Briefing on ITER Test Program

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ITER Test Program
Suggested Topics for Discussion During the Week of December 13-17

1) What needs to be done on the Test Program
i.e. definition of the tasks

2) How to carry out these tasks:
   - what each party will do
   - how the work will be coordinated among the home teams and JCT
   - organizational structure and role of working group

3) General strategy for the Test Program e.g.:
   - goal of testing (data for DEMO?)
   - four separate testing programs for the four parties? or one integrated test program?
   - how do we allocate space? by party? or by concept?

4) Time schedule for carrying out the tasks (and dates for future meetings)

5) [Side topic (maybe not this week, but should be discussed some time in the future) --
R&D for the Test Program: what is needed, whether the parties need to collaborate, and how]

Proposing Party: USA

D2 Test Program Development

US Interest: High

Parties Involved:

All parties must be involved in this task in order to accommodate the needs of the parties for performing tests on ITER. These needs must be coordinated and integrated into an effective Test Program. The US is also willing to have the lead role in working with the parties and JCT to develop a well integrated test program that utilizes ITER capabilities efficiently and effectively.

Description of Work:

The overall objective of this task is to develop the details of the ITER Test Program for A) Basic Performance Phase, and B) Extended Performance Phase. Specific tasks are as follows:

Subtask 1) Identify information to be obtained from the operation of the basic ITER device (components and overall system). Evaluate the importance of this information to the development of a data base for DEMO.

Subtask 2) Identify and characterize tests to be performed on ITER using test articles and modules. Possible tests should be defined for all relevant components such as blankets, divertors, rf antennas as well as special-purpose tests for materials (structural materials, breeding materials, insulators, etc.)

Subtask 3) Develop examples of test article and module designs using engineering scaling to maximize the relevance of test data for extrapolation to DEMO.

Subtask 4) Develop the specific details of the Test Program. These details should include:

- number and size of test articles/modules.
- test schedule showing insertion, irradiation period and withdrawal of test articles. Space requirements should be defined for all periods of ITER operation.

US Organizations:

The US effort will be lead by UCLA with major contributions by ANL, SNL, LLNL, ORNL and LANL. M. Abdou will be responsible for the US effort.

Milestones & Deliverables:

Preliminary Report on Subtasks 1, 2 & 3; April '94
Interim Report on Subtasks 1 through 4; August '94
Final Report on all Subtasks; December '94

Credit Requested: 0.25 PMY

The requested US share is 25% of the resources allocated for the task. If it is agreed that the US coordinate this task, then the US share should be increased to 0.4 PMY.

Proposing Party: USA

D3 Integration of Test Modules in the Main Blanket and Vacuum Vessel

US Interest: High

Description of Work:

The overall objectives of this task are to define the engineering interface between the test program and the ITER basic device and resolve related issues so as to maximize the effectiveness of the Test Program without unduly burdening the basic device. Specific tasks include:

Subtask A) Summarize requirements of the Test Program on ITER major design parameters. Develop an effective compromise between what is needed and what can be achieved.

Subtask B) Working closely with JCT designers, develop engineering details for incorporating the test articles/modules into the test ports. Engineering issues related to placement of different types of modules (e.g. sharing the same test port by blankets that have the same coolant or alternatively by blankets that have the same breeder, or ports are simply allocated by party) should be addressed. Designs of support lines (coolant manifolds, tritium recovery, data acquisition, etc.) should be developed and integrated into ITER design.

Subtask C) Define auxiliary (ancillary) equipment requirements. These should include the large space requirements around the device for heat rejection, tritium extraction, coolant processing, etc.

Milestones & Deliverables:

Preliminary Report on Subtasks A, B & C; April '94
Interim Report on Subtasks A, B & C; August '94
Final Report on all Subtasks; December '94

Credit Requested: 0.5 PMY

The requested US share of this task is 25%. In addition, the JCT should designate an engineering designer responsible for interaction with the home teams to perform this task.

ITER Test Program Working Group

The Home Team Leaders and the Director agreed to forming this group in September 1993 meeting.

Membership

- 2 or 3 members of JCT.
- 4 members from the parties (one from each party).
- Supplement by experts from JCT and Home Teams as needed.

Responsibility

Should be defined carefully.
[General: Coordinate Test Program with JCT. What tests are needed? What are the requirements on the ITER design? Can these requirements be accommodated? Can changes in tests or machine designs be made to reach an acceptable compromise?]

Meetings

- Once every 3 or 4 months.

Reporting

- Summary reports from the Working Groups should be available to JCT, Home Teams and user community.
- Progress and issues from the Working Group should be part of the TAC and MAC reviews.

Examples of Present US Effort on ITER Test Program

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 $MW{\cdot}y/m^2$
Fuel Cycle	Self sufficient, demonstrate doubling time requirements
Plasma Mode of Operation	Steady state (or very long burn, short dwell)
Net Plant Availability	> 50% (demonstrate reliability and maintainability)

Fusion Nuclear Technology Development Approach

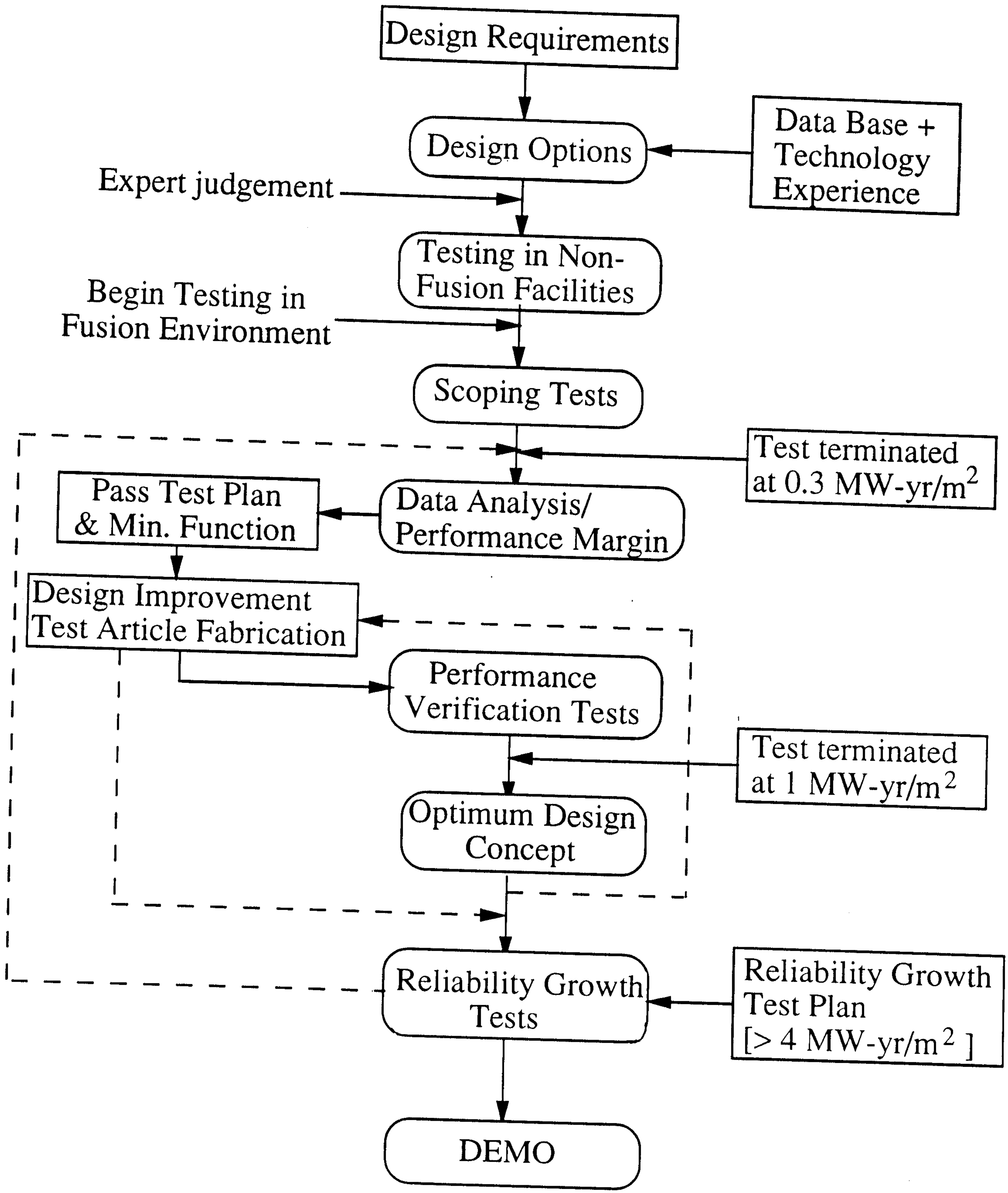


TABLE 1. Preliminary Testing Requirements

Wall Load

- Minimum: > 1 MW/m^2
- Substantial benefits: 2–3 MW/m^2
- Much higher wall loads can be beneficial and will alter strategy (accelerated testing, more ambitious technology performance goals for fusion, etc.)

Surface Heat Load

- Critical for tests of first wall, solid breeder blankets, liquid-metal blankets
- Critical: > 20 W/cm^2
- Important: > 40 W/cm^2
- Methods to enhance surface heat flux in fusion test facilities are important

Plasma Burn Cycle

- Pulsing sharply reduces the value of many tests
- Minimum burn time: > 1000 s
- Maximum dwell time: < 100 s
- Prefer steady state

Minimum Continuous Time

- Many periods with 100% availability
- Duration of each period
  Critical: Several days
  Important: Several weeks

Availability

- Minimum: 20%
- Substantial benefits: 50%

Fluence

- Fluence requirements will depend on whether a neutron source or other means is available for high fluence material testing
- In general, component tests in the early stages of development are carried out to fluences lower than those for specimen
- In all cases, higher fluences are desirable but costly; modest fluence are still extremely valuable
- For component tests:
  Critical: 1–2 $MW\text{-}yr/m^2$
  Very important: 2–4 $MW\text{-}yr/m^2$
  Important: 4–6 $MW\text{-}yr/m^2$
  Desirable: 6–10 MW-yr/m

Minimum Size of Test Assembly

- Interactive tests: ~ 0.2m×0.2m×0.1m
- Integrated tests: ~ 1m×1m×0.5m

(Some liquid-metal blanket designs tend to require larger size, sector scale)

Test Surface Area

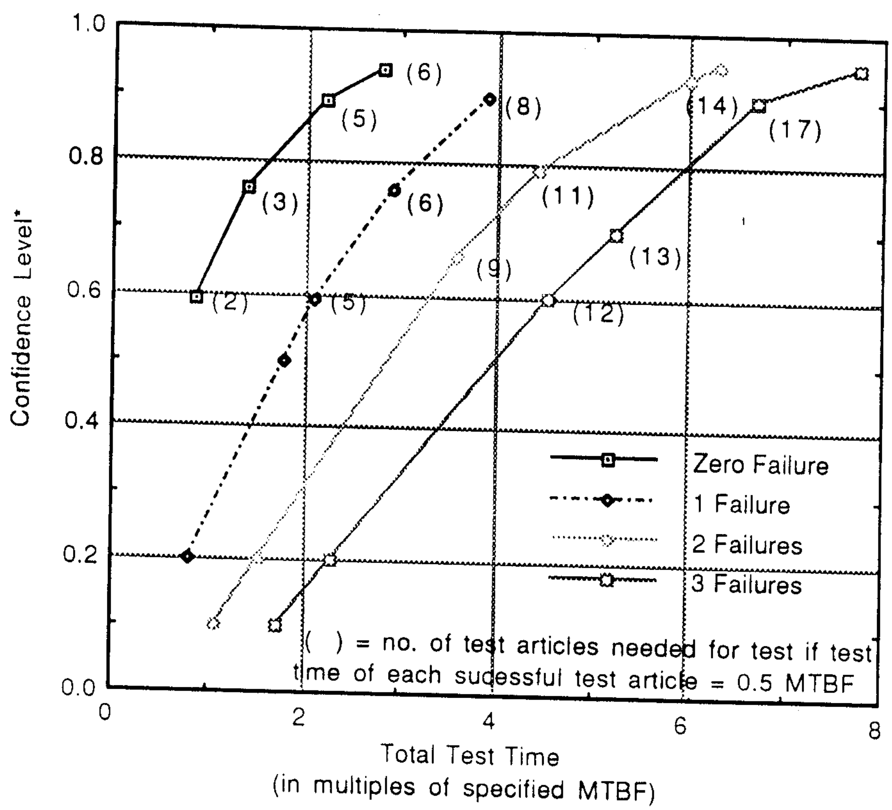
- Critical: > 5 m^2
- very important: > 10 m^2
- Important: 15–20 m^2
- Desirable: 20–30 m^2

Magnetic Field

- Critical: > 3 T
- Important: > 5 T

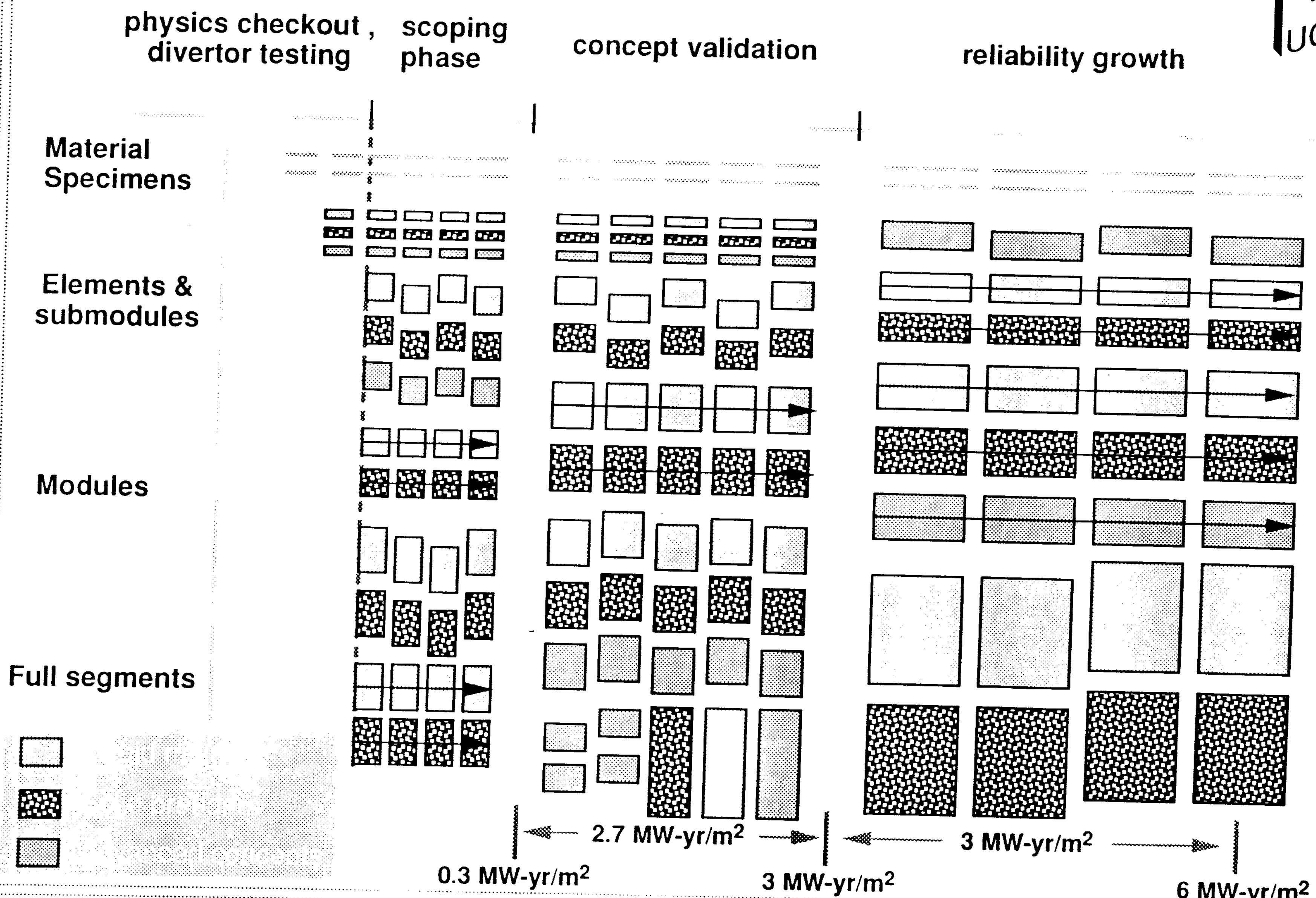
Test Time and Number of Test Articles vs Confidence Level

- For MTBF tests, the minimum test time per component = 0.5 MTBF (assuming that the component useful operating time is equal to the MTBF)
- This requirement implies that 6 test components are needed for achieving a 90% confidence level, if the number of failure is zero.
- With 1 failure during the test, the number of test articles would be 8 for achieving a 90% confidence and 7 for 80% confidence.

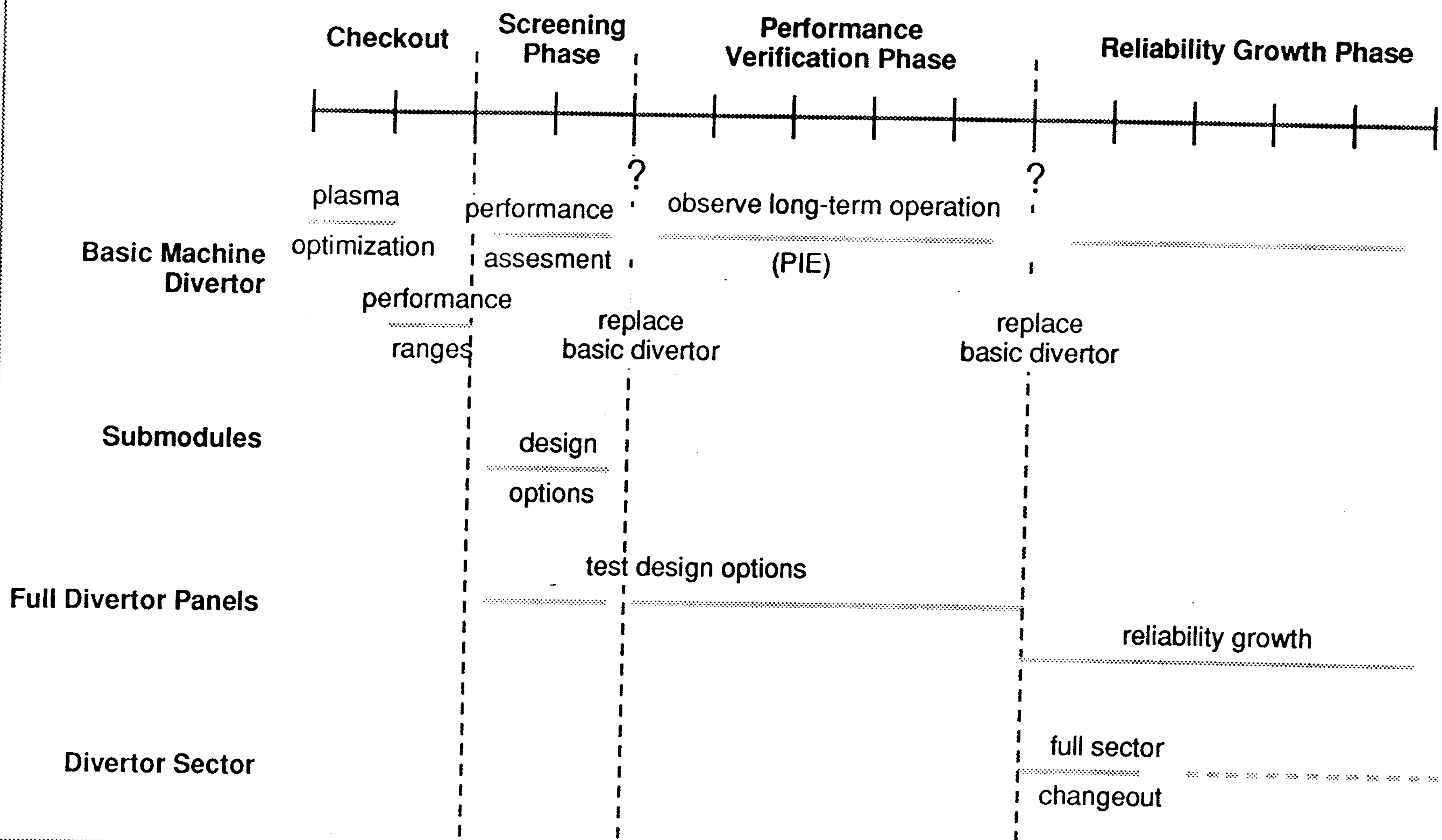


* Confidence level 0.8 means that the confidence of the lower limit on the MTBF being equal to the specified MTBF is 80%.

Blanket Test Sequence



Example Test Sequence for Divertors



Liquid Metal Blanket Test Matrix

Tests	Typical Test Article Sizes (Toroidal x Poloidal x Radial; cm)	Number of Test Articles
Basic tests (Specimen/Element)		
Structural material irradiated properties	2.54 x 1 x 2.54	5000
Insulator material irradiated properties	2.54 x 1 x 2.54	500
Welds/brazed joints behavior experiments	10 x 10 x 10	100 (material x shape x fluence)
Multiple-effect/multiple interaction tests (Submodule)		
Corrosion verification	25 x 25 x 25	2x2x3 (material x velocity x temperature x redundance)
Welds/Brazed joints with flow	25 x 25 x 25	5 x 2 x 3 x 5 (geometry x velocity x temperature x redundance)
Insulator self-healing	25 x 25 x 25	5 x 2 x 3 x 5 (geometry x velocity x temperature x redundance)
MHD pressure drop	25 x 25 x 25	5 x 3 x 5 (geometry x velocity x redundance)
Transient electromagnetic effect	Variable x 25 x 25	5 x 5 (toroidal dimension x redundance)
Performance Validation (Module)		
Integrated performance test - stage 1	100 x 100 x 50	5 x 3 (concept x redundance)
Integrated performance test - stage 2	100 x 100 x 50	3 x 3 (concept x redundance)
Reliability Growth	100 x 100 x 50	9
Total Test Area for LM (m^2)	**15**	

EXAMPLE SOLID BREEDER TESTS

Tests	SB (SBxformxpor)	Be Form (formxpor)	Structure	T	Fluence	Dupl.	Total	Element Size (Test Size)	Volume m^3	FW Area m^2
Basic Tests										
Solid breeder irradiated properties (4 properties)	4 x 2 x 3			4	4	2	3072	1 x 1 x 2 cm (2 x 2 x 3 cm)	0.037	0.077
Be irradiated properties (4 properties)		2 x 3		4	4	2	768		0.009	0.019
Single Effect Tests										
Solid breeder tritium recovery	4 x 2 x 2			4	4	1	256	2 x 2 x 4 cm (3 x 3 x 5 cm)	0.012	0.014
SB/structure interaction	4 x 2 x 1		3	4	4	1	384		0.013	0.022
Be tritium inventory &rec.		2 x 3		4	4	1	96		0.004	0.005
SB/Be interaction	4 x 2 x 1	2 x 1	3	4	4	1	768		0.035	0.043
Be/structure mechanical inter.		2 x 1	3	4	4	1	96		0.004	0.005

EXAMPLE SOLID BREEDER TESTS

Tests	SB	Be	Structure	Config.	Total	Element Size (Test size)	Volume m^3	FW Area* m^2
Multiple Effect Tests (submodule)								
Thermal:								
water	4	1	1	2	8	10 x 50 x 30 cm	0.288	0.48
helium	4	1	1	2	8	(15 x 60 x 40 cm)	0.288	0.48
Corrosion:								
water	4	1	1	2	8		0.288	0.48
helium	4	1	1	2	8		0.288	0.48
Tritium Recovery and Permeation:								
water	4	1	1	2	8		0.288	0.48
helium	4	1	1	2	8		0.288	0.48
Integrated Tests:								
Module:								
Full module performance verification:								
water	2	1	1	2	4	1 x 1 x 0.5 m	4.03	3.36
helium	2	1	1	2	4	(1.2 x 1.2 x 0.7 m)	4.03	3.36
Qualification (5 x selected configuration)	1	1	1	1	5		5.04	4.2
Lifetime (1 x initial preferred conf.)	1	1	1	1	1		1.01	0.84
Sector								
Prototypical full sector test	1	1	1	1	1	6 x 1 x 0.5 m (6.5 x 1.2 x 0.7 m)	5.21	4.55

* Preliminary assumption is that all submodules and modules require plasma interface. FW test area estimates are thus quite conservative.

Summary of Space Requirements for Test Modules

(concept screening and performance verification tests)

Test Component	Port Size m^3	Number of Ports	Total Area m^2	Duration
Blanket test modules	1 x 2 x 1	6	12	life of machine
Materials test module	1 x 2 x 1	1	2	life of machine
Dedicated neutronics tests	1 x 2 x 1	1	2	short term
Divertor	1 x 1 x 1	4	4	life of machine