Fusion Development Path Panel

Preliminary Report

Rob Goldston and
the Development Path Panel

Report to the Fusion Energy Sciences Advisory Committee

November 25, 2002

Panel Members

- **Mohamed Abdou, University of California, Los Angeles**
- **Charles Baker, University of California, San Diego**
- **Michael Campbell, General Atomics**
- **Vincent Chan, General Atomics**
- **Stephen Dean, Fusion Power Associates**
- **Robert Goldston (Chair), Princeton Plasma Physics Laboratory**
- **Amanda Hubbard, MIT Plasma Science and Fusion Center**
- **Robert Iotti, CH2M Hill**
- **Thomas Jarboe, University of Washington**
- **John Lindl, Lawrence Livermore National Laboratory**
- **Grant Logan, Lawrence Berkeley National Laboratory**
- **Kathryn McCarthy, Idaho National Engineering Laboratory**
- **Farrokh Najmabadi, University of California, San Diego**
- **Craig Olson, Sandia National Laboratory, New Mexico**
- **Stewart Prager, University of Wisconsin**
- **Ned Sauthoff, Princeton Plasma Physics Laboratory**
- **John Sethian, Naval Research Laboratory**
- **John Sheffield, ORNL – UT Joint Institute for Energy and Environment**
- **Steve Zinkle, Oak Ridge National Laboratory**

MFE and IFE are Working Together on the Fusion Development Path

Rob Goldston, PPPL   John Sethian, NRL

Fusion Materials and Technologies, from A to Z

Mohamed Abdou, UCLA Steve Zinkle, ORNL

Pre-Halloween Development Path Meeting

Or is this One Scarier?

Charge for Preliminary Report

- "… I would like FESAC to develop a **plan with the end goal of the start of operation of a demonstration power plant in approximately 35 years.** The plan should recognize the capabilities of all fusion facilities around the world, and include both magnetic fusion energy (MFE) and inertial fusion energy (IFE), as both **MFE and IFE** provide major opportunities for moving forward with fusion energy."

- "The report would be most helpful if it could be done in two phases. Building as much as possible on previous work of FESAC, the first phase would be a **preliminary report, completed by December 1, 2002**, which would both provide a **general plan** to achieve the aforementioned goal and identify those **significant issues that deserve immediate attention**. As a second phase, I would like by March 2003, or earlier, a more detailed plan upon which budgeting exercises can be based."

Process

- **October 3 – 4**
  - Preliminary definition of a Demo.
  - Identified key factors affecting logic and timeline.
- **October 28 – 30**
  - Heard from experts on key factors.
  - Heard from EU and JA development path groups.
- **Nov 11 (UFA), 12 (FESAC), 15 (Dev. Path Committee)**
  - Progress report and input to Panel at APS [also devpath@pppl.gov]
- **November 15 – 16**
  - Completed Preliminary Report
- **November 25, FESAC Review of Preliminary Report**
- **Dec 3, Presentation at Fusion Power Associates meeting**
- **January 13 – 14, Open Workshop in San Diego**
- **January 15 - 16 Panel Meeting**
- **March 2003 or earlier, Final Report to FESAC**

Outline

- Principles
  - Definition of Demo
  - Portfolio Management Philosophy
  - External Linkages
- Illustrative General Plan
  - Panel’s Assessment
- Significant Issues that Deserve Immediate Attention
  - MFE Burning Plasma
  - Domestic Research – MFE & IFE
- Conclusions

Principles: Definition of Demo

The goal of the plan is operation of a US demonstration power plant (Demo), which will enable the commercialization of fusion energy. The target date is about 35 years. Early in its operation the Demo will show net electric power production, and ultimately it will demonstrate the commercial practicality of fusion power. It is anticipated that several such fusion demonstration devices will be built around the world. In order for a future US fusion industry to be competitive, the US Demo must:

a. be safe and environmentally attractive,
b. extrapolate to competitive cost for electricity in the US market, as well as for other applications of fusion power such as hydrogen production,
c. use the same physics and technology as the first generation of competitive commercial power plants to follow, and
d. ultimately achieve availability of ~ 50%, and extrapolate to commercially practical levels.

Principles: Portfolio Management (a)

The plan recognizes that difficult scientific and technological questions remain for fusion development. A diversified research portfolio is required for both the science and technology of fusion, because this gives a robust path to the successful development of an economically competitive and environmentally attractive energy source. In particular both Magnetic Fusion Energy (MFE) and Inertial Fusion Energy (IFE) portfolios are pursued because they present major opportunities for moving forward with fusion energy and they face largely independent scientific and technological challenges. The criteria for investment, in order to optimize cost-effectiveness, are:

a. **Quality**

i. Excellence and innovation in both science and technology are central.

ii. Development of fundamental plasma science and technology is a critical underpinning.

iii. The US must be among the world leaders in fusion research for the US fusion industry to be competitive.

Principles: Portfolio Management (b,c)

b. **Performance**:

i. The plan is structured to allow for cost-effective staged investments based upon proven results. Decision points are established for moving approaches forward, as well as for "off-ramps".

ii. Technically credible alternative science and technology pathways that are judged to reduce risk substantially or to offer substantially higher payoff ("breakthroughs") are pursued.

   It is not a requirement, however, that every pathway be funded at the level needed for deployment in 35 years.

iii. Inevitably later elements of the plan are less well defined at this time than earlier ones; a goal of earlier elements is to help define later ones.

c. **Relevance**:

i. Technical credibility

ii. Environmental attractiveness

iii. Economic competitiveness

Principles: External Leverages

The plan recognizes and takes full advantage of external leverages.

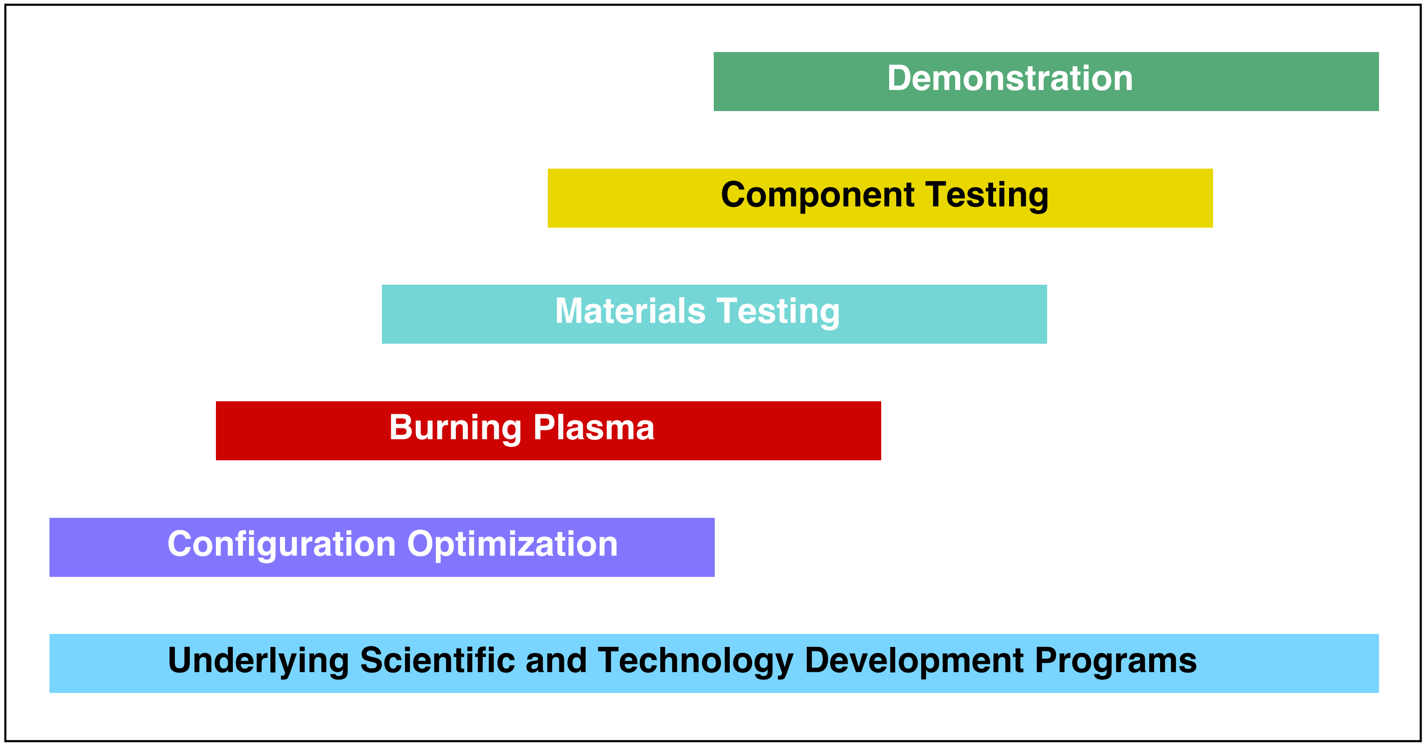
a. The plan depends upon the international effort to develop fusion energy, positioning the U.S. to contribute to this development and ultimately to take a leadership position in the commercialization and deployment of fusion energy systems.

b. The plan takes full advantage of developments in related fields of science and technology, such as advanced computing and materials nanoscience.

c. The high quality of the science and technology developed for fusion gives rise to opportunities for broader benefits to society. Thus connections to other areas of science and technology are actively pursued.

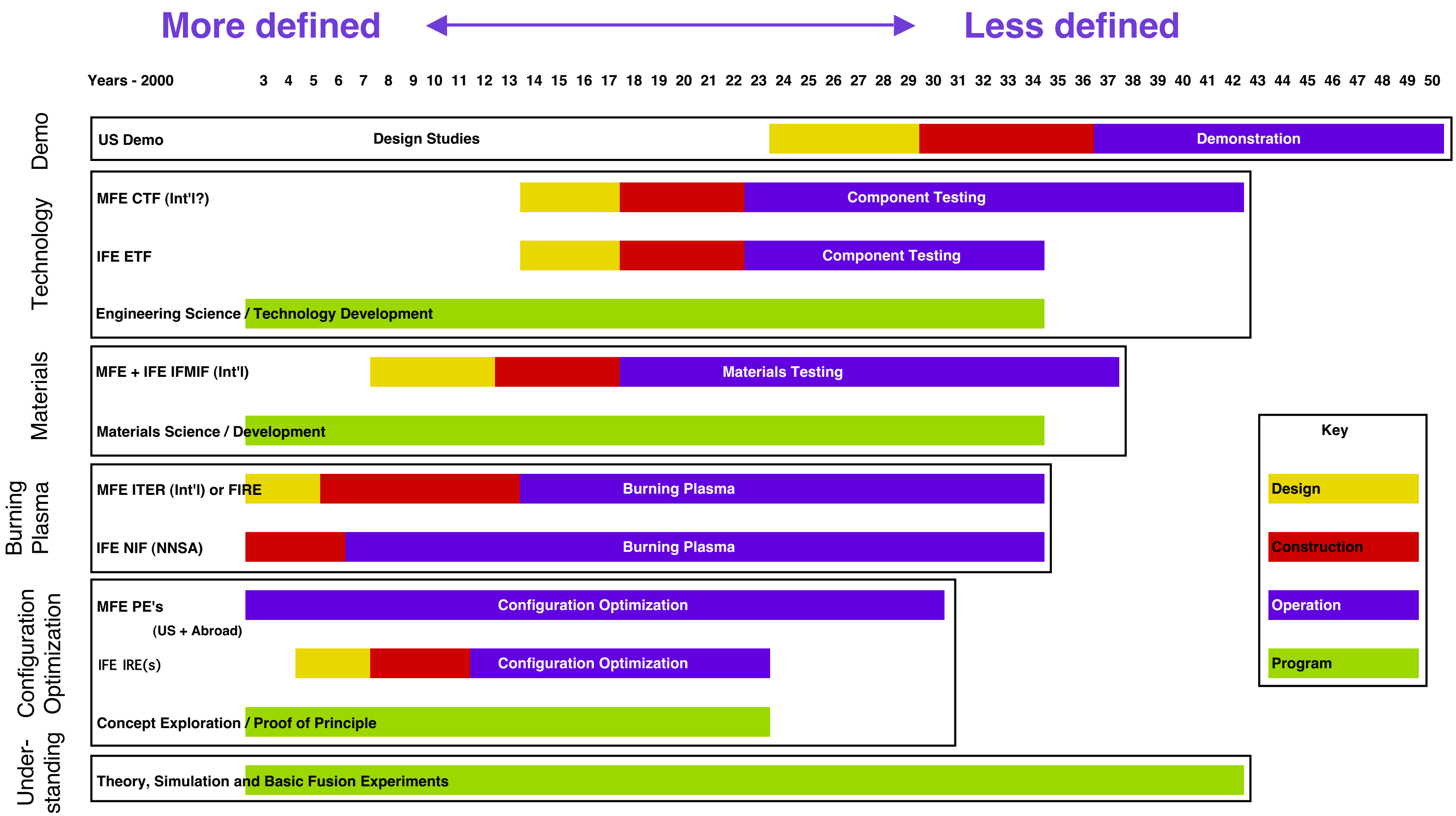
d. For Inertial Fusion Energy, the plan takes full advantage of advances supported by the US National Nuclear Security Administration (NNSA) in the area of Inertial Confinement Fusion (ICF).

The Fusion Development Path is Defined by a Set of Overlapping Scientific and Technological Challenges



Overlapping scientific and technological challenges define the sequence of major facilities needed in the fusion development path. Programs in theory and simulation, basic plasma science, concept exploration and proof of principle experiments, materials development and plasma and fusion power technologies precede and then underlie research on the major facilities.

Illustrative General Plan



Includes both programs and facilities.
No costing at this time.

Panel's Assessment

The Panel has done a preliminary examination of the components of the plan, both their individual duration and the linkages between them, and has concluded that these are consistent with the operation of a Demo on the desired timescale. Achievement of this timescale requires that appropriate funding is provided so that the schedule for the design, construction and operation of facilities is technically driven. Furthermore in some cases design must begin before all information is in hand, and the decision to construct a facility must then be taken promptly when confirmatory information becomes available.

It is the judgment of the Panel that the plan illustrated here can lead to the operation of a demonstration fusion power plant in about 35 years and enable the commercialization of fusion power. It should be recognized … that significant scientific and technological challenges remain for the development of fusion as a practical energy source, necessitating a portfolio approach. Furthermore, while costing of the plan is a task for the Panel's Final Report, it is clear that substantial additional resources will be needed to implement this plan. In particular, in order to initiate this plan, funding for fusion energy research including both MFE and IFE needs to begin to ramp up in FY2004.

Significant Issues that Deserve Immediate Attention - I

MFE Burning Plasma

The MFE portion of the plan depends fundamentally on US participation in a magnetically confined burning plasma experiment. It is time critical for the US to move forward with the burning plasma recommendations of FESAC. This is a dual-path strategy including both the ITER and FIRE options, that begins with US participation in the ITER negotiations with the aim of becoming a partner in the undertaking. The sooner the US joins ITER negotiations the larger will be US leverage on critical decisions. There are matters of urgent concern to the US, such as cost-control, project management, research decision-making and – of course – its own benefits and obligations.

Significant Issues that Deserve Immediate Attention - II

Domestic Research – MFE & IFE

Materials science and fusion chamber and power technology development work needs to be accelerated for both MFE and IFE. The Engineering Validation phase of the International Fusion Materials Irradiation Facility must begin expeditiously.

MFE facilities devoted to configuration optimization (from concept exploration to performance extension) need to be adequately utilized and innovative new such facilities need to be constructed at a cost-effective pace. The enabling technology program needs to provide necessary plasma control tools to support these experiments, and new opportunities in theory and advanced computing need to be pursued. Preparations for a burning plasma experiment need to be started.

The IFE portion of the plan, including elements that are currently distributed between the Office of Science and the NNSA, needs to be adopted as a significant mission with appropriate emphasis within the DOE. Within IFE, the heavy ion beam program needs to begin design of a next-step proof-of-principle experiment. The z-pinch approach to IFE and fast ignition research need to be pursued more aggressively. The development of laser fusion energy has been supported through the high-average-power laser program. This activity is of critical importance to the laser IFE development path, and needs to be supported on a continuing basis.

The recommendation by the NAS/NRC to strengthen connections to other areas of science and technology needs to be implemented.

Conclusion

Dramatic scientific and technological advances have been achieved over the last decade, from the understanding and control of turbulence in magnetically confined plasmas to the demonstration of the positive impact of improved symmetry control in inertial confinement. This strengthened scientific understanding of fusion systems, bolstered by the application of advanced computing, provides enhanced confidence that practical fusion systems can be realized. Increased concern about the impact of human activity on the global ecosystem points to the need for new broadly available, non-polluting energy sources such as fusion. In addition, escalating international tensions underscore the importance of long-term national energy security.

A commitment now to expend the additional resources to develop fusion energy within 35 years is timely and appropriate.