilities and equipment is taken into account.

d/ EDI percentage is higher than other on-going DOE construction projects in part due to application of a new DOE laboratory overhead accounting policy.

1. Title and Location of Project: Tokamak Physics Experiment (TPX)
Princeton Plasma Physics Laboratory (PPPL)
Plainsboro, New Jersey*

2a. Project No. 94-E-200
2b. Construction Funded

12. Funding Schedule of Project Funding and Other Related Funding Requirements

(1) Total project funding	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998
(a) Total facility costs						
(i) Line item (Section 10)...	0	$ 0	$ 0	$ 48,000	$122,000	$130,000
Total facility costs	0	$ 0	$ 0	$ 48,000	$122,000	$130,000
(b) Other project costs						
(i) R&D necessary for construction............$	200	$ 4,300*	$ 10,900*	$ 10,192	$ 13,008	$ 900
(ii) Concept design costs.....$	10,100	0	0	0	0	0
(iii) Decontamination & decommissioning (D&D)....						
(iv) NEPA Documentation Costs....................$	300	0	0	0	0	0
(v) Other project related costs (project physics & prep for ops)..........$	2,200	$ 1,900*	$ 2,000*	$ 2,000	$ 2,000	$ 2,000
(vi) Non-Federal contribution.						
(vii) Preliminary design.......$	0	$ 13,000*	$ 29,100	$ 0	$ 0	$ 0
Total other project costs......$	12,800	$ 19,200	$ 42,000	$ 12,192	$ 15,008	$ 2,900
Total project costs............$	12,800	$ 19,200*	$ 42,000*	$ 60,192	$137,008	$132,900

1. Title and Location of Project:	Tokamak Physics Experiment (TPX) Princeton Plasma Physics Laboratory (PPPL) Plainsboro, New Jersey*	2a. Project No. 94-E-200 2b. Construction Funded

12. Funding Schedule of Project Funding and Other Related Funding Requirements (Continued)

(1) Total project funding	FY 1999	FY 2000	FY 2001	TOTAL
(a) Total facility costs				
(i) Line item (Section 10)...	$129,000	$125,000	$ 56,000	$610,000
Total facility costs	$129,000	$125,000	56,000	$610,000
(b) Other project costs				
(i) R&D necessary for construction............	0	0	0	$ 39,500
(ii) Concept design costs.....	0	0	0	$ 10,100
(iii) Decontamination & decommissioning (D&D)....				$ 0
(iv) NEPA Documentation Costs....................	0	0	0	$ 300
(v) Other project related costs (project physics & prep for ops)..........	$ 6,900	$ 13,000	$ 8,000	$ 40,000
(vi) Non-Federal contribution.				$ 0
(vii) Preliminary design.......	$ 0	$ 0	$ 0	$ 42,100
Total other project costs......	$ 6,900	$ 13,000	$ 8,000	$132,000
Total project costs...........	$135,900	$138,000	$ 64,000	$742,000

(2) Other related annual costs (FY 2001 dollars. Estimated life of facility: 10 years)

(a) Facility operating costs..	$ 95,000
(b) Programmatic operating expenses directly related to the facility............................	$ 45,000
(c) Capital equipment not related to construction but related to the programmatic effort to the facility..	$ 10,000
Total related annual costs...	$150,000

*Consistent with Congressional intent for TPX project design to be conducted in FY 1994 and FY 1995 using operating expense funds (See Conference Reports 103-305 dated October 22, 1993, and 103-672 dated August 4, 1994).

13. Narrative Explanation of Total Project Funding and Other Related Funding Requirements

a. Total project funding

1. Total Facility Costs - Description is provided in Sections 8 and 9.
    - (a) Line item -- Description is provided in Sections 8 and 9.
    - (b) PE&D -- Included in the Line Item (Section 10).
    - (c) Expense-funded equipment -- None.
    - (d) Inventories -- None.
    - (e) Non-Federal contribution -- None.

2. Other Project costs
    - (a) R&D necessary to Complete Construction -- Technology development, prototyping, and mockup, fabrication and testing to support the design and cost-effective fabrication of the magnets, vacuum vessel, divertor and first wall, remote maintenance, shielding, and instrumentation and control systems.
    - (b) Conceptual Design -- Includes establishing the mission, objectives, and requirements for the project and developing the scope and cost of the project to meet these requirements. The project scope is defined in summary level engineering drawings and specifications in sufficient detail to enable preparation of a total project cost estimate and schedule.
    - (c) Decontamination and Decommissioning (D&D) -- Not applicable to this Construction Project. Costs to D&D the TFTR device and test cell is covered as a separate project.
    - (d) NEPA documentation costs are to prepare an Environmental Assessment for construction and operation of TPX. Other documentation such as the PSAR and FSAR is included in the Line Item (a)(1)(a) above.
    - (e) Other project related costs include physics design support and preparation for operations staffing build-up and training.
    - (f) Non-Federal contributions -- None positively identified to date. Preliminary discussions with State of New Jersey have been held.
    - (g) Preliminary Design - Engineering design activities funded by operating funds approved in FY 1994 and FY 1995, Energy & Water Development Appropriations Conference Reports (103-305 dated October 22, 1993, and 103-672 dated August 4, 1994).

13. Narrative Explanation of Total Project Funding and Other Related Funding Requirements (Continued)

b. Related annual funding

(a) Facility operating costs -- This facility is estimated to operate for a period of 10 years. The major elements comprising the annual operating costs will be personnel salaries, materials and services, maintenance, spare parts, and utilities.

(b) Programmatic operating expenses directly related to the facility -- Primarily includes the salaries and expenses of the staff personnel (physicists, engineers, and technicians) to carry out the experimental program.

(c) Capital equipment not related to construction but to programmatic efforts -- Estimated annual capital equipment expenses to support the experimental programmatic goals.