An Assessment of the Department of Energy's Office of Energy Sciences Program

Fusion Science Assessment Committee

Plasma Science Committee

Board on Physics and Astronomy

Commission on Physical Sciences, Mathematics, and Applications

National Research Council

(Released Monday, October 23, 2000)

Wednesday, November 15, 2000

FeSAC Meeting

Bethesda, MD

The Charge

- The committee will assess the scientific quality of the fusion program of the DOE's Office of Science. Criteria will include excellence, impact, role in education, and contribution to strengthening the scientific foundation for fusion. A science strategy for the program will provide a context for judgement and a direction for future development.

The Panel Members

Charles Kennel, Scripps Inst. of Oceanography(*)		O/A
Linda Capuano, Honeywell, Inc.		O/A
Patrick Colestock, LANL		O
France Cordova, UC Santa Barbara(*)		O/A
James Drake, U. of Maryland(*)	P	
Nathaniel Fisch, Princeton U.	P	
Lennard Fisk, U. of Michigan		O/A
Raymond Fonck, U. of Wisconsin/Madison	P	
Robert Frosch, Harvard U.(*)		O/A
George Gloeckler, U. of Maryland		O
Zoran Mikic, SAIC		O
Albert Narath, Lockheed Martin Corp.(*)		O/A
Claudio Pellegrini, UC Los Angeles		O
Stewart Prager, U. of Wisconsin/Madison(*)	P	
Robert Rosner, U. of Chicago(*)		O
Andrew Sessler, LBNL		O
Robert Socolow, Princeton U.(*)		O
James Van Dam, U of Texas/Austin	P	
Jonathan Wurtele, UC Berkeley		O

Joel Parriott, NRC staff

Don Shapero, NRC staff

(*) Steering Group Member

P: Plasma physicist
O: "Outsider"
A: Administrative background

How we wrote the Report I

Meetings and presentations

- May 16-19, 1999 (La Jolla, CA)
  - presentations: science and program overviews
- July 20-23, 1999 (Snowmass, CO)
  - presentations: science
  - attended 1999 Fusion Summer Study
  - informal discussions with FESAC chair
  - finished “Interim Report”
- Nov. 17-18, 1999 (Seattle, WA; APS DPP meeting)
  - presentations: science and technology, FESAC, Labs, universities
  - discussions
- Feb. 23-25, 2000 (Washington, DC)
  - presentations: OMB, DOE/OFES
  - discussions and draft writing
- May 8-9, 2000 (Irvine, CA)
  - discussions and draft writing

How we wrote the Report II

A number of previous reports provided context:

- *Congress and the Fusion Energy Sciences Program: A Historical Analysis* Richard E. Rowland (Congressional Research Service 2000)
- *Plasma Science: From Fundamental Research to Technological Applications* (NRC Press 1995)
- *Realizing the Promise of Fusion Energy: Final Report of the Task Force on Fusion Energy* (DOE/SEAB 1999)
- *Report of the FESAC Panel on Priorities and Balance* (DOE/FESAC 1999)

How we wrote the Report III

- Committee divided into four groups:
  - Steering Committee (leader: C. Kennel)
  - Science Progress and Development of Predictive Capability (leader: J. Drake)
  - Plasma Confinement Configurations (leader: S. Prager)
  - Interactions of Fusion Program with Allied Areas of Science and Technology (leader: R. Rosner)

We also met with Washington “stakeholders”, representing

- DOE
- U.S. Congress
- Office of Management & Budget (OMB)
- Office of Science & Technology Policy (OSTP)
- Congressional Research Service

How we wrote the Report IV

- We received a rigorous review:
  - A. Bers, MIT
  - S.C. Cowley, UC Los Angeles
  - M.L. Goldberger, UC San Diego
  - W. Happer, Jr., Princeton U.
  - C.S. Liu, U. of Maryland
  - R.F. Schwitters, U. of Texas/Austin
  - C.M. Surko, UC San Diego
  - Lilian Wu, IBM
  - E.G. Zweibel, U. of Colorado

- My (RR) personal thanks to:
  - Jim Drake, U. Maryland
  - Joel Parriott, NRC

A quick overview of our conclusions

13 “Findings”, 7 major Recommendations

- Fusion research has led to great science and technological innovation, on par with other fields of science
- Fusion science is isolated: the science is not widely appreciated outside the program
  - Reduced respect and credibility for the field on the “outside”
  - Difficult to replace faculty at major research universities
  - Selling of new initiatives much more difficult
- Overarching scientific themes should play a greater role in program decision making and organization

Summary Finding 1: Science Quality

- The quality of the science that has been deployed in pursuit of a practical fusion power source … is easily on a par with other leading areas of contemporary basic and applied science.

Summary Finding 2: Science Quality

- The study of high temperature plasma has historically had a strong empirical emphasis. With the development of a new theoretical, computational, and experimental capabilities, a fundamental transition away from the empirically dominated approach is now taking place.

Summary Finding 3: Science Quality

- Scientific discovery has and continues to play a critical role in shaping the direction of research and facilitating the significant enhancements in the energy containment properties of magnetic bottles which have been achieved over the history of the fusion program.

Summary Finding 4: Science Quality

- Since the redirection of the fusion program in 1996 towards establishing the scientific knowledge base for fusion, a greater emphasis has been placed on understanding the plasma dynamics underlying the operation of the various confinement configurations. However, performance goals rather than [overarching] scientific goals continue to act as the primary driver for the allocation of resources in the program.

Summary Finding 5: Science Quality

- In the context of the international fusion energy effort, the U.S. program has traditionally played a central role as a source of innovation and discovery. The goal of understanding at a fundamental level the physical processes governing observed plasma behavior has been a distinguishing feature of the U.S. program.

Summary Findings 6-9:
Role of Science

- A fusion research program requires investigation of a range of confinement schemes.
- The fusion program benefits from experiments covering a range of scales.
- In the past several years, the OFES program has effectively broadened the spectrum of confinement configurations under study.
- FESAC has developed a set of categories to judge the level of development of individual fusion concepts towards the fusion energy goal and effective metrics to assess whether a particular concept is ready to advance … While these categories are effective in defining progress of a given experimental concept toward the fusion energy goal, they are not effective in defining and promoting the solution of cross-cutting science issues which are essential to progress toward fusion.

Summary Finding 10-13:
Coupling and the Future

- In the key scientific areas … there is a clear history of intellectual exchange between the plasma physics community and the broader scientific community in areas such as MHD, nonlinear dynamics, instabilities, and transport.
- The current fusion program is relatively weakly coupled to the rest of the physics community.
- The future representation of plasma science at the universities is threatened by an apparent lack of "new blood".
- [In the area of theory/computation,] the absence of "critical mass" closely interacting teams composed of researchers from different and varied institutions is inhibiting the successful attack on a number of central science issues confronting the fusion research program.

Summary Recommendation 1

- Increasing scientific understanding of fusion-relevant plasmas should become a central goal of the US fusion energy program on a par with the goal of developing fusion energy technology.

Summary Recommendation 2

- A systematic effort to reduce the scientific isolation of the fusion research community from the rest of the scientific community is urgently needed.

Summary Recommendation 3

- The fusion science program should be broadened both in terms of its institutional base and its reach into the wider scientific community; the program should be open to evolution in terms of content and structure as it continues to strengthen its portfolio of research.

Summary Recommendation 4

- Several new, openly competed centers devoted to exploring the frontiers of fusion science are needed for both scientific and institutional reasons.

  - The committee believes this recommendation to be critical enough to the new science-based approach to fusion energy that ways should be found to fund a first center ***even in a level budget scenario***.

Details for Summary Recommendation 4

- **Many of the issues in fusion science are now of sufficient complexity that they require closely interacting, critical mass groups of scientists to make progress.**
  - appropriate physical models
  - understanding of non-linear physics
  - computational algorithms
  - efficient programming on massively parallel computing platforms
  - tight coupling with a parallel experimental effort
- **Loose collaborations of the past have not worked well for the most challenging topics.**
- **New "frontier centers" could create a new focus on scientific issues within the U.S. fusion program.**
- **"Ingredients"**
  - Plan to identify, pose and answer scientific questions whose importance is widely recognized.
  - Size comparable to current NSF-sponsored centers, with annual operating costs ~ $1-$5M per yr.
  - ~ 4-6 co-investigators
  - Links to various scientific disciplines, including physics, mathematics, computer science, and others depending on the problem focus of the center.
  - The institutions housing or participating in such centers should make a commitment to add faculty or career staff, as appropriate, in plasma/fusion science and/or related areas.
  - The centers should have a strong educational component.
  - Centers should sponsor multidisciplinary workshops and summer schools focused on their central problem.
- **Examples of Center science topics**
  - turbulence and transport
  - magnetic reconnection
  - energetic particle dynamics
  - materials
- **Interagency, and particularly NSF, collaboration in one or more fusion frontier center is encouraged, but with lead role played by DOE.**
- **Selection process for the centers should feature open, competitive peer review employing clear, science-based selection criteria.**

Summary Recommendation 5

- Solid support within a broad scientific community for US investment in a fusion burning experiment should be developed.

Summary Recommendation 6

- The NSF should play a role in extending the reach of fusion science, as well as sponsoring general plasma science.

Summary Recommendation 7

- There should be continuing broad assessments of the outlook for fusion energy, and periodic external reviews of fusion energy science.

… and that brings us to

Questions and discussions