Outline of Suggested Approach and Technical Tasks to the IEA HVPNS Study

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Presented to first HVPNS meeting
at IPP-Garching, April 28, 1994

Suggested Agenda for the First HVPNS Study Meeting at IPP Garching, April 28-29, 1994

Session 1:

Thursday, April 28, Afternoon (1:00 pm - 6:00 pm)

- Opening Remarks, Charge and Objectives of the Study	Proust/Berk
- Discussion on Study Objectives	Participants
- Outline of Suggested Approach and Technical Tasks to the Study	Abdou
- Discussion on Approach and Technical Tasks	Participants
- Schedule for the Study	Participants
- Dates for Next Two Meetings	Participants

Suggested Agenda for the First HVPNS Study Meeting at IPP Garching, April 28-29, 1994

Session 2:

Friday April 29, Morning (9:00 am - 12:00 noon)

- Presentations and Remarks by Participants

Please feel free to prepare any presentation or remarks relevant to the study. Presentations on any technical topic or remarks related to the five technical tasks are welcome. Information on previous studies, reports or papers are useful (so, please bring copies of these reports/papers or a list of where they can be found).

If you want to make a presentation please let me know by Thursday afternoon, so I can prepare an agenda for Friday. I do encourage you to make a presentation. Malang and Abdou plan on giving presentations, each about 30 minutes.

Suggested Agenda for the First HVPNS Study Meeting at IPP Garching, April 28-29, 1994

Session 3:

Friday, April 29, Afternoon (1:00 pm - 5:00 pm)

- Continue Presentations

- Technical Discussion Related to Technical Aspects of Tasks 1-5 (and Other Technical Issues Related to the Study)

- Other Issues Participants Want to Address

- Finalize Homework Tasks and Dates for Future Meetings

Purposes of the Meeting

- Reach agreement on the HVPNS Concept Definition Effort objective, approach, and schedule, with the attached draft work outline serving as the basis for discussion.
- Identify roles and responsibilities of the participants.
- Begin technical discussions on the Phase 1 effort, including any ongoing or planned work that is relevant to the Phase 1 effort.
- Agree on technical tasks.
- Develop plans for future meetings.
- Identify homework assignments.
- Time schedule for performing the tasks.
- Discuss participation by Associate Contracting Parties.

IEA Activity on VNS

- The Fusion Power Coordinating Committee (FPCC) requested the IEA Executive Committee on Fusion Materials to study and make recommendations regarding:

  - IFMIF: an accelerator-based international fusion materials facility
  - VNS: high volume source

- A workshop was held in Moscow July 12-18, 1993 with participants from EC, Japan, Russia, USA

- Conclusions from workshop
  i) A volumetric neutron source (VNS) fusion facility is needed to test, develop and qualify fusion nuclear components and material combinations for DEMO
  ii) An attractive range of design options exists for VNS

- Recommendations from workshop
  Recommend IEA initiate VNS study activity with 3 phases (with decisions to proceed or terminate at the end of each phase)

  <u>Phase 1</u>: Concept definition (2 years)
  - Develop detailed statement of mission and objectives
  - Elucidate detailed test requirements
  - Identify envelope of design concepts, evolve the concepts to a level sufficient for making selection
  - Select design concept

  <u>Phase 2</u>: Conceptual Design (2 years)

  <u>Phase 3</u>: Engineering Design (3 years)

Charter for HVPNS Concept Definition Effort

The PEC should proceed with the development of a concept definition effort involving the interested Contracting Parties and possible Associate Contracting Party(ies). The first task should be to review the mission of and the technical approaches to such a source. The US will initially take the lead in organizing the activity. The US has offered to lead the organization subject to approval of the PEC.

Objective

The objective of the HVPNS Concept Definition Effort is to develop the technical and programmatic bases for a decision by the FPCC on whether or not to recommend that the interested Contracting Parties and possible Associate Contracting Party(ies) undertake a conceptual design effort on a HVPNS facility for fusion nuclear technology development.

APPROACH, LEADERSHIP, AND SCHEDULE

The approach to the HVPNS Concept Definition Effort will be to conduct the following two phases in series:

Phase 1: Assess the needs for HVPNS from the viewpoint of fusion nuclear technology developers, reach a consensus on the mission for HVPNS, and determine the general testing capabilities, design features, and operating parameters required for a HVPNS to accomplish its mission

Phase 2: Identify candidate plasma-based device concepts that can potentially meet the HVPNS requirements and assess the technical and economic feasibility of the leading concepts.

Relative to the Phase 1 effort, which would be conducted as a user community assessment by specialists in fusion nuclear technology development, the following factors would be considered:

- Definition of DEMO and long-range fusion development strategies leading to DEMO
- Nuclear technology data base needs for DEMO
- The testing capabilities of ITER and non-fusion facilities for meeting the nuclear technology data base needs of DEMO
- Potential for arriving at a DEMO with too high of a technological risk (e.g., too low a probability of achieving target availability levels) based on the nuclear technology data bases from testing only in ITER and non-fusion facilities
- The DEMO technological risk reduction benefits derived from HVPNS nuclear component and materials combination testing that complements nuclear testing in ITER and non-fusion facilities
- Optimal strategies for phasing of ITER, HVPNS, and non-fusion facility operation and testing programs

Professor Mohamed Abdou of the University of California, Los Angeles, will lead the Phase 1 effort.

It will be aimed to complete the Phase 1 effort by no later than mid-1995. The PEC will report to the FPCC at its next meeting (February 1995) on the progress made, thereby giving the FPCC an opportunity to review and comment on the effort.

The Phase 2 effort, which would be conducted by proponents of plasma-based options for HVPNS, would follow the completion of the Phase 1 effort. The participating Contracting Parties and possible Associate Contracting Party(ies) could, on a voluntary and informal basis, conduct Phase 2 type of activities during the Phase 1 effort in order to prepare for Phase 2.

It will be aimed to complete the Phase 2 effort by no later than mid-1996.

Principal Questions
for VNS Study

1) Do we need VNS and why?

2) What are the mission and objectives of VNS?

3) What are the major parameters and general design features of VNS to meet its mission and objectives?

4) What is the suggested time frame for construction and operation of VNS (particularly relative to other major facilities, e.g. ITER)? This question may be closely coupled with Question 1.

Draft of Suggested Tasks for HVPNS Study

Task 1:
Definition of DEMO and Power Reactors

(The emphasis is on DEMO but we can also list similar parameters and features for power reactors.)

a. Definition of DEMO major parameters and key features.

   An example is given in an attached table. We can expand, revise and change numbers. We can list another column for power reactors, if needed.

b. Specific goals for performance parameters and availability for blanket in DEMO (we can add another column for blanket in power reactors, see attached table).

c. Fusion development schedule (for each party/country). In particular, state date for beginning of operation of DEMO. From this date of operation and assuming 6 years for construction and 4 years for design of DEMO, determine the date when development of components such as the blanket need to be completed and ready. Example: if DEMO operation is scheduled to start by the year 2025, then we need a complete database from fusion testing of blankets by the year 2015 (i.e., 2025-6-4). Use other assumptions as you see appropriate.

Task 1 (cont.)

d. Develop a summary of the key technical issues for fusion nuclear technology (FNT) components that need to be resolved prior to construction of DEMO. FNT components include, of course, the blanket/first wall but we can also include the nuclear/thermo-mechanical issues for divertors, limiters, rf antenna, etc.

Task 2: Database Needed for FNT to Construct DEMO

What database is needed for fusion nuclear technology (FNT), e.g. blanket, to design and construct DEMO? The emphasis here should be on fusion testing. We need to quantify how much testing in fusion facility(ies) is needed to fully develop and qualify FNT components (e.g. blanket) prior to construction of DEMO?

This is a key task, which has never been addressed directly before. Studies such as FINESSE and EC were concerned more with how much testing in non-fusion facilities (fission reactors, MHD facilities, etc.) is needed to construct a test module for testing in facilities such as NET or ITER. In ITER-CDA, we addressed the question of what testing we can do in ITER whose parameters were fixed. Here, the question is different. The question is how much testing in the fusion environment we need to develop and qualify blankets for construction of DEMO assuming that a fusion facility can be specially designed to meet these needs?

The challenge here is to quantify the needs for how much fusion testing. Examples of key parameters are total fluence required at the test module, wall load, surface heat flux, total surface area for tests and whether we need a steady or pulsed neutron source. Parameters such as wall load can be derived from engineering scaling and there is good information from previous studies. The most difficult and critical parameters are the testing time per test article, the total cumulative test time for a sequence of test articles and the corresponding accumulated fluence in the device. Many of us make a common mistake of just saying how much fluence we need in a test module and we quote this as the device fluence. We need to avoid this

Task 2 (cont.)

mistake because a) there is a sequence of test modules; so total testing time is the sum of different test times for sequential test, b) testing time may be controlled by component development needs rather than just radiation effects, and c) fluence for the device at the first wall is different from that at the module.

One method to facilitate this is to agree on the stages for fusion testing. For example:

A. Screening of concepts (and checking results from fusion testing against those from non-fusion tests).
B. Performance verification of concepts.
C. Component engineering development and reliability growth.

Each stage may have different requirements. For example one may need submodules for Stage A, modules for Stage B, and modules or sectors for Stage C. The point is illustrated in an attached figure. The number of concepts at the end of each stage becomes smaller. (For example 6 at the end of A, 3 at the end of B with a "concept" referring to material combinations/material form/configurations, etc.)

We need suggestions on how to quantify this task. In other technologies (e.g., aerospace and defense), a level of confidence in the final product (here the blanket for DEMO) and the testing requirements (particularly the testing time and number of test articles that need to be tested for a given design) are quantified using a statistical approach. Can we do this? Other approaches? We need suggestions here.

Task 3:

Time Schedule for Fusion Testing

Given the information from Task 2, we can try to develop a time schedule in terms of calendar years required to fulfill the fusion testing tasks. Here, we need to assume a device availability. I suggest using 3 values: 10%, 30% and 50%. We should note here the testing time in years is not just the fluence divided by the product of wall load and availability. We need to account for time needed to insert and replace test articles and time to fix problems and possibly redesign and reconstruct the test articles.

(Results of this task together with the DEMO schedule, define when fusion testing needs to begin.)

Task 4:

ITER and Non-Fusion Testing Capabilities

Given the present EDA ITER design, how much of the fusion testing identified in Task 2 can be done on ITER? When can it be done on ITER? How does it fit with the schedule for the DEMO?

A question that is inevitable is how much risk to the DEMO is involved in going directly from only ITER testing directly to the DEMO?

While the experts are clear on the difference between testing in fusion and non-fusion facilities, the differences are not clear to the outside community. We need to summarize the role and limitations of non-neutron test stands, fission reactors and accelerator based neutron source.

Task 5

Given the results from Tasks 1-4 (and other tasks that might be suggested by the participants) we should be able to develop options for the strategy on how to best satisfy fusion testing needs to develop and qualify FNT (e.g. blanket/first wall) for construction of DEMO.

In this task, we should address the principal questions for the study; namely

1) Do we need VNS? And why? What are the benefits of VNS? What are the consequences of a program strategy with and without VNS?

2) What are the mission and objectives suggested for VNS?

3) What are the major parameters and general design features of VNS to meet its mission and objectives?

4) What is the suggested time frame for construction and operation of VNS (particularly relative to other major facilities, e.g. ITER)?

Future Meetings

A) Brief (2-3 hours) meeting during ISFNT-3 (June 27-July 1, 1994) at UCLA. Many of the people in the study will attend ISFNT-3. Therefore, it is a good idea to meet briefly to review progress and to clarify any issues that may come up between now and the end of June. The schedule for ISFNT-3 is full, so we need to fix the date and time by next week. Possible dates are --

Sunday June 26 (1:00pm - 4:00pm)
Friday July 1 (2:00pm - 5:00pm)
Saturday July 2 (anytime during the day)

B) Workshop meeting (2-3 days)
Progress Report on results of technical tasks. Discussions, definition of new work and development of outline for report.

This meeting could be in Europe (Paris, Karlsruhe or Garching) just before or after the IAEA Conference in Spain. Suggested dates --

September 22 - 23
or October 3 - 4

If these dates are not acceptable, please suggest other dates.

C) Workshop meeting
2 - 3 days in early December (place?). Meeting is to review and discuss results, begin to draft conclusions, writing assignment for Progress Report to FPCC.

D) Other meetings in 1995 are to be agreed upon later.

Table 1. DEMO Characteristics

A DEMO Plant is one that demonstrates dependability and reliability. The size, operation and performance of DEMO must be sufficient to demonstrate that there are no open questions about the economics of prototype/first commercial reactor.

Neutron wall loading	2 - 3 MW/m^2
Fluence	10 - 20 $MW.y/m^2$
Fuel cycle	Self sufficient
Plasma mode of operation	Steady state or very long burn, short dwell
Net plant availability	> 50% (demonstrate reliability and maintainability)
Thermal conversion efficiency (gross electric/thermal power)	> 30%
Disruption resistance	One major disruption during lifetime

Technical Goals for Blanket/First Wall

Parameter	DEMO	Power Reactor
Neutron Wall Load, MW/m^2	2-3	4-5
Surface Heat Load, MW/m^2	1	1-2
Peak Magnetic Field, T	13	13-15
Gross Thermal Conversion Efficiency	> 35%	> 40%
Coolant Outlet Temperature		
Structure Maximum Temperature		
Tritium Breeding Ratio		
Mean Time Between Failures (MTBF)	3 years (per blanket module)	3-4 years
Mean Time to Replace (MTTR)	2-3 months	2 months
Lifetime, $MW{\bullet}y/m^2$	10-20	20-30
Safety/environment Disruptions Off-normal Decay Heat Vulnerable Tritium Inventory Total Tritium Inventory Material Recycling Waste Management		

Technical Goals for Blanket/First Wall

Parameter	DEMO	Power Reactor
Neutron Wall Load, MW/m^2 Surface Heat Load, MW/m^2 Peak Magnetic Field, T Gross Thermal Conversion Efficiency Coolant Outlet Temperature Structure Maximum Temperature Tritium Breeding Ratio Mean Time Between Failures (MTBF) Mean Time to Replace (MTTR) Lifetime, $MW \cdot y/m^2$		
Safety/environment Disruptions Off-normal Decay Heat Vulnerable Tritium Inventory Total Tritium Inventory Material Recycling Waste Management		

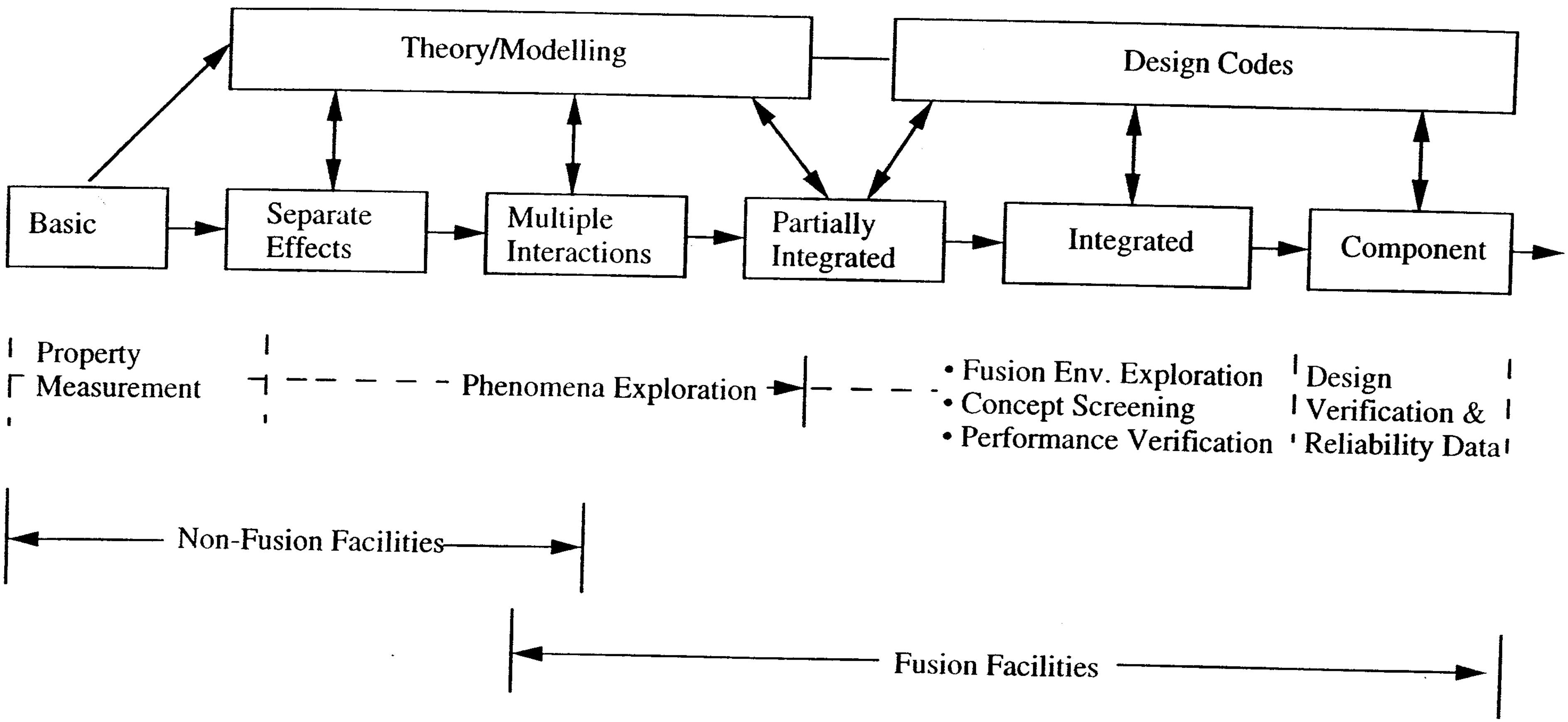


Figure 1. Types and role of experiments and facilities for fusion nuclear technology

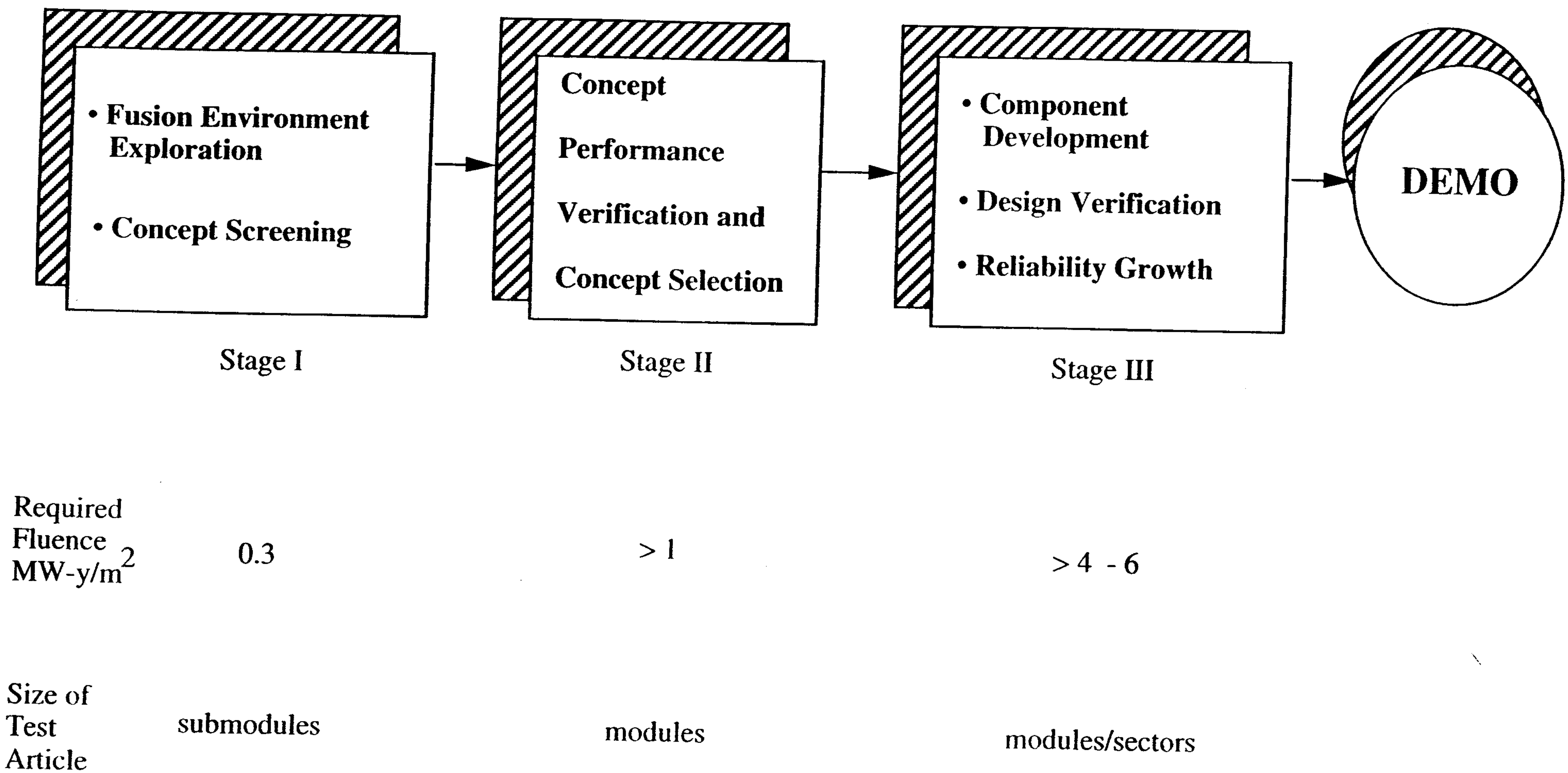
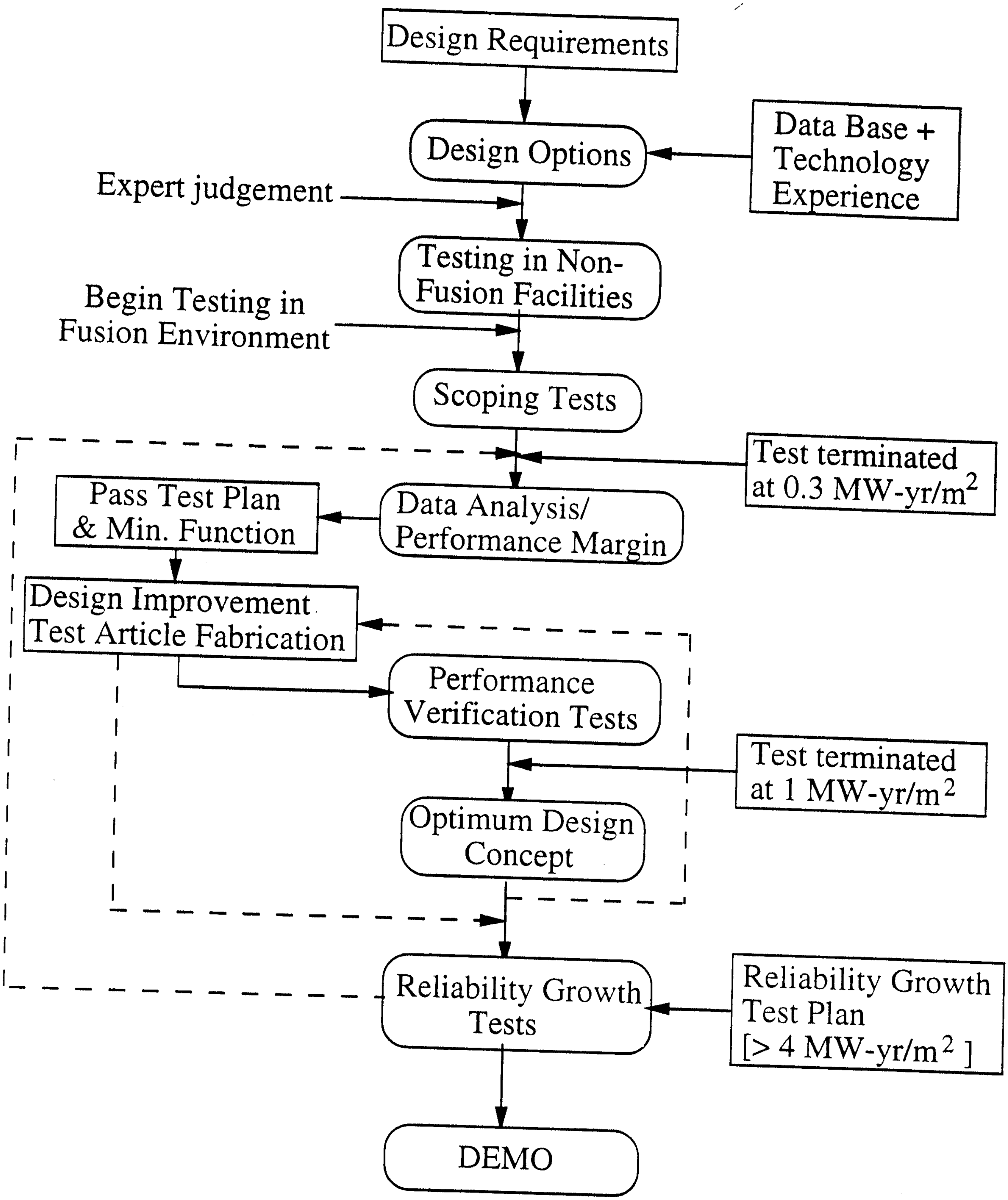


Figure 2. Stages of fusion nuclear testing in fusion facilities

Fusion Nuclear Technology Development Approach



Contribution of Nonfusion Facilities to Resolving Critical Issues for Fusion Nuclear Technology

Critical Issue	Non-neutron Test Stands	Fission Reactors	Accelerator Based Neutron Sources	
			DT	d-Li
1. D-T fuel cycle self sufficiency	none	none	partial	none
2. Thermomechanical loadings and response of blanket components under normal and off-normal operation	small	small	none	none
3. Materials compatibility	some	some	none	none
4. Identification and characterizations of failure modes, effects and rates	none	none	none	none
5. Effect of imperfections in electric (MHD) insulators in self cooled liquid metal blanket under thermal/mechanical/ electrical/nuclear loading	small	small	none	none
6. Tritium inventory and recovery in the solid breeder under actual operating conditions	none	partial	none	none
7. Tritium permeation and inventory in the structure	some	partial	none	none
8. Radiation shielding: accuracy of prediction and quantification of radiation protection requirements	none	small	partial	small
9. In-vessel component thermomechanical response and lifetime	some	some	none	some
10. Lifetime of first wall and blanket components	none	partial	none	partial[a]

[a] - Partial: substantial contribution when followed by fusion test; not meaningful in the absence of fusion tests

Capabilities of Non-fusion Facilities for Simulation of Key Conditions for Fusion Nuclear Components Experiments

	Neutron Effects(1)	Bulk Heating(2)	Non-Nuclear(3)	Thermal/ Mechanical/ Electrical(4)	Integrated Synergystic
Non-Neutron Test Stands	no	no	partial	no	no
Fission Reactor	partial	partial	no	no	no
Accelerator-Based Neutron Source	partial	no	no	no	no

(1) radiation damage, tritium and helium production
(2) nuclear heating in a significant volume
(3) magnetic field, surface heat flux, particle flux, mechanical forces
(4) thermal-mechanical-electrical interactions (normal and off normal)