Journal of Fusion Energy, Vol. 15, Nos. 3/4, 1996

Report of the FESAC Inertial Fusion Energy Review Panel

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Dr. Robert W. Conn, Chair — April 8, 1996
Fusion Energy Advisory Committee
School of Engineering
University of California, San Diego
9500 Gilman Drive
La Jolla, California 92093-0403

Dear Dr. Conn:

This letter forwards the charge that follows up on a specific recommendation made by your Committee in its report, "A Restructured Fusion Energy Sciences Program." The report calls for a programmatic review to assist the Department in setting technical priorities for the Inertial Fusion Energy (IFE) Program.

Inertial fusion has been reviewed often in the past decade, including the Fusion Policy Advisory Committee in 1990, the Fusion Energy Advisory Committee (FEAC) in 1993, as well as two reviews by the National Academy of Sciences during the 1980s. Questions of scientific merit and appropriate energy relevance have been addressed positively by the previous reviews. For the near term, however, we would like you to provide us with an assessment of the content of an inertial fusion energy program that advances the scientific elements of the program and is consistent with the Fusion Energy Sciences Program, and budget projections over the next several years.

Please consider augmenting the expertise of FEAC with appropriate individuals from inertial fusion programs that are active in this country, as well as foreign participants that would be helpful.

I would like to have your recommendations regarding this program by July 1996.

The Department is appreciative of the time and energy provided by the members of FEAC in this continuing effort to improve and orient the fusion energy sciences program to the needs of the times. I will look forward to hearing the Committee's recommendations on this matter.

Sincerely,

Martha A. Krebs
Director
Office of Energy Research

Charge to the Fusion Energy Advisory Committee for an Inertial Fusion Energy Review

Since 1990, the fusion program has had a mandate to pursue two independent approaches to fusion energy development, magnetic and inertial confinement fusion. In magnetic fusion, our strategy is to continue to use international collaboration, especially participation in the International Thermonuclear Experimental Reactor, to pursue fusion energy science and technology. In inertial fusion, our strategy has been to assume the target physics is the highest priority activity and would be developed as a part of the weapons research program; and,

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indeed, the next step in the development of target physics, namely the National Ignition Facility, is proceeding into construction in Defense Programs.

Based on the Fusion Policy Advisory Committee report of 1990, we had taken as our highest priority in inertial fusion energy the development of heavy ion accelerators as the most desirable driver for energy applications. That development program has met all of its milestones and has received numerous positive reviews, including one by the Fusion Energy Advisory Committee (FEAC), which in 1993 recommended a balanced Inertial Fusion Energy program of heavy ion accelerator development, plus other smaller scale efforts, at $17 million per year.

The potential for inertial fusion energy has been judged to be real, but the fusion program no longer has as a goal the operation of a demonstration power plant by 2025. Given that the basic mission of the fusion program has changed from energy development to fusion energy science, and that funding for the entire fusion program will be constrained for some number of years, I would like FEAC to again consider inertial fusion energy and recommend what the new Fusion Energy Sciences program should be doing in support of this future fusion application, and at what level?

Dr. Martha Krebs July 17, 1996
Director
Office of Energy Research
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Dr. Krebs:

The Fusion Energy Science Advisory Committee (FESAC) transmits to you the report of the FESAC Inertial Fusion Energy Panel, formed to address the issues you raised in your charge letter to me this past April. The Panel, chaired by Dr. John Sheffield prepared this comprehensive report in a short time and we acknowledge with appreciation all the work of the Panel members.

The FESAC has reviewed and discussed the Panel's findings and funding recommendations, and we support them on the assumption that the President's budget request is approved. The Panel finds that Inertial Fusion Energy (IFE) research is scientifically and technically challenging and fits appropriately as a part of the restructured fusion program. The Panel also finds that the IFE program now conducted by the Office of Fusion Energy Sciences of Energy Research benefits from an "essential symbiotic relationship with the Inertial Confinement Fusion (ICF) program conducted by Defense Programs." The Panel recommends that a joint IFE steering committee between Energy Research and Defense Programs be formed to review the IFE program and related programs in Defense Programs on a regular basis, to ensure strong coordination.

The Panel accepts the findings and recommendations of earlier reports about the heavy ion beam development program. The Panel recommends that $2 million to $3 million per year be devoted to non-driver science and technology, with highest priority (beyond heavy ion driver development) being wall protection and cavity clearance schemes and confirmatory simulations of heavy ion driver target performance. The Panel notes that if the budget were to remain at the present level of about $8 million per year, the pace of development of the heavy ion accelerator would be substantially slowed.

The Panel, while not unanimous about the appropriate budget level, indicates that the budget for the IFE program should be increased to about $10 million per year for the next few years to resolve both driver and non-driver issues. This would allow the program to make an informed decision on whether to proceed with a full heavy ion driver and target experiment in three to four years while increasing the breadth of the program. FESAC recommends that a final judgement on the proper budget level and program balance await final resolution of the FY 1997 budget for OFES programs.

Sincerely,

Robert W. Conn
Chairman, on behalf of the Fusion
Energy Sciences Advisory
Committee

Professor Robert W. Conn July 17, 1996
Dean
School of Engineering
University of California, San Diego
9500 Gilman Drive
La Jolla, California 92093-0403

Dear Professor Conn:

In May, you sent me by fax a copy of the charge to the Fusion Energy Sciences Advisory Committee (FEAC) from Martha Krebs, regarding the Inertial Fusion Energy (IFE) program of the Office of Fusion Energy Sciences. Enclosed is a copy of the Charge.

The panel of technical experts (see Enclosure 2) that I chaired held two meetings in June, one at the Lawrence Berkeley National Laboratory and one at the Lawrence Livermore National Laboratory. We received input from DOE/OFES and DOE/DP/ICF and from numerous experts from the many institutions involved in inertial fusion research.

The new mission of the OFES is to "Advance plasma science, and fusion technology—the knowledge base necessary for an economically and environmentally attractive energy source for the nation and the world".

Because of the short time given to respond to this charge, we decided to rely on background information contained in the FEAC-7 report of a more extensive review of this subject published in 1993, and to hear mainly about programs since that time.

Our panel has the following findings:

(1) Progress in the IFE program since the 1993 FEAC-7 review has been good, despite its being funded at the $8 million per year level, rather than the then-recommended $17 million level.

(2) A strong IFE program is a proper and important component of the restructured OFES/DOE program. Challenging and relevant scientific issues need to be resolved, notably in collective effects in high current accelerators and beam-plasma interactions.

(3) With DP/ICF physics development and supporting science and technology and the high repetition rate driver development in the OFES/IFE program, the United States is positioned to lead the world in IFE science and technology.

(4) There has been significant progress since 1993; a substantial declassification in the DP/ICF area allows wider participation and more rapid scientific progress; in progress in preparation for the National Ignition Facility (NIF); in target physics; heavy ion accelerator technology; in operation of improved laser systems; operation of light-ion systems; and in improved understanding of power plant issues.

(5) The inertial fusion program involves much exciting science and technology, and there are opportunities because of declassification to broaden the work in the IFE program. The work of LBNL, LLNL and the institutions is of high scientific quality.

(6) There are numerous challenges in physics and technology but there are no show-stoppers.

(7) The time frame is set by a succession of anticipated events in the DP and the OFES programs. In the restructured OFES program, it is envisaged that there will be "a growing portfolio of new experiments". By 1999, the International Thermonuclear Experimental Reactor Engineering Design Activities will be complete, if the presently proposed schedule is followed the NIF should be well advanced in its construction phase, and the Tokamak Fusion Test Reactor program at the Princeton Plasma Physics Laboratory will be completed. This is a period in which some new initiatives—including one in IFE—should be ready for consideration by OFES. The NIF program is designed to have the capability to ignite a D-T target in the 2005 time frame.

(8) The heavy ion driver is the most promising for energy applications because of its greater efficiency, about 3 times greater than laser driver candidates. Further, the induction linac approach is the most likely to meet performance/cost targets.

In the longer term, breakthroughs in the development of laser systems could change these conclusions, and reassessments should be made on a regular basis.

(9) There is a need for an Integrated Research Experiment (IRE) to have in one facility the ability to resolve basic beam dynamics, final beam focusing and transport issues in a reactor relevant beam parameter regime, and to evaluate the target heating phenomonology. Progress in beam development encourages the belief that the conceptual design of a 3kJ-30kJ, 100 MeV driver could be developed around 1999, provided there is continued support for accelerator development.

(10) Target physics will not be tested conclusively before the experiment on NIF. LLNL has just completed an integrated simulation of a heavy ion driver target. It is important for other groups to develop new codes and to perform independent confirmatory simulations. Such efforts, would provide an important link between the MFE and the IFE communities.

(11) Several comprehensive conceptual design and system studies have been completed. They show the potential for and the requirements for IFE to provide competitive power plants. The IFE program within OFES should have sufficient breadth beyond driver development to cover those other areas that are critical to its feasibility and competitiveness.

As a first priority, we suggest work on wall protection scheme evaluations and development and confirmatory simulations of heavy ion driver performance. As a second priority, there should be work on cavity clearing technologies at IFE repetition rates and the development of final focusing optics for lasers (we assume that focusing and transport work for beams will be undertaken as a part of the accelerator development program.) As a third priority, work on target factory studies, rep-rated laser systems (a promising area but the present funding level will only support development of the most promising driver), shielding, blanket and tritium studies, and further detailed power plant conceptual design studies.

(12) We suggest that a joint IFE steering committee, between ER and DP, consisting of all interested parties, should review the program on a regular basis, and define the expectations for the ER and DP parts of the program. In addition, this steering committee could facilitate international collaboration.

(13) The position of the Panel is that there should be an increase in the non-driver part of the IFE program, raising it from the present ~$1M per year to $2–3M per year. It is noted that if this were done at a constant level of about $8M per year it would substantially slow the pace of accelerator development. In fact, the FEAC-7 report identifies the $5M per year case as one in which there is no credible program for the development of a heavy ion fusion energy option. The following finding, concerning funding for the IFE program, represents a medial opinion of the Panel. A minority of the Panel would support a more aggressive approach and a comparable minority, a less aggressive approach.

The medial opinion is that funding for the IFE program should be increased to about $10M per year for the next few years to strengthen the scientific and technological understanding of the prospects of IFE and to involve a wide range of institutions in these efforts. Such an annual budget would allow maintaining the pace of heavy ion accelerator development. In total, the program would provide the breadth of support necessary for initiation around the year 2000 of a construction project for an integrated research experiment using a multi-kJ heavy ion driver with a target chamber. An increased budget in the 1999 time frame would be required for developing such a proposal.

Sincerely,

John Sheffield

A. Charge to Panel

This report provides an analysis by a Fusion Energy Advisory Committee (FEAC) Panel, of future program options for the Inertial Fusion Energy (IFE) component of the Fusion Energy Sciences Program of the Office of Fusion Energy Sciences. The report is in response to the following request to FEAC from the Director of the Office of Energy Research:

Charge to the Fusion Energy Advisory Committee for an Inertial Fusion Energy Review

Since 1990, the fusion program has had a mandate to pursue two independent approaches to fusion energy development, magnetic and inertial confinement fusion. In magnetic fusion, our strategy is to continue to use international collaboration, especially participation in the International Thermonuclear Reactor, to pursue fusion energy science and technology. In inertial fusion, our strategy has been to assume the target physics is the highest priority activity and would be developed as a part of the weapons research program; and, indeed, the next step in the development of target physics, namely the National Ignition Facility, is proceeding into construction in Defense programs.

Based on the Fusion Policy Advisory Committee Report of 1990, we had taken as our highest priority in inertial fusion energy the development of heavy ion accelerators as the most desirable driver for energy applications. That development program has met all of its milestones and has received numerous positive reviews, including one by the Fusion Energy Advisory Committee (FEAC), which in 1993 recommended a balanced Inertial Fusion Energy program of heavy ion accelerator development, plus other smaller scale efforts, at $17 million per year.

The potential for inertial fusion energy has been judged to be real, but the fusion program no longer has as a goal the operation of a demonstration power plant by 2025. Given that the basic mission of the fusion program has changed from energy development to fusion science, and that funding for the entire fusion program will be constrained for some number of years, I would like FEAC to again consider inertial fusion energy and recommend what the new Fusion Energy Sciences program should be doing in support of this future fusion application, and at what level."

B. Review Process

The panel was briefed by Dr. N. Anne Davies, Director of the Office of Fusion Energy Sciences (OFES) of the Office of Energy Research, and by Dr. David Crandall, Director of the Office of Inertial Confinement Fusion (ICF) and the National Ignition Facility (NIF) of Defense Programs, on the roles of IFE and ICF in the Department of Energy. A summary was given of previous reviews of the IFE program, including that of the Fusion Policy Advisory Committee (1990) and the FEAC Panel 7 (1993). The panel was asked by Dr. Davies, and agreed to assume, that NIF would be built and that the IFE mission belonged in OFES. Presentations were also heard on the progress and prospects in the various areas of the program from a number of the collaborating institutions. Written comments were received from experts in the field.

It was agreed that, given the short timescale for conducting this review, the panel would rely on the extensive technical background provided in the FEAC Panel 7 report, supplemented by the more recent information given in presentations and written comments.

C. Overview

Inertial confinement of plasmas provides an important fusion option with the potential for a competitive power plant. There are two inertial fusion program elements. The OFES/OER/DOE has the mandate to support energy applications through its Inertial Fusion Energy (IFE) program. The ICF program in DP/DOE is motivated by science based stockpile stewardship. The DP program is funded in FY 1996 at about \$240 M/year, about 30 times the OFES inertial fusion energy program. Obviously, much of the key research will be undertaken in the DP program. The IFE program must concentrate on energy issues not covered by DP, and try to position itself to apply the results of DP research in the energy area. Significant developments in the ICF program continue to provide crucial scientific and technical results that support the IFE component. It is important to capitalize on this symbiotic relationship between IFE and ICF. Further, progress in the IFE program since the 1993 FEAC-7 review has been good, despite its being funded at the \$8M per year level rather than the then-recommended \$17 M level.

A strong IFE program is a proper and important component of the restructured OFES/DOE program. Challenging and relevant scientific issues need to be resolved, especially in the areas of collective effects in high current accelerators and beam-plasma interactions. With the ICF physics development in Defense Programs, and supporting science and technology and the high repetition rate driver development in the OFES program, the United States is positioned to lead the world in developing IFE science and technology.

The following finding, concerning funding for the IFE program, represents a medial opinion of the Panel. A minority of the Panel would support a more aggressive approach and a comparable minority, a less aggressive approach. The medial position of the Panel is that there should be an increase in the non-driver part of the IFE program beyond the present level to strengthen the scientific and technological understanding of the prospects of IFE and to involve a wider range of institutions in these efforts. The medial opinion is that, to achieve this goal, the funding for the IFE program should be increased to about \$10M per year for the next few years. Such an annual budget would allow maintaining the pace of heavy ion accelerator development. In total, the program would provide the breadth of support necessary for initiation around the year 2000 of a construction project for an integrated research experiment using a multi-kJ heavy ion driver with a target chamber.

D. Findings

1. Progress Since 1993

- An opportunity for wider participation and more rapid scientific progress has been created by a substantial declassification in the ICF area funded by DOE's Defense Programs;
- The progress in the preparation of the National Ignition Facility (NIF), for which the Inertial Confinement Fusion Advisory Committee (ICFAC, November 1995) indicated that "as far as ignition is concerned there is sufficient confidence that the program is ready to proceed to the next step in the NIF project. . . .";
- Excellent progress in:
  - — the understanding of target physics through the NOVA program;
  - — heavy ion accelerator technology;
  - — operation of improved, fusion relevant, laser systems—KrF (Nike at NRL), the new Omega Upgrade Direct Drive Facility (U. Of Rochester) and diode pumped solid state development (at LLNL);
  - — operation of light ion systems that support some beam-target interaction assumptions; and
  - — improved understanding of power plant issues and refinements that could lead to competitive fusion power plant prospects.

2. Science and Technology

The inertial fusion program involves much exciting science and technology, as seen in the continuing developments in the target physics area. Although most of the science of target design and implosion is undertaken in the ICF Program, there are opportunities, because of declassification, for a broadening of the work in the IFE Program. The development of energetic, high current density, space-charge-dominated beams and their focusing onto a target involves fundamental science—instabilities, beam-plasma interactions, plasma lenses, etc.—

and a great opportunity to compare sophisticated computer models with experiments. These developments will have importance broadly across the accelerator field. The development of the drivers and of power plant systems requires innovative new technologies. Work to date has already led to some significant advances.

The panel finds the work at LBNL to be of high scientific quality and was impressed that the ongoing theory and experiments, even at present funding levels, will contribute significantly to the science base required for heavy ion driver development and beam propagation. The complementary IFE programs at LLNL and other institutions have also made impressive progress.

3. Challenges

Many scientific and technological challenges remain to be overcome before the goal of an economic power plant can be realized. Success is not assured although we see no show stoppers. In rough order of importance, the most critical of these are:

- Overcoming the hydrodynamic instabilities (and possible laser-plasma or beam plasma instabilities), and obtaining adequate symmetry to produce a high gain target yield. We must rely on NIF for the basic experimental proof or disproof.
- Providing viable protection of the target chamber against the X-rays, neutrons, blast, and debris to be expected from the pellet explosion. This may be particularly critical for the final focusing optics of a laser system. An analogous issue for heavy ions is finding an adequate mode for beam transport, compatible with the chamber environment that is present with various wall protection schemes.
- Development of a driver with adequate efficiency, rep-rate, and reliability.
- Mass producing targets at a cost of about $0.25 apiece, including their injection and accurate positioning in the target chamber.

All of the above must of course be done at a cost compatible with economic electricity production.

4. Timeframe

The pace and content of the IFE program is driven by a succession of anticipated events in the DP and OFES programs:

- In the Restructured Fusion Energy Sciences Program, it is envisaged that there will be "a growing portfolio of new experiments . . ."
- By 1999, the International Thermonuclear Experimental Reactor Engineering Design Activity will have been completed, the NIF should be well advanced in its construction phase, assuming the presently proposed schedule is met, and the Tokamak Fusion Test Reactor program at PPPL will be completed. This is a period in which some new initiatives—including one in IFE—should be ready for consideration by OFES.
- The proposed NIF program is designed to have the capability to ignite a D-T target in the 2005 timeframe.

5. Opportunity for the U.S. in IFE

A strong IFE program is a proper and important component of the restructured OFES/DOE program. Challenging and relevant scientific issues need to be resolved, especially in the areas of collective effects in high current accelerators and beam-plasma interactions. With the ICF physics development in Defense Programs and supporting science and technology and the high repetition rate driver development in the OFES program, the United States is positioned to lead the world in developing IFE science and technology.

6. Logic for Heavy Ion Accelerator Driver

In agreement with previous reviews of inertial fusion energy by the National Academy of Sciences and two FEAC panels, we consider the heavy ion accelerator to be the most promising driver for energy applications. The reasons include the relatively high efficiencies that are possible with accelerators, exceeding 30%, and the demonstrated high reliability of high power accelerators operating at rep rates of several Hz. In contrast, the best laser options—KrF and DPSS—have efficiencies less than 10%. Among the alternatives for heavy ion accelerators, the induction linac (or possibly the recirculating version) is well matched to the multikiloamp currents and submicrosecond pulse lengths required for inertial fusion.

An alternative accelerator approach is the rf/storage ring driver. This approach fits well within the existing European accelerator programs, and is a valuable complementary program. In a presentation at the review meetings, our European panel member agreed that the induction linac has potential cost advantages in comparison with the rf linac/storage ring approach they are exploring.

In the longer term, breakthroughs in the development of laser targets, including direct drive and other approaches (such as the fast ignitor described below) could modify the decision on drivers. Reassessment of the driver and target should be made on a regular basis.

7. Need for Integrated Research Experiment

Excellent progress has been made in the past by the IFE Program in accelerator development on key issues (e.g., beam bending, merging, pulse compression, final transport) through a series of small scale experiments—closely coupled with theoretical modeling—to understand fundamental aspects of the basic beam phenomenology. These innovative small scale experiments and associated theoretical modeling should continue. However, progress at the level needed to fully evaluate the HIF approach to IFE will also require an integrated experiment capable of resolving the basic beam dynamics issues in the accelerator, studying the final focusing and transport issues in a reactor-relevant beam parameter regime, and evaluating the target heating phenomenology.

With a succession of delays in the funding of the (less ambitious) ILSE project, the IFE team believes a more comprehensive "Integrated Research Experiment" (IRE) should be the focus of the next decade of IFE research and development. The IRE is discussed in more detail in section IID. The overall objective of IRE is to provide the data base needed to support a decision to proceed with the construction of a full scale IFE driver, on a time scale consistent with NIF demonstrations of fusion target performance.

While various options for such a facility have been considered over the years, no particular option has been selected. Consequently, the Panel received only limited information on this topic. Nevertheless, it seems clear that trade studies of various options leading to the development of a conceptual design for the IRE should be a major focus of the heavy ion program over the next two to three years.

8. Target Physics

The key scientific issue for any IFE system is target physics. This will not be tested conclusively before the experiments on the NIF. Nonetheless, the best possible simulations are indicated for a program of this importance and scientific value. LLNL has just completed the first successful "integrated" simulation of a heavy ion driven target. We believe it is important for other groups to develop new codes and perform independent confirmatory simulations as one element in a driver decision. We believe that the recent declassification makes this feasible, and that this essential task could be undertaken by an MFE theory group, providing an important link between the MFE and IFE communities with eventual mutual enrichment. Developing new target physics codes is a challenging multiyear project. In the interim, MFE theorists could contribute to such issues as beam propagation, and participate in target design using existing codes.

9. Program Needs Derived from Power Plant Studies

Several comprehensive, conceptual design and systems studies have been completed. They show the potential for and requirements for IFE to provide competitive power plants. Other than development of the driver, the key issues are:

- Demonstration of high gain at moderate driver energy.
- Development of chamber technology, including wall protection and cavity clearing schemes at power plant repetition rates.
- Development of power plant technologies to provide tritium self-sufficiency, radiation shielding, radiation resistant materials, and low-cost target production.

The IFE program within OFES must have sufficient breadth, beyond driver development, to cover those other areas that are critical to its feasibility and competitiveness. Progress in these areas will influence driver research priorities and should provide the data needed in the near term to perform meaningful experiments on NIF that are important to IFE.

10. Priorities Outside Heavy Ion Accelerator Development

The panel suggests the following priorities for the broader program:

First priority:

- Wall protection scheme evaluations and development.

- Confirmatory simulations of heavy ion driver target performance.

Second priority:

- Cavity clearing technologies at IFE repetition rates.
- Development of the final focussing optics for laser systems. (It is assumed that final focussing and transport studies for heavy ion beams are undertaken as a part of the accelerator development program.)

Third priority:

- Target factory studies.
- Work on rep-rated laser systems. This is an important area but until IFE funding increases substantially, development of only the presently most promising driver can be afforded.
- Shielding, blanket and tritium studies.
- Detailed power plant conceptual design studies. The extensive studies made in recent years have identified the principal issues for IFE. It is time now to concentrate the scientific and technological studies on these specific issues.

11. Roles of DOE/Energy Research and DOE/Defense Programs, and International Collaboration

This Panel has reviewed and commented on the IFE program conducted by the OFES of Energy Research. The program benefits from an essential symbiotic relationship with the ICF program conducted by Defense Programs. The Panel notes that the NIF program expects to offer testing time to a range of institutions and program interests. A 1994 workshop, organized by DP, identified a wide range of IFE relevant issues that could be addressed by NIF. The Panel is not in a position to comment on the balance between the various elements of the DP program, but feels strongly that greater clarification is needed regarding possible implementation of these IFE relevant elements of the DP-supported ICF program.

A joint IFE steering committee between ER and DP, consisting of all interested parties, should review this program on a regular basis.

In addition, such a committee might be used to facilitate international cooperation in IFE. This FESAC/IFE panel did not review the foreign programs, except for a brief discussion of some European developments (see IIC). We note, however, that the French are building a NIF-scale facility, that there is a proposal in Europe to expand IFE, and that there are significant IFE programs in Japan and Russia.

12. Budgets

The position of the Panel is that there should be an increase in the non-driver part of the IFE program beyond the present level to strengthen the scientific and technological understanding of the prospects of IFE and to involve a wider range of institutions in these efforts. We believe that this is needed even though there is a large measure of breadth because of related DP-funded efforts. For a total OFES/IFE budget in the range of \$8M or greater, this total investment in non-driver science and technology should be \$2M–\$3M per year.

The following finding, concerning funding for the IFE program, represents a medial opinion of the Panel. A minority of the Panel would support a more aggressive approach and a comparable minority, a less aggressive approach. The medial opinion is that funding for the IFE program should be increased to about \$10M per year for the next few years to strengthen the scientific and technological understanding of the prospects of IFE and to involve a wide range of institutions in these efforts. Such an annual budget would allow maintaining the pace of heavy ion accelerator development. In total, the program would provide the breadth of support necessary for initiation around the year 2000 of a construction project for an integrated research experiment using a multi-kJ heavy ion driver with a target chamber. An increased budget in the 1999 timeframe would be required for developing such a proposal.

At the present OFES/IFE budget level of \$8M, a significantly increased investment in program breadth is desirable but would be achieved at the expense of a substantial slowing of the pace of development of a heavy ion accelerator. At lower budget levels, the elements of the program would have to be done serially rather than in parallel, delaying the pace of the program beyond that needed to meet the goals above. At some lower level, it would be impossible to mount a coherent driver development program. The FEAC Panel report identified the \$5M/year case as one in which "there is no credible program for the development of a heavy ion fusion energy option."