PANEL #1

REPORT TO FEAC

ON

"...THE APPROPRIATE SCOPE AND MISSION OF ITER..."

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Chairman R. K. Linford
Co-Chairman H. Weitzner
M. A. Abdou
D. E. Baldwin
K. H. Berkner
L. A. Berry
F. L. Culler
S. O. Dean
D. A. DeFreece
W. B. Gauster
J. P. Holdren
R. P. Hora
N. F. Ness
D. O. Overskei
R. R. Parker
P. H. Rutherford
H. W. Shaffer
R. E. Siemon
D. Steiner

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with an approach that defers moderate-fluence nuclear testing to a second phase of ITER, after major machine modifications, is the programmatic risk that the second phase will be unacceptably delayed or may never be implemented at all. This risk is serious, both of itself and because the uncertainty whether or not the second phase of ITER will actually be implemented will tend to inhibit effective program planning in the area of nuclear and blanket testing. There is also a technical risk that the minimal, low-fluence nuclear testing program that will be possible in the first phase of ITER will be inadequate to provide the data needed for development of a DEMO-relevant blanket in the second-phase. Finally, there could be a public-perception risk in not operating ITER up to the reliability/availability levels of which it would be intrinsically capable because of an enforced reliance on external tritium supplies. Public perception of fusion practicality could be adversely affected by the inability of ITER to demonstrate levels of machine availability exceeding about 5%.

On the basis of analysis carried out during the CDA, the fluence achievable in the first phase of this "sequenced" scenario has been assumed to be limited by external tritium supplies to about 0.3 MW-yr/m^2. The impact of more aggressive assumptions regarding availability of tritium from external civilian sources is discussed in Appendix C.

D. Parallel Path Scenario

The Panel has also explored a third scenario that, if adopted, could avoid some of the potential problems identified for the above scenarios. This alternative, which would contain two parallel, coordinated facilities, would be designed to achieve the full ITER objectives with reduced technical risk on an accelerated timescale. The second of the two facilities could be incorporated within the ITER agreements only after negotiations with our partners. Alternatively, it could be done under other international agreements or as a national initiative.

This scenario would contain a large superconducting tokamak, much like the current vision of ITER. In a first phase of operation, it would address the physics of long-pulse ignition with steady state as an ultimate objective, and would carry out a program of testing blanket modules at low-to-moderate fluence. In its second phase, which would last only a few years or less, this machine would address integrated testing of DEMO-relevant blanket sector(s) and other nuclear technologies.

As described, this machine's objectives would be very much those of the ITER CDA technical objectives, except that it would not need to operate in its technology phase for sufficient duration to accumulate the 1-3 MW-yr/m^2 target fluence for ITER's nuclear testing. It is an important point that the desired nuclear testing at moderate-to-high fluence does not require the full 1000-MW power level of ITER. In fact, all that is required is some 20 m^2 of testing surface, or 20 MW of fusion power at the ITER's wall loading. Using the full ITER for this purpose is very inefficient in both operating costs and tritium consumption.

If the large machine did not have the requirement to operate to the full fluence level and if it were to be used in its second phase only for integrated demonstration of blankets and technologies that had been developed elsewhere, there could occur a savings in capital cost of 15% relative to the CDA design (a savings also realized in the E.C. approach), and a more significant savings in operating cost resulting from the reduced operating lifetime. Also, the reduced demand for tritium, a factor of 10 less than for the other scenarios, would eliminate the need for a driver blanket.

A second, much smaller and less expensive, driven (not ignited), steady-state machine producing neutrons at ~1 MW/m^2 would complement the larger facility in important ways as suggested above. It would be used to preselect blanket and other nuclear technologies, and it would need to operate for sufficient duration to fulfill the ITER fluence requirements, i.e. 1-3 $MW\text{-}yr/m^2$. By starting operation well in advance of the larger machine's second phase, the smaller machine could complete the high fluence earlier than could a testing program using the larger machine, thereby better matching the planned schedule for the DEMO. A comparison of the time lines for the three scenarios is shown in Fig. II.1.

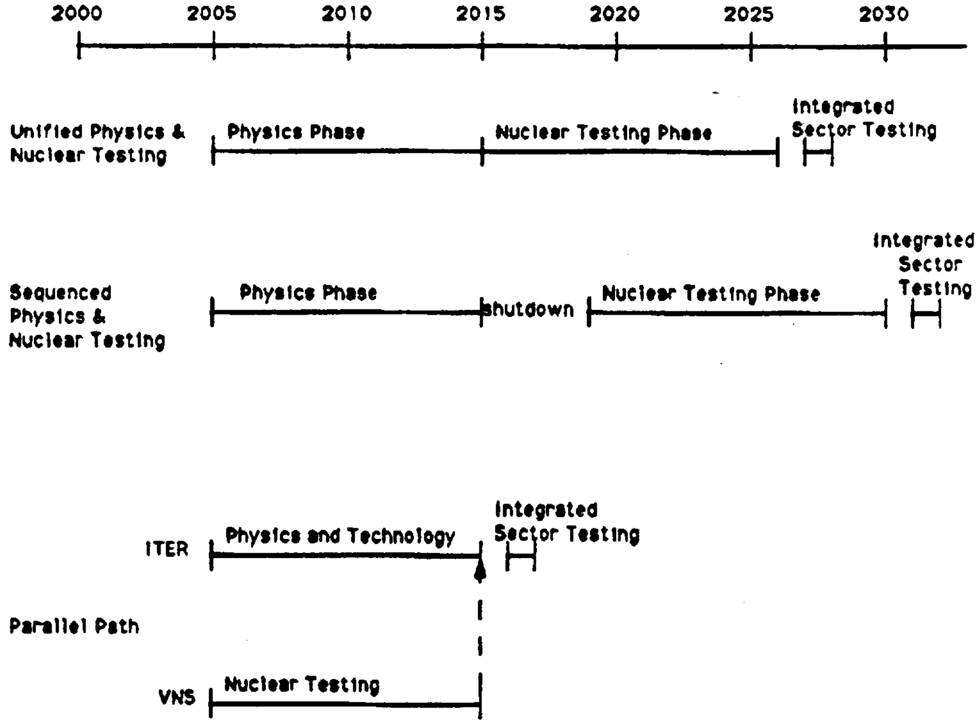

Fig. II.1. Time lines for development scenarios.

In order for the two-machine approach to be economically competitive in terms of overall costs, the capital cost of the smaller machine must be of the order of the savings in costs realized by the reduction in operation of the larger machine. It could be more, as shown in Fig. II.1, but if this reduction were taken as 5-6 years (one-half the currently estimated 10-12-yr technology phase) at an annual budget of $350-400 M/yr, one obtains a target of up to $2 billion for the construction costs of the smaller machine. Designing a technically achievable machine to meet this mission at this budget would be a challenge owing to the costs associated with achieving high fluence. Preliminary estimates suggest that this should be possible, but this cost question needs careful examination.

There is a second way by which this two-machine strategy could be cost effective, although it is a manner that is hard to quantify. Use of the large machine to obtain high-fluence data in the planned 10-yr technology phase has been widely recognized to require a technically very demanding level of availability, 10-30% averaged over a 10-yr period. A similar reliability would, of course, be required in use of the smaller machine for this purpose. However, there, it is expected that necessary high availability could be developed in a less costly manner.

For the smaller machine to complement the larger in the way described, the two machines would need to be constructed as nearly as possible at the same time. Unacceptably large annual budgets during the construction time could be avoided by omitting the cost of the driver blanket, delaying the introduction of the current drive power, and (possibly) stretching out somewhat the construction of the large machine--emphasizing again that completion of the entire ITER mission would thereby be accelerated in comparison with the single-machine scenarios.

In the foregoing, it has been implied that the smaller machine would be a driven tokamak. Although the tokamak might indeed prove the most cost effective and useful device, other technologies should also be considered. If, in addition, the universally agreed-upon need for an intense 14-MeV neutron source is considered, then this scenario has the advantage that it would be possible to site ITER, the nuclear technology test facility, and the 14-MeV neutron source in different countries. This might facilitate the site-selection process for ITER.

In view of the potential advantages that this variant of the ITER program might provide, the Panel believes that it warrants further consideration but recognizes that many important questions remain to be examined.

ITER Development Options Findings

The Panel endorses the ITER EDA, including commitment to construction, as a pivotal activity in the U.S. fusion program. This activity must be coupled with a strong national program that addresses other DEMO-related tasks in addition to ITER tasks. We emphasize that the U.S. program goals, as stated in the National Energy Strategy, would not be achieved if complementary activities to ITER were not carried out.

To accomplish the programmatic objectives of ITER, we find that there are basically three scenarios of interest. The first we call the "unified scenario of physics and nuclear testing;" the second we call the "sequenced scenario of physics and nuclear testing." The third we call the "parallel-machine scenario." The Panel finds that while each scenario has particular advantages and elements of risk, all the scenarios provide an acceptable means of meeting the programmatic objectives.

A **unified scenario of physics and nuclear testing** is accomplished with either the CDA design or its variant known as the high-aspect-ratio (HARD) design. The CDA design is viewed as not entirely satisfactory by the E.C., Japan, and the U.S. Specifically, the CDA design lacks a self-consistent steady-state operating scenario in which the divertor constraints are satisfied.

The HARD design, as typical of a moderately aggressive design to accomplish unified nuclear testing, makes moderately aggressive physics assumptions with respect to aspect-ratio scaling of confinement times, provides some relief in regard to the still severe divertor design and impurity problems, and improves the prospects for the achievement of most ITER physics and technology objectives, including blanket studies, nuclear testing, and steady-state operation.

In the unified scenario of physics and nuclear testing, a strong R&D program will be needed in parallel with ITER design to validate the moderately aggressive technical assumptions and to provide the component reliability needed for a successful and timely nuclear testing program. Otherwise, component failures during ITER operation will lead to increased operating costs because of delayed or extended ITER operations.

A **sequenced scenario of physics and nuclear testing** is represented by the E.C. approach. Based on conservative physics assumptions, the E.C. approach consists of a first stage directed toward the achievement of long-pulse ignition, very limited nuclear testing, and no tritium breeding. The second stage would be devoted to blanket operation, nuclear testing, current drive, and steady-state operation. The fluence in the second stage is moderate, ≤ 1 MW-yr/m^2. The sequenced scenario is likely to provide less nuclear experience and entail larger operating costs than the unified scenario. To the extent that conservative confinement scalings are used, the E.C. device will be larger and more expensive in capital cost than the CDA or HARD designs and, therefore, unattractive from the point of view of cost.

A third **parallel-machine scenario** proposes an ITER-class device with moderate (0.1-1.0 MW-yr/m^2) fluence. This superconducting device would carry out an initial phase of operation to explore ignition physics and start nuclear testing. In parallel, nuclear testing would be carried out on a lower power high-fluence (≥1 MW-yr/m^2) nuclear testing machine to provide initial qualification of blanket modules and materials. A tokamak that would serve this purpose as a volumetric neutron source would be much smaller than ITER, non-ignited, and beam-driven. In a briefer second phase of ITER, qualified blanket designs, developed and validated in the smaller machine, would be incorporated for integrated testing, with a need for only low fluence (<0.1 MW-yr/m^2). This scenario lowers the risks by providing an alternate path for technology development and fault correction. The initial capital cost is somewhat higher, but the total cost to project completion is likely to be less than the other scenarios because of reduced operating time in the second phase of the larger facility. This scenario also could shorten the time for commercial fusion power development by ten to fifteen years, thus reducing the worldwide costs by $20-30 billion.

None of the scenarios address adequately the issue of materials development necessary to achieve the maximum environmental benefit of fusion energy.

The use of copper in an ignited ITER-style device would not reduce cost significantly, nor would it fit within the international ITER consensus.