WHITE PAPER

A "Volumetric Neutron Source" -
an Industrially Led, U.S./R.F. Initiative
Having a Central Nonproliferation Mission

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Background

The world's fusion programs have focused on the International Thermonuclear Experimental Reactor (ITER) as a plausible next step in fusion development and have embarked on the Engineering Design Activities (EDA), planned to last six years, for the device. The ITER is expected to operate starting in ~ CY 2005, initially on a ten year physics phase, then on a subsequent ten year nuclear testing phase and finally on a one to two year integrated sector testing phase. The last phase, critical to the design of a "demonstration" (DEMO) reactor, would occur in the time interval ~ CY 2026-2028 - after the tentatively scheduled start-up date of CY 2025 for the U.S.'s DEMO.

USDOE Fusion Energy Advisory Committee (FEAC) findings and recommendations

The United States Department of Energy's Fusion Energy Advisory Committee established a "Panel 1" to advise it on the scope and mission that the U.S. should recommend for ITER and the extent to which the cost and schedule could be reduced from the present estimates. Panel 1 submitted its advisory report to FEAC on 31 January 1992 entitled "...The Appropriate Scope and Mission of ITER..." in which three ITER development options were compared:

- Unified scenario of physics and nuclear testing - basically the ITER program as planned and described above in the background section.
- Sequenced scenario of physics and nuclear testing - a more conservative approach, emphasizing physics and minimizing nuclear testing and with no tritium fuel breeding.
- Parallel-machine scenario - an ITER to carry out an initial phase of operation to explore ignition physics and start nuclear testing. In parallel, fusion nuclear testing would be carried out on a much smaller (e.g., R ~ 2 meters) and lower power (e.g., 100 MW) high-fluence tokamak to provide initial qualification of blanket modules and materials (a "volumetric neutron source" or VNS).

The parallel-machine scenario was reported to have a somewhat higher initial capital cost but that the total cost to (ITER) project completion was likely to be less than the other scenarios because of reduced operating time in the second phase of the larger (ITER) facility. "This scenario could also shorten the time for commercial fusion power development by ten to fifteen years, thus reducing world-wide costs by $20-30 billion." Finally, the parallel-machine scenario could significantly reduce the risks associated with fusion power development simply because it avoids relying completely on one ITER device.

The FEAC accepted only portions of the Panel 1 advisory report and sent its own letter report to the Director of the Office of Energy Research at the USDOE on 14 February 1992. This letter report stated:

> "The necessity of using ITER for the first detailed investigations of high-Q and ignited burning plasmas will extend the phase of ITER dedicated mainly to such physics issues. This first phase is now estimated to take as much as 10 years in which case it would not be completed until about 2015. If an additional 10-12 years of ITER operation is required to obtain the required nuclear testing data, the U.S. program goal of a fusion demonstration reactor (hereafter, DEMO) operating by 2025 will not be achievable."

The FEAC letter report goes on to say:

> "Additional complementary activities dedicated to acquiring part of the nuclear testing data would permit shortening the ITER test program. FEAC recommends that a study of the feasibility of such a complementary program be undertaken with a view toward making the 2025 DEMO goal more realistic."

Figure II.1, taken from the Panel 1 advisory report, illustrates the potential benefit of the parallel-machine scenario.

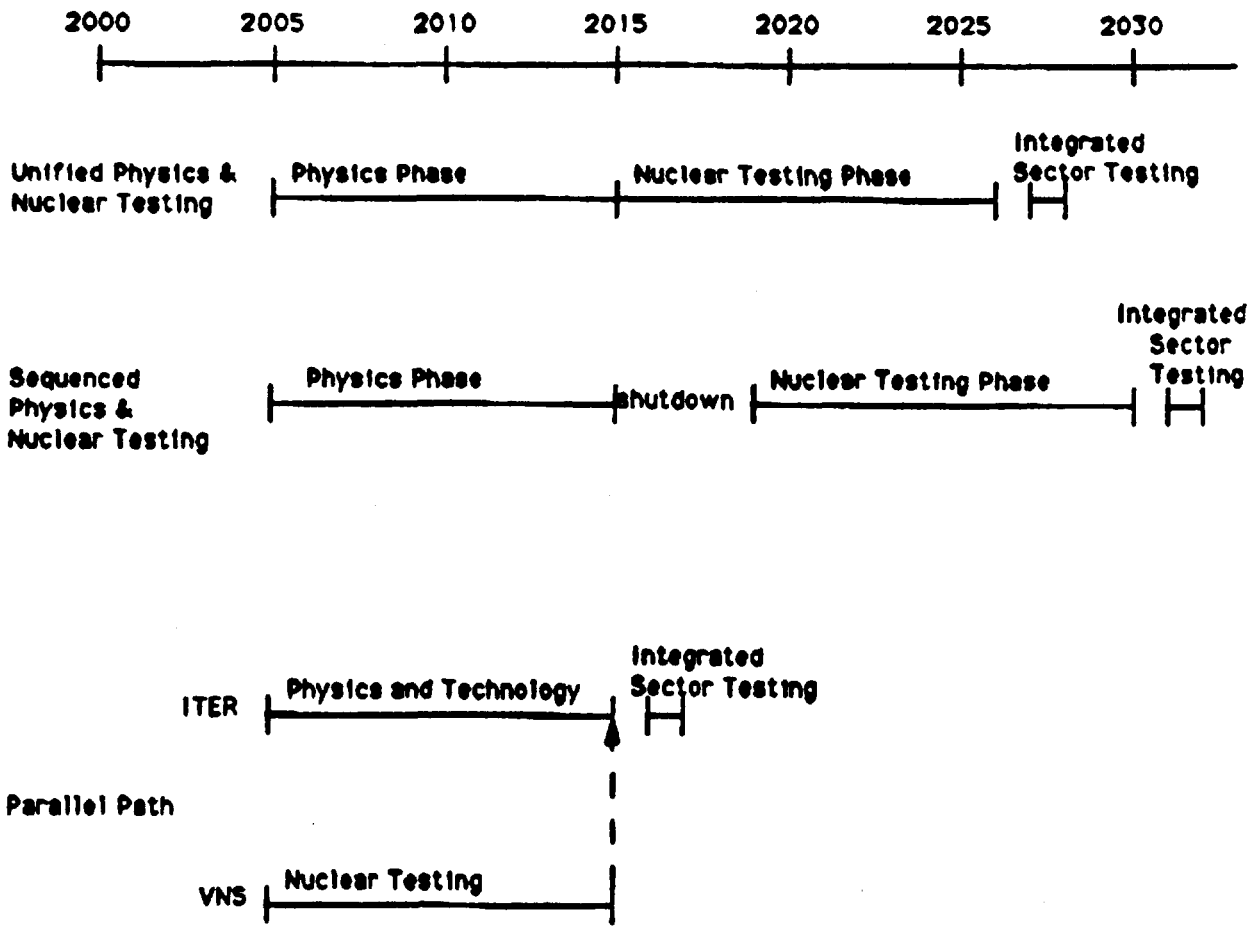

Fig. II.1. Time lines for development scenarios.

The DOE has yet to embark on the study recommended by FEAC because of the absence of an international agreement on the mission of and requirements for the ITER. Special Working Group One is now preparing a mission and requirements statement which will be presented to the ITER Council in December 1992 for discussion and approval.

Status of VNS design

Volumetric Neutron Source design has been underway for nearly two decades. The first of these was called the Fusion Engineering Research Facility (FERF) and was based on minimum-B mirror confinement. Almost in parallel, a tokamak version of the FERF was proposed by the University of Wisconsin which was called the Tokamak Engineering Test Reactor (TETR). This prescient study also proposed a fusion development approach essentially identical to the parallel-machine scenario, described above, but now delayed by more than 15 years. In the mid 1980s, an activity called FINESSE (December 1985) produced a number of VNS conceptual designs based on tokamaks (and their variants), mirrors and reversed field pinches.

Since 1991 in the U.S., two efforts have been underway that address the conceptual design of VNS-like facilities: the Steady Burn Experiment work at MIT and the Small Fusion Development Plant at ORNL. A related facility, called a Pilot Plant, has been pursued since 1988 under Fusion Power Associate leadership and includes laboratory, industry and utility personnel. These device concepts are small (e.g., R ~ 2 meters), low power (e.g., 100 MW), normally conducting, jointed magnet tokamaks where the designs emphasize maximum access to the fusion core. This approach was also emphasized in the Demountable Toroidal Fusion Core design prepared by Energy Applications & Systems, Inc. (1987).

The above mentioned conceptual designs are sufficiently advanced so that preliminary design could be initiated with ease. Each approach has sufficient merit that all should be subjected to preliminary design prior to either a downselect or a merging of the designs into one common baseline.

Nuclear weapons proliferation implications of the dissolution of the USSR

Over the past half year, there has been considerable concern about Russian nuclear weapons scientists and engineers seeking employment with nations trying to develop nuclear weapons. The problem is that these individuals have skills, but no productive tasks or income, because of the economic problems presently facing Russia. Simply to survive, they may be tempted to take new jobs in countries seeking to develop nuclear weapons. The U.S. has recognized this and, in 1992, contributed $25 million to the formation of the International Science and Technology Center to identify suitable employment for these individuals.

For FY 1993, the US. Congress appropriated substantial funds in H.R. 5504, the DOD Appropriations bill, to address the above mentioned problem and others. It is expected that this is the first installment of additional appropriations in subsequent years. The authorizing language in the Freedom Support Act (S. 2532) includes the following:

"Title V: Nonproliferation and Disarmament Activities"

"Authorize the President to provide assistance to promote nonproliferation and disarmament activities by supporting:

(1) dismantlement and destruction of nuclear, biological, and chemical weapons, their delivery systems, and conventional weapons,

(2) efforts to halt the proliferation of such weapons, systems and related technologies

(3) establishment of science and technology centers for nonmilitary purposes; and

(4) the conversion of military technologies and capabilities and defense industries of the independent states into civilian activities.

Authorizes the President to support one or more of such centers to provide incentives for weapons scientists and engineers of the former Soviet Union to apply their expertise to civilian projects."

"Authorizes the Director of the National Science Foundation to establish an endowed, nongovernmental, nonprofit foundation to: (1) promote and support joint research and development projects for peaceful purposes between scientists and engineers in the United States and the independent states on subjects of mutual interest; and (2) seek to establish joint nondefense industrial research, development, and demonstration activities thorough private sector linkages which may involve participation by scientists and engineers in the university and academic sectors."

Recommendations

Russian weapons scientists and engineers are well trained to apply their skills to assess the feasibility of a VNS. Consequently, it is proposed that a VNS project be funded from part of the U.S. DOD appropriation. Russia, possibly the Kurchatov Institute and a related industry, would prepare a proposal to the appropriate U.S. or international agency (e.g., the International Science and Technology Center). Proposal development should be supported by interested U.S. institutions.

The timeframe of the proposed effort is about five years. Initially, considerable predesign on a number of concepts is required to establish VNS feasibility. This phase requires extensive technical labor but is relatively inexpensive and would last approximately two years. Subsequently, engineering design would be performed at a slightly less manpower-intensive degree as the effort would focus on only one concept. Engineering design would be expected to last three years and would be followed by a determination of VNS feasibility and usefulness in the world's fusion effort.

The VNS will involve U.S. scientists and engineers throughout the project. Initially, U.S. involvement will be technology transfer between the Russian and U.S. design teams. As the project matures, U.S. and Russian scientists and engineers would continue to work together on the evolving design. However, maximum employment of Russian weapons scientists and engineers will be sought to meet the nonproliferation objectives of the project.

In the United States, these activities would be led by industry and would involve U.S. University and National Laboratory participants. Industrial leadership ensures that machine design and fabrication is performed according to industrial standards and objectives to reflect free market commercial values.

In closing, it is important to state that the VNS, which is considered by many to be an essential fusion facility, should attract the interest of other participants in what is becoming a truly global international enterprise. Should this occur, then such participation will be welcomed and encouraged to the extent that it not interfere with the nonproliferation objective of the proposed project.