# Summary of the Review Panel (July-December 1991)

# on

# ITER Plasma Facing Components

presented by
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# Panel on ITER Plasma Facing Components
(July-December 1991)

## Members of the Panel

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R. Watson (SNL)

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# Charge to the Panel

Charge was from Dr. C. Baker (as Manager of U.S. ITER Technology R&D) and agreed to by OFE (M. Cohen et al.)

## Highlights of the Charge

1) Review Design Parameter space for PFC in ITER

2) Review the Technical Issues that require resolution prior to a decision to construct ITER

3) Review the Testing Needs of PFC for ITER

4) Evaluate the capabilities of existing, upgrades, and new Facilities in meeting ITER testing needs

5) Identify one or more Strategies for the U.S. Contribution to meeting the needs for ITER PFC

- Design parameters and features for CDA were different from those presently considered for EDA

- Many of the issues remain the same; some are reduced to a more manageable level; there are new issues

<u>CDA (Panel Review)</u>

- Peak heat flux on divertor: 30 $MW/m^2$ with sweeping → 15 $MW/m^2$

- Physics phase divertor design
  10 mm - thick carbon fiber composite brazed to 16 mm diameter water cooled tubes made of either Cu, Mo or Nb alloys

- Technology phase
  - 2 mm tungsten coating is plasma sprayed onto a Mo or Nb alloy heat sink
  - beryllium alternate material

# Technical Issues

## Findings

- PFC's represent one of the most critical issues for ITER
  PFC's severely limit ITER performance

- Critical issues that require extensive modelling, testing and qualification can be classified into two categories

  Category A
  Relates to the ability to specify to a reasonable accuracy the plasma edge characteristics and the resultant loading parameters such as heat and particle fluxes and peaking factors under normal and off-normal conditions

  Category B
  Relates to the ability to predict the engineering response and the performance characteristics of the divertor plate and other PFC's

# Critical Issues for Engineering Response

1 Heat Removal

Issues include critical heat flux limits in long heated lengths for one-sided heating; and thermal conductivity, and temperature and thermal stress limits of the armor tile and braze interface.

2 Erosion/Redeposition

Uncertainties exist in predicting erosion and redeposition rates. The net erosion rate affects directly the lifetime of the divertor plate. The temperature limit for a carbon self-sputtering runaway is also highly uncertain.

3 Disruptions

Runaway electrons generated during the plasma current quench are critical issues.

4 Helium Removal

The primary function of the divertor is to exhaust helium. The presently predicted helium pumping efficiency is low.

5 Safety

Chemical reactions with air and stream, tritium inventory, and transport of activated corrosion products are among the key issues.

6 Component Lifetime and Reliability

Very little data exists on failure modes, reliability and lifetime of PFC's.

# Overall Recommendations

Specific conclusions and recommendations are contained in the report. The panel makes the following overall recommendations:

1 Funding for ITER R&D for PFC should be enhanced in order to assure that ITER achieves its objectives. Increased use of existing facilities, including upgrade of capabilities, as well as the construction of new facilities are required.

2 More extensive utilization of tokamaks for divertor testing is strongly recommended. DIII-D appears to be the only tokamak in the U.S. capable of significant divertor testing. DIII-D's mission for ITER divertor studies should be strongly enhanced. However, DIII-D has limitations in achieving the required plasma conditions, e.g. pulse length, and in the flexibility to accommodate engineering changes required for testing and optimization. Therefore, the construction of a small divertor-technology-oriented tokamak will be extremely useful. Such a tokamak should have a long pulse with capabilities of upgrade to steady state operation if the need arises. It should also have the necessary flexibility to test and optimize different divertor designs with a reasonably short turn-around time.

# Overall Recommendations Cont.

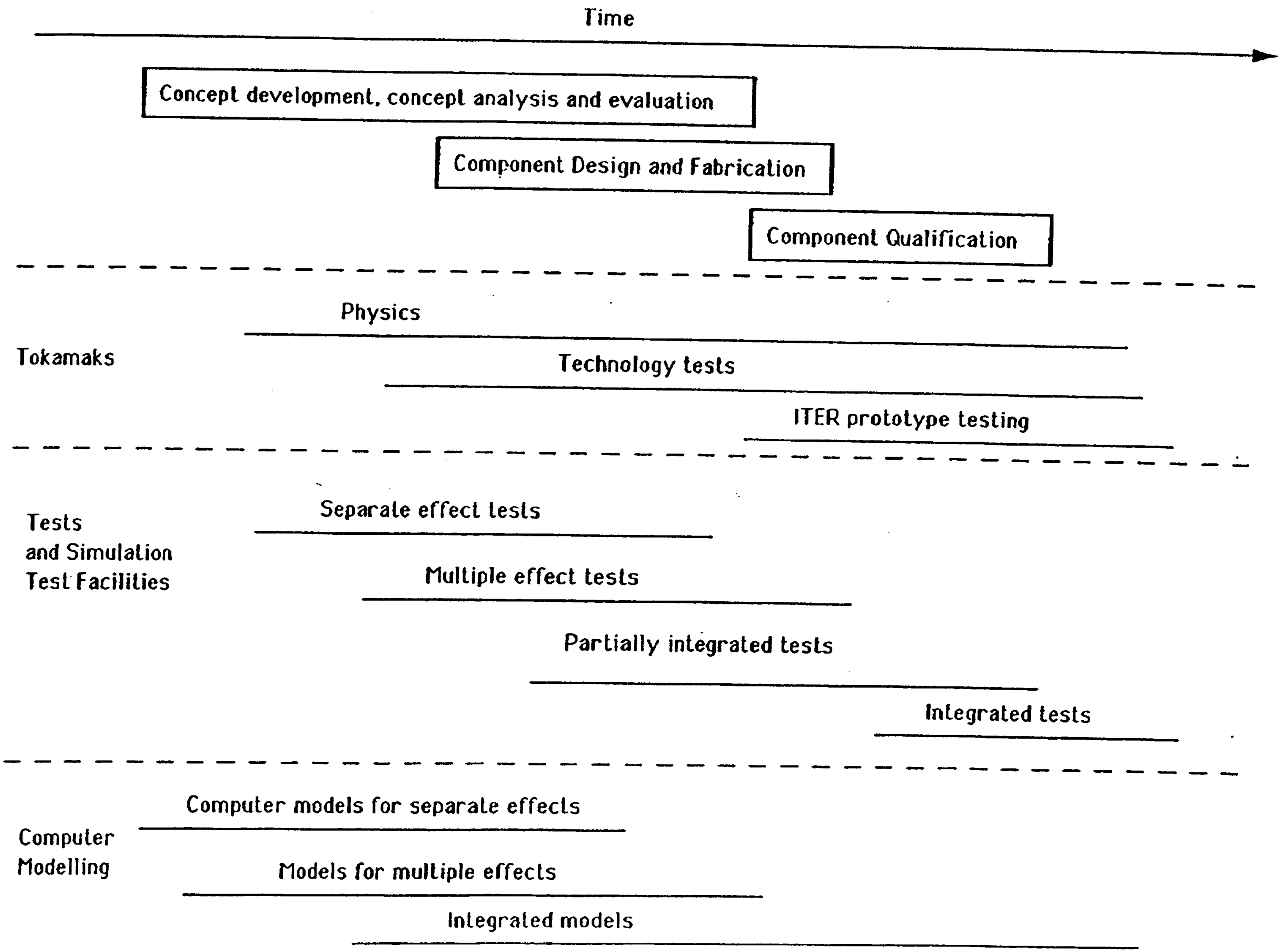
3 A design study of a cost-effective linear divertor simulator that approximates the ITER conditions is strongly recommended. The flexibility and relatively low cost of linear simulators as compared to tokamaks make linear simulators highly effective facilities for performing the large matrix of divertor tests necessary to resolve many of ITER divertor critical issues such as erosion/redeposition and heat removal. The design concepts of IDEAL and SUPERPISCES as presented to the panel scored the highest among all proposals for linear simulators. However, the panel has serious concerns with both concepts. While IDEAL addresses many of the relevant issues well, the physics risk of IDEAL appears quite high; with concerns about startup, wall conditioning, radial transport, and RF heating. There are also concerns about the accuracy of the cost estimate. SUPERPISCES is lower cost and is based on a moderate extrapolation from PISCES-B but the achievable operating conditions, e.g. sheath conditions and erosion-redeposition conditions, would still require significant extrapolations to ITER like conditions. The panel recommends that the design studies focus on the challenging tasks of designing a linear simulator with better capabilities for resolving critical issues, lower cost and acceptable risk. The design effort should fully utilize the valuable information developed in both the IDEAL and SUPERPISCES proposals. The results of the studies should be reviewed by an expert panel for further recommendations.

# Overall Recommendations Cont.

4 The upgrade of the high heat flux simulator, PMTF-U, is strongly recommended because of its modest cost, low risk, and ability to achieve high heat flux loading with simultaneous plasma disruption simulation to address the heat removal and component lifetime and reliability issues of ITER.

5 It is recommended that significant effort be devoted to developing the alternate concepts in the Concept Improvement Path. In view of the large uncertainties in the solid divertor plate concept of the Reference Path, it is prudent to develop a backup approach. Furthermore, R&D should explore whether concepts such as liquid-metal-surface and gaseous divertors truly offer a more attractive solution to the divertor problem in ITER and future tokamaks.

# The Timeline for PFC Development



COSTS

| Device | Construction Costs ($M) | Additional Costs for Upgrades ($M) | Operating Costs ($M) |
|---|---|---|---|
| Super-PISCES | 4.0 | 3.2 | 0.8 |
| IDEAL | 8.4 | 6.0 | 2.5 |
| CMPX | 0.8 | - | 0.4 |
| DIII-D | 13.0 | - | 3.5 |
| ATF | 3.0 | - | 3.0 |
| VTF-D | 2.0 | 0.4 | 1.7 |
| TST | 20.0 | | 2.0 |
| PMTF-U | 2.5 | - | 0.8 |
| Univ of Ill. | 0.4 | - | 0.1 |

Capabilities of Proposed Facilities
as Described by the Presenters

| | Heat Removal | Plasma Materials Interactions | Disruptions | Safety | Helium Removal | New Concept Development |
|---|---|---|---|---|---|---|
| IDEAL | Yes | Yes | No | Yes | Yes | Yes |
| Super-PISCES | Yes | Yes | No | No | No | Yes |
| CMPX | Yes | Yes | No | No | No | No |
| DIII-D | No | Yes | Yes | No | Yes | Yes |
| VTF-D | No | Yes | No | No | No | Yes |
| TST | Yes | Yes | No | No | No | Yes |
| ATF | Yes | Yes | No | No | No | Yes |
| PMTF-U | Yes | No | Yes | Yes | No | No |
| Univ of Ill. | No | Yes | Yes | No | No | No |

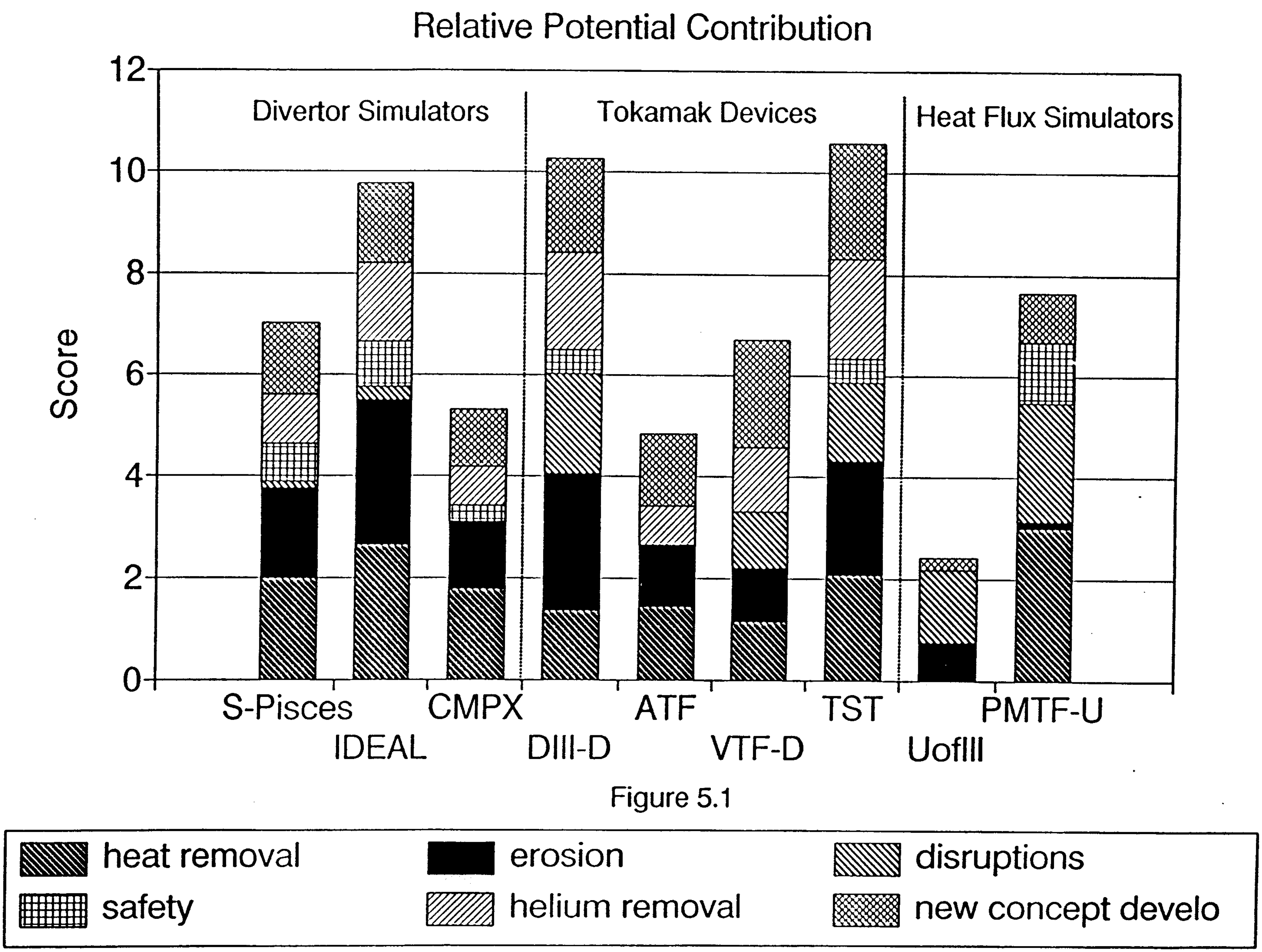

Relative Potential Contribution
Score
0
2
4
6
8
10
12
Divertor Simulators
Tokamak Devices
Heat Flux Simulators
S-Pisces
IDEAL
CMPX
DIII-D
ATF
VTF-D
TST
UofIll
PMTF-U
heat removal
erosion
disruptions
safety
helium removal
new concept develo

Figure 5.1