Burning Plasma Developments

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Presented to
VLT Program Advisory Committee
UCLA

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Outline

- Response to VLT PAC Recommendation on NSO and Burning Plasma Issues
- NSO PAC Activities
  - First Meeting July 20-21, 2001 at GA
    - Action Items and Status
  - Second Meeting January 17-18, 2001 at MIT
    - Agenda items
- FuSAC Recommendation on a burning plasma experiment
- Value of the Science, and Scientific Readiness to proceed.
  - Interface with UFA workshop on Burning Plasma Science
  - Interface with FESAC Panel on Burning Plasmas
- FIRE Plans in FY01

VLT-PAC June 2000

- Requested report on the first NSO PAC meeting

- "..recommend(ed) that the NSO PAC somewhat expand its mission to address two key issues: the scientific value of a burning plasma physics experiment, and the scientific readiness to proceed with such an experiment."

  will be a major topic at the next NSO-PAC meeting January 17-18 at MIT

- requested report on the UFA Workshop.

First NSO/PAC Meeting Report-Action Plan

- **First meeting (for detailed info see link at http://fire.pppl.gov)**

- **Members:** Tony Taylor Chair), Gerald Navratil, Ray Fonck, David Gates, Dave Hill, Wayne Houlberg, Tom Jarboe, Mitsuro Kikuchi, Earl Marmar, Raffi Nazikian, Craig Petty, Rene Raffray, Paul Thomas, James VanDam

- **Charge for First meeting**
  - **Scientific value of a Burning Plasma experiment***
  - **Scientific readiness to proceed with such an experiment***
  - **Is the FIRE mission scientifically appropriate?**
  - **Is the intial FIRE design point optimal?**
  - ***intial discussion at first meeting followup at the second NSO-PAC**

- **NSO-PAC Recommendations and FIRE Action Plan (http://fire.pppl.gov)**
  - **will discuss in more detail under FY 2001 Plans**

- **Second meeting January 17-18, 2001 at MIT**

FuSAC Recommendation on Burning Plasma Experiment*

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

An eventual burning plasma experiment is scientifically necessary as well as being on the critical path to fusion energy. The determination of the optimal route toward a burning plasma experiment is beyond the scope of the committee; rather, the route should be decided in the near term by the fusion community. Resources above and beyond the present program will be required. The US scientific community needs to take the lead in articulating the goals of an achievable, cost-effective scientific burning experiment, and to develop flexible strategies to achieve it, including international collaboration.

… However, since the US Fusion Energy Science program is now positioned strategically as a science program, advocacy by the larger scientific community for the next US investments in a fusion burning experiment now becomes even more critical to developing that support. For this reason alone, the scientific isolation of the fusion science community needs to be reduced. ……

*from The FuSAC Prepublication Report, Executive Summary, October, 2000

European News on Burning Plasmas

Assessment of Fifth Framework and Recommendations for the Sixth Framework (July 24, 2000), Airaghi Report to the European Commission.

2. The European Fusion Programme should continue to be reactor orientated and the construction of the 'Next Step' should be started in FP6. ……..

3. To proceed with the ‘Next Step’ in the international collaboration perspective of the New-ITER, the European Union should within the next 2 years: · Conclude negotiations on the legal and organisational structure of the future venture · Actively seek a European site for the New-ITER, since this is the best option from a European viewpoint. · Conduct a thorough review of the financial issues, including the different financial costs and benefits of siting it in Europe, Canada or Japan, and establish the extent to which Japan would support the construction of New-ITER outside Japan. · Examine in detail the recent interesting expression of interest received from the Canadian Consortium.

4. In the same 2-year period, due to the uncertainty over the outcome of the international negotiations, Europe should study an alternative to New-ITER, which would be suitable to be pursued by Europe alone. For example, a copper magnet machine which would still achieve the required objective of demonstrating a burning plasma under reactor conditions even if this would delay the integration of the superconducting technologies. Europe would then be ready by mid FP6 to drive forward the development of fusion even in the event of a further lack of positive decision on the construction of the New-ITER.

European News on Burning Plasmas(2)

Research Council Meeting (November 16, 2000)

The Council approved the negotiating directives for the Commission on the establishment of an international framework allowing the ITER (International Thermonuclear Experimental Reactor) EDA (Engineering Design Activities) Parties and qualified third countries to prepare jointly for the future establishment of an ITER legal entity for ITER construction and operation, if and when so decided.

It was pointed out that the current international ITER EDA Agreement is due to expire on 21 July 2001. Since international cooperation in this field is crucial, it is necessary to maintain the legal basis for such cooperation until the end of the current research framework programme (EURATOM) which comes to an end in December 2002 in order to avoid creating a legal vacuum. However, although work on the technological aspects of the new ITER will be completed next year, no decision as to its construction or operation can be taken until the content of the 6th Framework Programme is known. An in–depth examination of the role of fusion and particularly of ITER in the context of Community research will be scheduled in the near future.

Preparation of a Proposal for Siting ITER-FEAT at Cadarache

About 22 FTE have been assigned to prepare a proposal for siting ITER at Cadarache. The proposal would be submitted to the French government and then to the European Commission before Dec, 2000.

Preparation of a Proposal for FTU* tokamak at ENEA Frascati

A preliminary proposal has been requested by C. Rubbia for a ≈8T copper coil tokamak with R = 1.32m to carry out DD experiments in a shaped plasma crosssection. this is envisioned as an upgrade of the FTU facility. One option being considered is to utilize prototypes constructed for IGNITOR. The proposal is due December 10, 2000.

Review of ITER-FEAT and IGNITOR

(Requested by R. Pellat)

Members

G. Laval, F. Porcelli, J. Jacquinot, J-F. Luciani, O. Gruber, G. Cordey, W. Horton, J. Callen

Recommendation 1: Panel members believe that the ITER-FEAT proposal is sound, has reached maturity and that the plasma performances required for reaching the stated objectives of ITER-FEAT rely on robust extrapolations from validated experimental databases. Panel members believe that the ITER-FEAT proposal will reach its main objectives and will bring an outstanding contribution to a reactor oriented strategy. The remaining issues, although not critical, deserve to be addressed but they must not delay any positive decision concerning the experiment.

Recommendation 2: In the near term, an effort should be made to acquire a degree of confidence on the remaining open issues concerning IGNITOR by appropriate R&D,dedicated experiments in existing tokamaks and numerical investigations. Such an experiment would be on the frontier of plasma physics and thus have both risks and opportunities, a feature in common with other great physics experiments.

Recommendation 3: Establish an international burning plasma study group.

November 24, 2000

UFA Workshop on Burning Plasma Science (December 11-13)

Purpose and Scope: Stimulated by the growing interest in the science of burning plasmas coming out of discussions at the 1999 Fusion Summer Study at Snowmass and the recent charge [5 Oct. 2000] to FESAC by the DOE Office of Science to "...address the scientific issues of burning plasma physics," the University Fusion Association (UFA) is sponsoring a Workshop on Burning Plasma Science, 11-13 December 2000, in Austin, TX, to provide a forum for in-depth community discussion of the critical scientific issues connected with burning plasmas. Based on progress achieved at this December workshop (which focuses on scientific issues), a follow-on workshop focusing on the technology of burning plasmas will be held next year.

The workshop is being organized by the UFA to be one of the primary sources of community input to the assessments of burning plasma science being carried out in the next year by FESAC and the Virtual Laboratory for Technology Next Step Options Advisory Committee. The emphasis of the workshop will be on burning plasma science issues in tokamak configurations, but discussion of burning plasma issues as they relate to other fusion concepts and more broadly to scientific areas outside of fusion energy will be strongly encouraged.

Science Issues for the UFA BPS Workshop

Building on the progress made in discussing these issues at Snowmass 1999 as summarized in the report of the Burning Plasma Physics Technical Subgroup and the Plasma Science Group [http://www.columbia.ap.edu/smproceedings], the key questions which speakers and discussion leaders are asked to address are:

1) **What are the compelling scientific issues which could be addressed by a burning plasma experimental facility?**

2) **Identify those burning plasma scientific issues which are inaccessible for study in existing or near-term non-burning plasma experiments.**

3) **What is the present physics basis and confidence level in achieving burning plasma conditions? In particular, how have recent developments in theory and experiment affected our confidence in achieving burning plasma conditions?**

4) **How comprehensively can these burning plasma science issues be addressed establishing a firm basis for extrapolation in scale and magnetic configuration?**

5) **Are there compelling scientific issues outside of fusion energy which can be addressed by a burning plasma experimental facility?**

UFA BPS Workshop Structure

Organizing Committee:
Gerald Navratil (Chair), Columbia University, Amitava Bhattacharjee, Univ. of Iowa, Ray Fonck, Univ. of Wisconsin, Earl Marmar, MIT, Raffi Nazikian, Princeton University, Jim Van Dam, University of Texas, John Wesley, General Atomics

Workshop structure similar to Snowmass with plenary sessions and breakout groups

(1) Energetic Alpha-Particle Physics
Raffi Nazikian, PPPL and
James Van Dam, Univ. of Texas

(2) Self-Heating, Transport, and Confinement at Reactor Scale
Bill Dorland, Univ. of Maryland and
Wayne Houlberg, ORNL

(3) Macrostability in a Self-Heated Burning Plasma
Chris Hegna, Univ. of Wisconsin and
Ted Strait, General Atomics

(4) Boundary Science
Daren Stotler, PPPL and
John Wesley, General Atomics

(5) Relation of Burning Plasma Science to Other Fields
Amitava Bhattacharjee, Univ. of Iowa and
Robert Rosner, Univ. of Chicago

FESAC Panel on Burning Plasmas

Charge

1.What scientific issues should be addressed by a burning plasma physics experiment and its major supporting elements? What are the different levels of self-heating that are needed to contribute to our understanding of these issues?
2.Which scientific issues are generic to toroidal magnetic confinement and which ones are concept-specific? What are the relative advantages of using various magnetic confinement concepts in studying burning plasma physics?

As a part of your considerations, please address how the Next Step Options program should be used to assist the community in its preparations for an assessment in 2004,as recommended in the Priorities and Balance report.

Members

J. Freidberg (Chair), Herb Berk, Riccardo Betti, Jill Dahlburg, Bick Hooper, Dale Meade, Jerry Navratil, Bill Nevins, Masa Ono, Rip Perkins, Stewart Prager, Kurt Schoenberg, Tony Taylor, Nermin Uckan

Schedule

Report by end of July, 2001

First meeting December 10, 2000

NSO PAC-1 Recommendations

Mission

More excitement in the mission
Dual mode BP and AT endorsed with emphasis on BP and BP+AT
Affordability is a must
Must enumerate the science to be gained

Design Point

Show how mission leads to objectives leads to experiment (eg., aspect ratio, size and cost)
Evaluate performance for H-mode operation using guidelines similar to ITER-FEAT

- ITER98(y,2) confinement scaling (20% lower than EDA scaling)
- flattish density profiles -
- lower plasma power threshold(≈1/2) to access H-mode

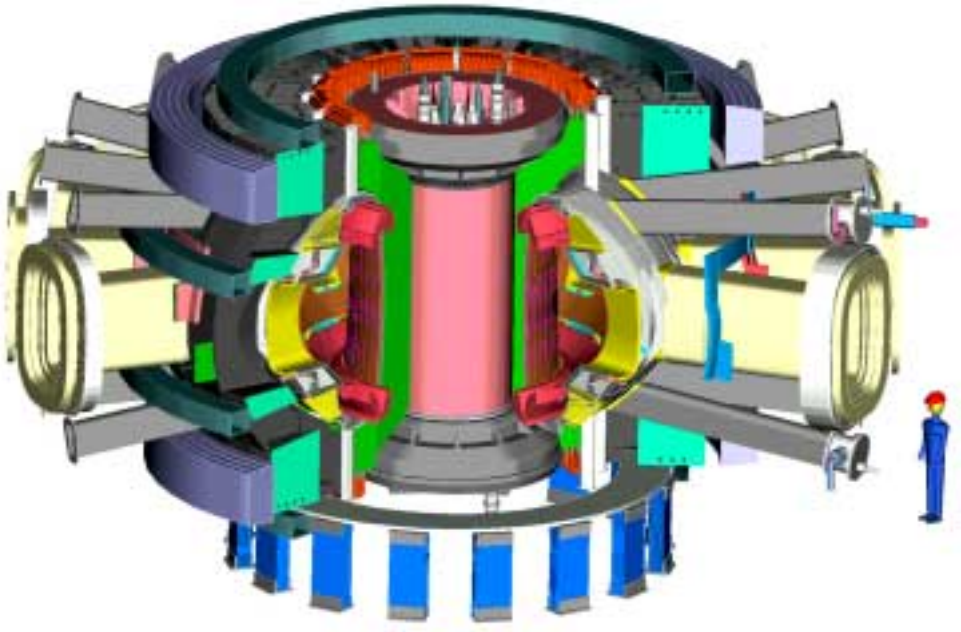
To more clearly understand the cost/benefit tradeoffs in designing a lower cost machine for the investigation of self-heated fusion-dominated plasmas, the PAC recommends the examination of at least one variation of FIRE at somewhat larger size. The design point of the larger device could be an increase in the device size by 50% or an increase in the cost by 50% to reach Q=5, using the ITER Y2 scaling and flatter density profiles.

Implications of reduced repetition rate for cryogenic system

Fusion Ignition Research Experiment

(FIRE)

http://fire.pppl.gov



Design Goals

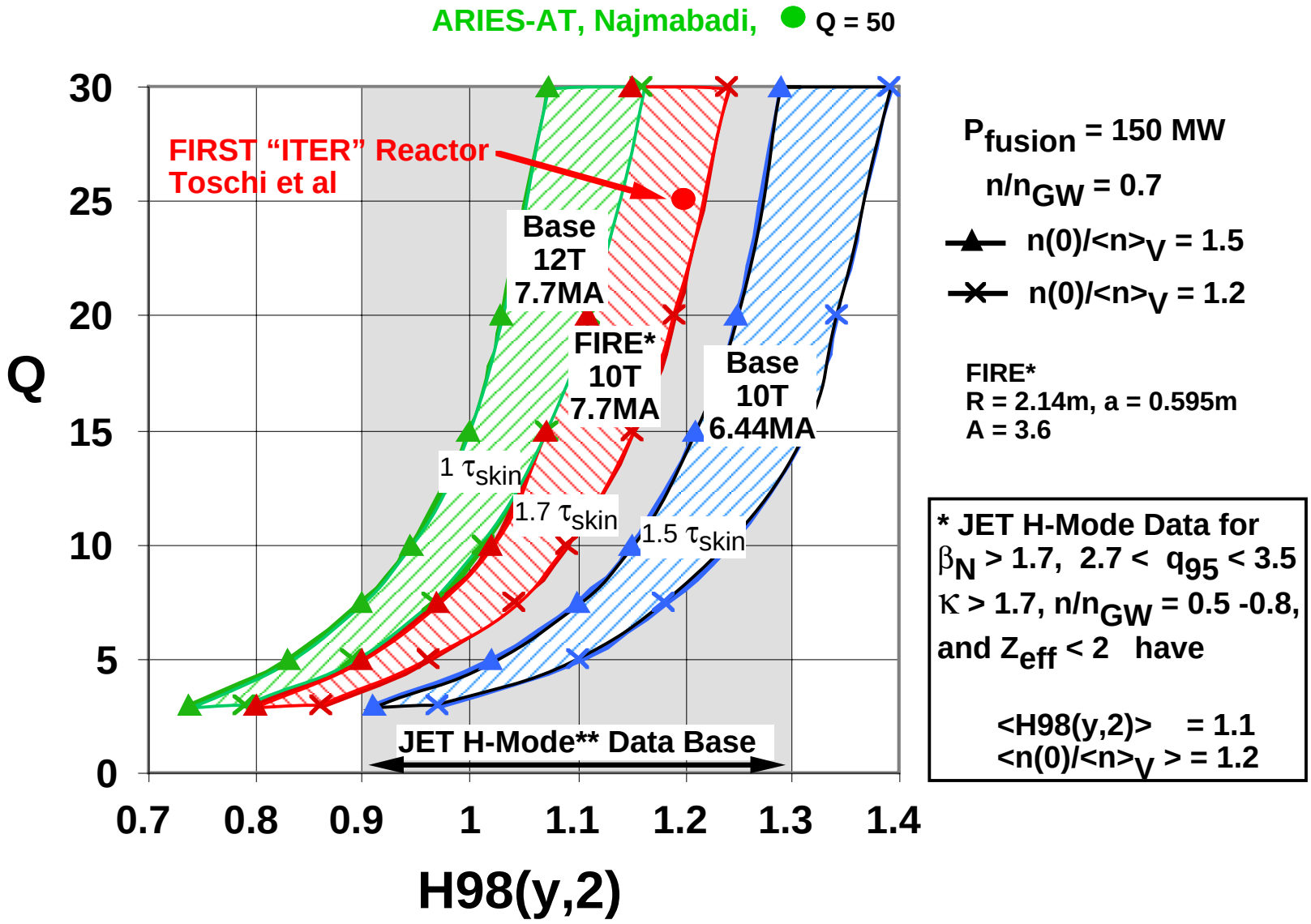
- R = 2.0 m, a = 0.525 m
- B = 10 T, (12T)*
- W_{mag} = 3.8 GJ, (5.5T)*
- I_p = 6.5 MA, (7.7 MA)*
- $P_{alpha} > P_{aux}$, $P_{fusion} < 200$ MW
- Burn Time ≈18.5s (≈12s)*
- Tokamak Cost ≤ $0.3B

  Base Project Cost ≤ $1B

* Higher Field Mode

Attain, explore, understand and optimize fusion-dominated plasmas that will provide knowledge for attractive MFE systems.

Projections of FIRE Compared to Envisioned Reactors



P_{fusion} = 150 MW

n/n_{GW} = 0.7

$n(0)/\langle n\rangle_V$ = 1.5

$n(0)/\langle n\rangle_V$ = 1.2

FIRE*
R = 2.14m, a = 0.595m
A = 3.6

* JET H-Mode Data for $\beta_N > 1.7$, $2.7 < q_{95} < 3.5$, $\kappa > 1.7$, $n/n_{GW} = 0.5$ -0.8, and $Z_{eff} < 2$ have

$\langle H98(y,2)\rangle = 1.1$

$\langle n(0)/\langle n\rangle_V \rangle = 1.2$

NSO-FIRE Plans for FY2001

- Physics Activities [continue to develop dual mode (BP/AT) capability]
  Broaden confinement analyses, increase interaction with experiments
  Develop AT modes, and experimental requirements

- Plasma Engineering Activities
  More detailed analyses of disruption scenarios

- Engineering Activities
  Improved Wedged TF Design
    Increase plasma current to 7.7 MA while maintaining ≈ 2 tau_skin burn
    Optimization of A subject to fixed performance at 2 tau_skin

  Evaluate pro/cons of Bucked/Wedged design
    potential benefits of 11.5 T for 40 s (no nuc heating), reduced P_{elec}

  Divertor targets, baffles and first wall cooled for ~ 20 - 30 s pulses

- Respond to NSO-PAC, UFA Workshop and FESAC requests.

- Continue proactive outreach activities