Initial Remarks on VENUS

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Meeting at UCLA, May 11, 1993

Dates for VENUS Meetings

Meeting 1:	May 11
Meeting 2:	June 17/18
Meeting 3:	August 9/10

VNS Mission

Overall

To test, develop and qualify those fusion nuclear technology components that are required for the DEMO and have the highest impact on the economic, environmental and safety attractiveness of fusion energy.

Specific

- Obtain data on performance in fusion environment, calibrate non-fusion tests
- Screen blanket concepts
- Select reference concepts for DEMO; optimize design, verify performance
- Obtain reliability data base to estimate MTBF; obtain data on failure modes and effects
- Iterative design/test/fix programs aimed at improving reliability
- Obtain data on MTTR (remote maintenance)
- Gain experience with design, construction and operation of a fusion device

Some Useful Ground Rules (Preliminary)

1) VNS is complementary to ITER. It is not a substitute for ITER

2) ITER does not need VNS to achieve its physics mission

3) VNS will allow risk to ITER, to DEMO, and to the fusion program to be reduced:
   - avoid a breeding blanket in ITER with unproven technology
   - reduce operating cost for large fusion power

VENUS

Near Term Tasks

Task 0: Mission, Objectives and Role of VNS

- One sentence mission statement
- Detailed mission statement
- Tasks to DEMO and devices in which they are accomplished

Responsibility: Abdou plus input from others

Schedule: Initial draft end of June '93
Continue to revise during study

Task 1: VNS Design and Performance Requirements

Define requirements for testing, validating and qualifying fusion nuclear components for DEMO. Delineate the implications of these requirements on VNS major parameters, design, options and engineering.

Parameters

Contained in the well-known "FINESSE" table (wall load, fluence, pulse length, availability, test area, etc.)

Revision

Revise based on:

A. Engineering scaling requirements
B. "Timely information": obtain desired information in 10 years (e.g. higher wall load, higher availability)

Engineering

Requirements for frequent replacement, module, sector, etc.

Test Matrix

Revise famous table for test matrix; generate time sequence

Responsibility

Abdou, Ying, Tillack, Raffray, Youssef, Tehranian

Solid Breeders: Raffray

Liquid Metal: Ying, Tillack

High Heat Flux: Tillack

Neutronics/Shield: Youssef

Subtask 1.A

How long and how much do you need to test to achieve 80% statistical confidence in a given MTBF

(Responsibility: Tehranian, others)

Task 2: VNS Concept Evaluation Methodology

Revise/update "FINESSE" methodology

Responsibility: Tillack, Peng

Task 3: VNS Concept Evaluation

Identify "envelope" of design concepts suitable for VNS
A) Parametric studies: Peng et al.
B) Engineering: ?
C) Availability evaluation: ?

Guidelines

- Cost < 0.5 ITER
- Low fusion power (< 600MW)
- Higher wall load (> 1 MW/m^2, prefer 2 or 3 if possible)
- No breeding blanket

Component R&D Prior to DEMO

- We need to be concerned with the tasks that must be accomplished prior to the DEMO
- Some of these tasks can be performed in ITER
- Other tasks will have to be performed parallel to ITER

Components:

Plasma	Tritium Systems
Blanket	Magnets
PFC	Plasma Heating
Shield	Diagnostic

R&D Tasks:

1. Performance verification and concept validation
2. Failure modes and effects
3. Remote maintenance demonstration
4. System integration
5. Availability/reliability growth
6. Component lifetime

DEMO Characteristics

Neutron Wall Loading	2-3 MW/m^2
Availability*	> 50%
Fluence	5-10 $MW\text{-}yr/m^2$
Fuel Cycle	Self-sufficient, demonstrate doubling time requirements
Plasma Mode of Operation	Steady state (or very long burn, short dwell)

* To achieve machine availability of 50%, means the availability per blanket module needs to be > 99%.

Example Only

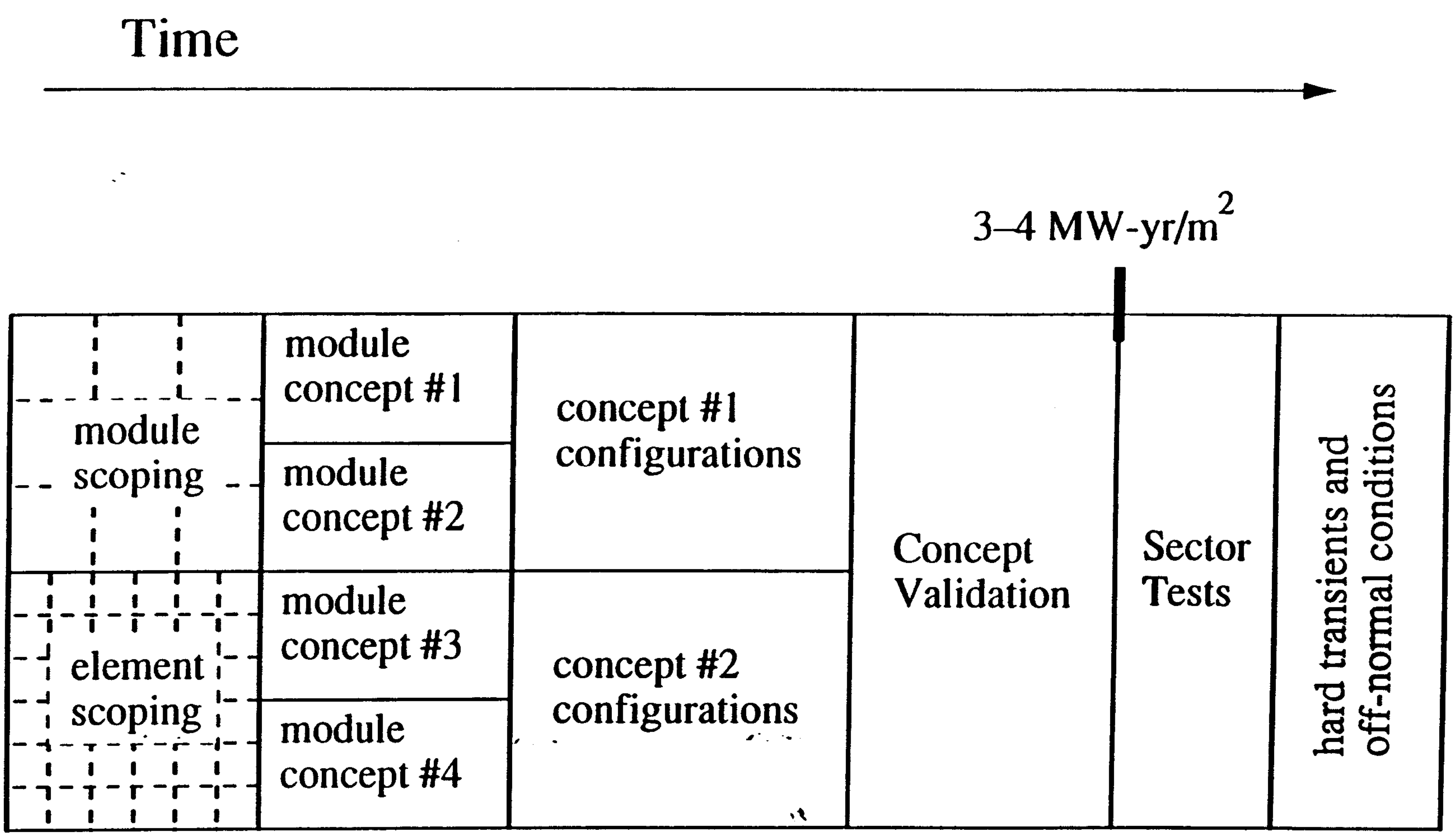
Devices in Which Development Tasks Could be Accomplished

	Performance Verification	Failure Modes and Effects	Remote Maintenance	System Integration	Availability Growth	Component Lifetime
Blanket	$ITER_1$, TDF	$ITER_1$, TDF	$ITER_1$	$ITER_1$	$ITER_1$, TDF	$ITER_1$, TDF
PFC	$ITER_2$	$ITER_2$	*	*	$ITER_2$	$ITER_1$, TDF
Shield	*	*	*	*	*	*
Tritium Processing	*	*	*	*	*	*
Tritium Fuel Cycle	$ITER_1$	*	*	*	$ITER_1$	*
Magnets	*	*	*	*	*	*
Plasma	$ITER_2$	$ITER_2$	*	*	$ITER_2$	*

* any DT-burning tokamak

$ITER_1$ = CDA, $ITER_2$ = reduced mission

Blanket Test Sequence



Physics and Technology Requirements for Testing Are Very Dissimilar

	Fusion Power	Integrated Burn Time	Tritium Consumption
Physics	1000 MW	15 days	0.7 kg
Technology (FNT)	20 MW	3 yr	1 kg
Combined e.g. ITER CDA	1000 MW	3 yr	50 kg

* Combining large power and high fluence leads to large tritium consumption requirements

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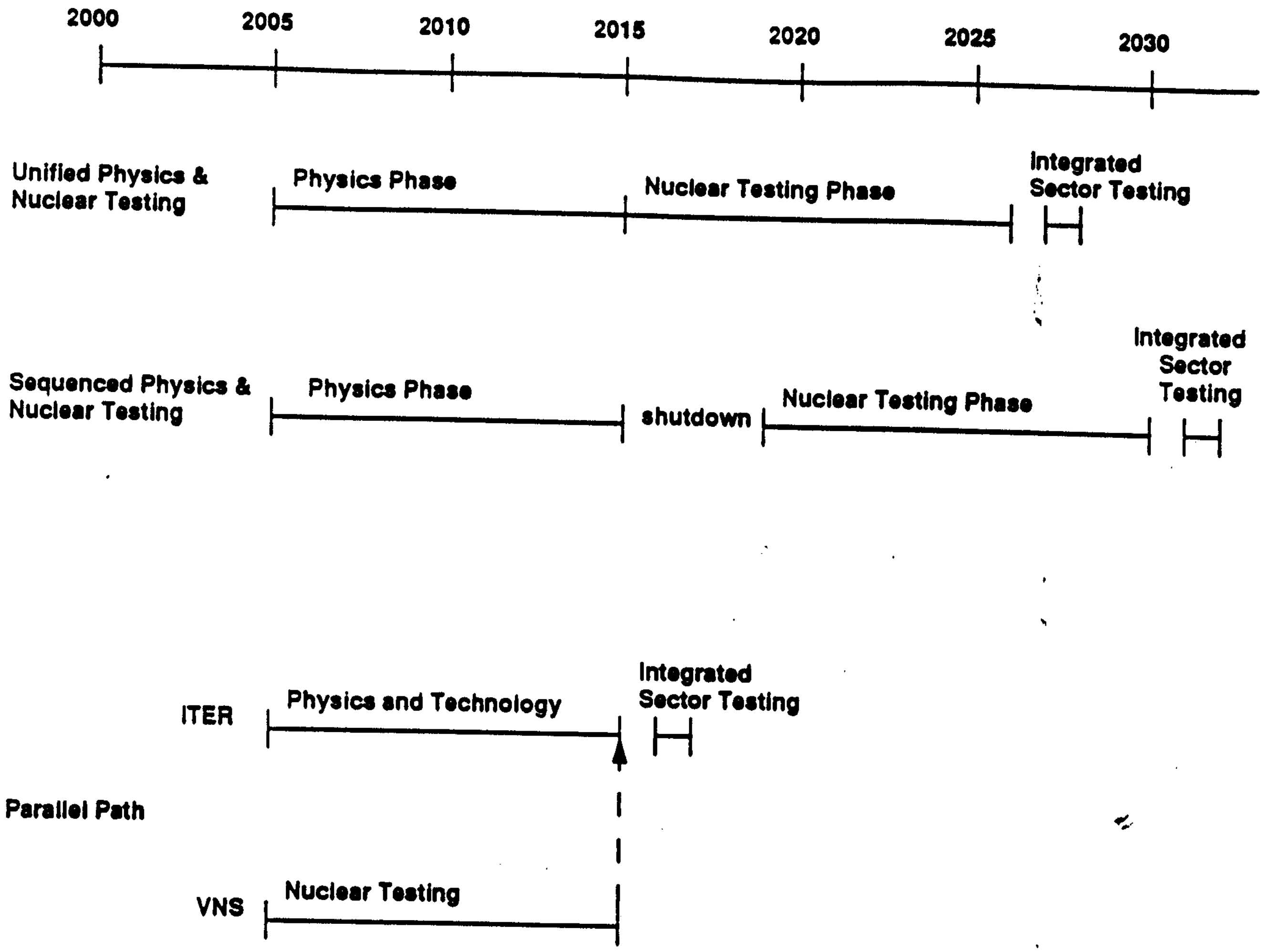

TIME-LINE FOR DEVELOPMENT SCENARIOS

NUCLEAR TESTING REQUIREMENTS

	Minimum	Highly Desirable
Neutron Wall Load (MW/m^2)	1	2
Plasma Burn Time Dwell Time Continuous Test Duration (steady state or back-to-back cycle 100% availability	> 1000 s a > 1 week	steady state (or long burn, hours) < 20 s 2 weeks
Average Availability Total Neutron Fluence ($MW\text{-}a/m^2$)	10 - 15 % 1.5	25 - 30 % 4 - 6
<u>Test Port Size</u> ($m^2 x m$) Module Outboard Sector <u>Total Test Area</u> (m^2) Modules Only Including Outboard Sectors	 0.5 X 0.3 2 x 0.5 5 7	 1 x 0.5 4 x 0.8 10 - 20 20 - 30

TABLE VI

Fusion Nuclear Technology Tests Requiring Fusion Neutrons

Tests	Typical Test Article Size (cm)	Number of Test Articles[a]
Basic tests		
Structural material irradiated properties	1 × 1 × 2	20 000
Solid breeder irradiated properties	1 × 1 × 2	1 200
Plasma interactive materials irradiated properties	1 × 1 × 5	900
Radiation damage indicator cross sections	1 × 1 × 0.5	500
Long-lived isotope activation cross sections	1 × 1 × 0.1	200
Neutron sputtering rate cross sections	1 × 1 × 0.1	30
Single-effect tests		
Structure thermomechanical response experiments	10 × 10 × 10	50
Weld behavior experiments	10 × 10 × 5	50
Shield effectiveness in complex geometries	50 × 50 × 100	50
Optical component radiation effects	2 × 2 × 2	20
Multiple-effect/multiple interaction tests		
Submodule thermal and corrosion verification	LB[b]: 100 × 100 × 30	5
	SB[b]: 10 × 50 × 30	5
Partially integrated and integrated tests		
Verification of neutronic predictions		
Tritium breeding, nuclear heating during operation, and induced activation	50 × 50 × 100	4
Full module verification		
Thermal and corrosion	LB[c]: 100 × 100 × 50	5
Module thermochemical lifetime	SB: 100 × 100 × 50	5
Tritium recovery		
Instrumentation transducer lifetime	1 × 1 × 2	70
Insulator/substrate seal integrity	1 × 1 × 2	20
Biological dose rate profile verification	D-T device	1
Afterheat profile verification	D-T device	1
Component tests		
Blanket performance and lifetime verification	SB: 30 × 100 × 80	3
	LB: 900 × 300 × 80	3
Radiation effects on electronic components	1 × 1 × 1	20
Instrumentation performance and lifetime	5 × 5 × 5	100

[a] A test article is defined as one physical entity tested at one set of conditions. Duplication of tests for statistical purposes, off-normal conditions, data at several time intervals, for high fluence tests, etc., are *not* included in the number of test articles.

[b] LB = liquid breeder blankets; SB = solid breeder blankets.

[c] Some designs require a larger test volume.

defined test matrices that specify the number, type, conditions, and size of specimens needed for structural and breeder materials testing,[1,3,9,10] but the more complex tests also indicated in this survey were not quantified. Such tests are obviously important, and Sec. IV focuses on their requirements.

One preliminary requirement that can be estimated from the information in this survey is the overall irradiation testing area (first-wall area) and volume. Based on Table VI for tests requiring significant fusion (or at least high-energy) neutrons, the irradiation testing area and volume are listed in Table VII. The space requirements are not needed in a given reactor at a given time, but rather represent the overall space integrated over the test program duration. While tentative, these numbers point to the need for a considerable amount of irradiation testing space for fusion R&D.

IV. EXPERIMENT REQUIREMENTS

IV.A. Introduction

In Secs. II and III, the issues were identified and the testing needs to resolve these issues were surveyed.

Higher TDF Availability Lead to More Test Time and Faster MTBF Growth

The ITER-CDA blanket is expected to have a minor impact on device availability (10–20% at best)

However, the low availability of the ITER device seriously limits blanket testing

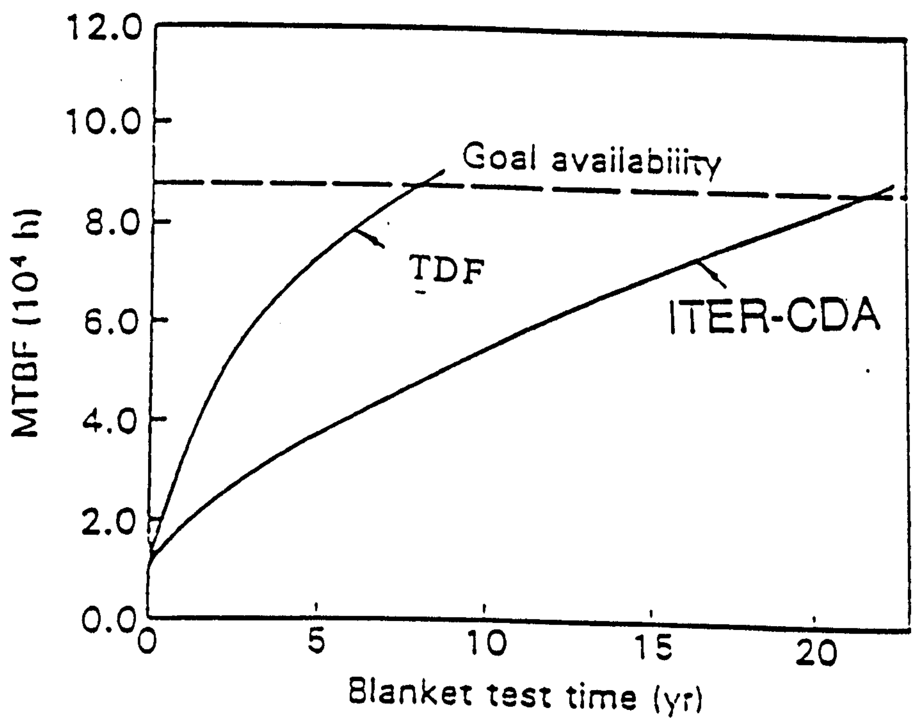

Fig. 25. Higher FERF availability leads to more test time and faster MTBF growth.

Key Assumptions in the Availability Analysis

	Blanket Test Modules	Blanket Tritium Breeding Modules
Initial MTBF (yr)	1	2.9
Initial test experience (day)	31	99
MTTR (week)	2	4
Goal MTBF (yr)	10	10
Test improvement factor	0.50	0.10
Experience factor[a]	0.50	0.50