Requirements and Design Envelope for

VNS
A Volumetric Neutron Source Fusion

Facility To Test, Develop and Qualify Fusion Nuclear Technology components (e.g. Blankets) for DEMO

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- Results are derived from a study, called VENUS, aimed at investigating and quantifying R&D needs, particularly testing facilities, to develop and qualify Fusion Nuclear Technology Components for DEMO

- The study is being carried out by a number of US organizations with support from a number of Russian scientists and Engineers

Presentation at (IAEA) Fifteenth International Conference on Plasma Physics and Controlled Nuclear Fusion Research; Seville, Spain,
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Time is Very Limited Here

- Only highlights are presented

- **Technical analysis details**
  are available in a preprint of a paper:

  "VNS: A Volumetric Neutron Source for Fusion Nuclear Technology Testing and Development," by M. Abdou et al.

  To appear in Fusion Engineering and Design, Volume 27 (December 1994)

VENUS Study Approach

1. Define DEMO major parameters and features

2. Identify technical issues for FNT components

3. Evaluate the role of non-fusion facilities

4. Evaluate the need and quantify the requirements for FNT testing in FUSION facilities

5. Examine scenarios for fusion facilities and quantitatively compare scenarios based on:

    - risk to DEMO
    - cost
    - time schedule

6. Recommendations

DEMO Parameters & Characteristics

Plasma Mode of Operation	Steady State
Neutron Wall Loading	2-3 MW/m^2
Fuel Cycle	Self Sufficient
- Tritium Release/Extraction - Tritium Breeding	
Thermal Conversion Efficiency (High Temperature Operation)	>30%
Lifetime of Blanket	10-20 $MW.a/m^2$
DEMO Reactor Availability	>60%
Safety (low decay heat, low failure rate, etc.)	Passive
Environmental Impact (low long term radioactivity, etc.)	Minimal

- **Capabilities of Non-Fusion Facilities for Simulation of Key Conditions for FNT Components Experiments are Limited**
- **None of FNT Critical Issues Can Be Resolved by Testing in Non-Fusion Facilities**

	Neutron Effects	Bulk Heating	Non-Nuclear	Thermal/ Mechanical/ Electrical	Integrated Synergystic
Non-Neutron Test Stands	no	no	partial	no	no
Fission Reactors	partial	partial	no	no	no
Accelerator-Based Neutron Sources	partial	no	no	no	no

- **FNT Testing in The Fusion Environment is Necessary**

Fusion Testing Needs
[How Much Fusion Testing is Needed to Construct DEMO Blanket]

Parameter	Value
Neutron Wall Load, MW/m^2	1-2
Plasma Mode of Operation	Steady State
Neutron Fluence at Test Module, $MW.y/m^2$	
Stage I : Scoping	0.3
Stage II: Concept Verification	>1
Stage III: Engineering Development & Reliability Growth	4-6
Total Neutron Fluence for Test Device, MW.a/m2	>6
Total Test Area, m2	>10
Minimum Continuous Operating Time, Weeks	1-2

Stages of FNT Testing in Fusion Facilities

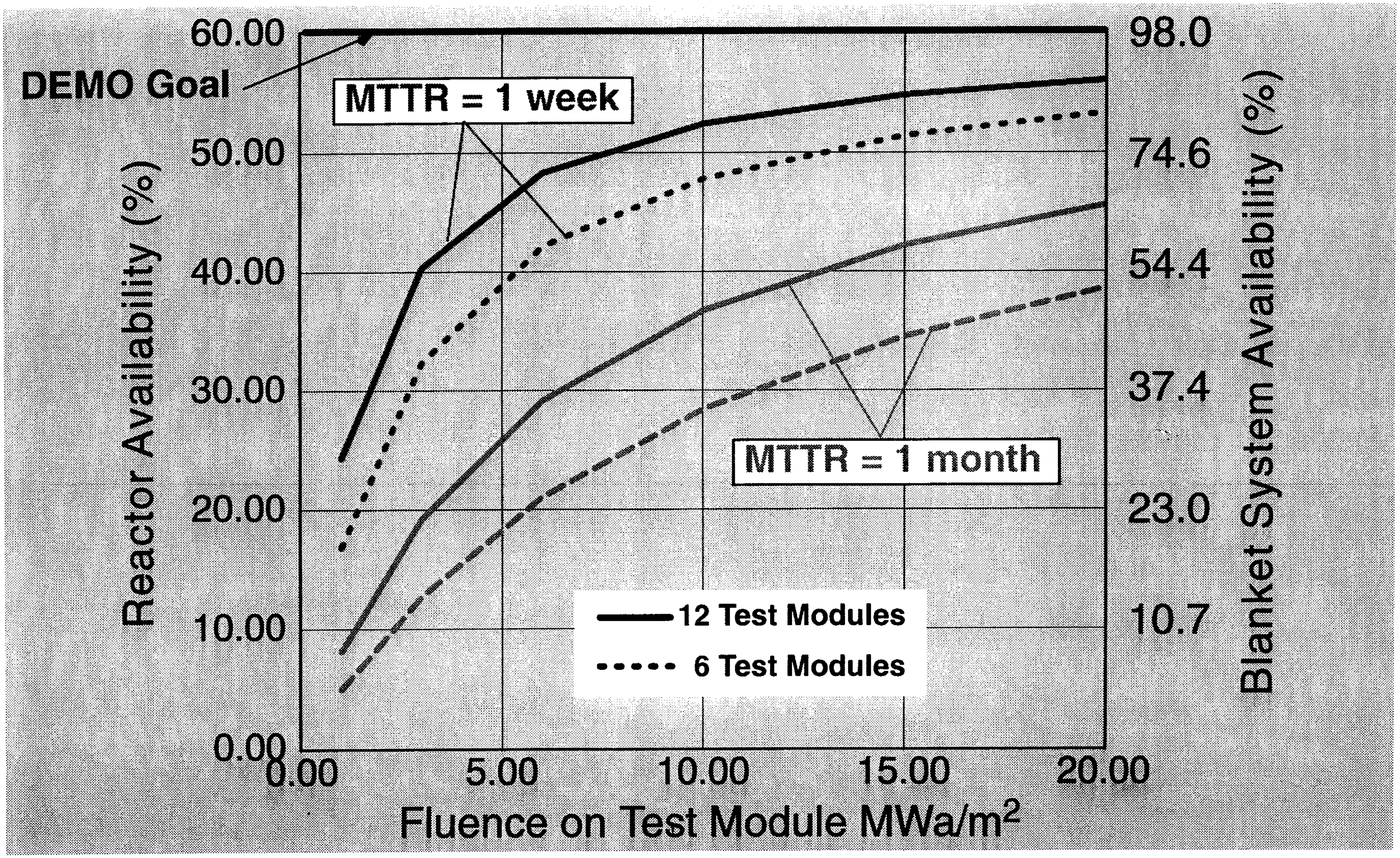
	Concept Screening	Concept Performance Verification	Component Engineering Development & Reliability Growth	DEMO
Stage:	**I**	**II**	**III**	
Required Fluence ($MW-y/m^2$)	**~0.3**	**>1.0**	**>4 – 6**	
Size of Test Article	**Sub–modules**	**Modules**	**Modules/Sectors**	

❑ **Engineering Development & Reliability Testing is Most Demanding:**

- ▶ Requires fusion operating environment (n,γ,B,T,V)
- ▶ Requires an aggressive design/test/fix iterative program
- ▶ Requires many test modules and high fluence

ACHIEVABLE DEMO AND BLANKET AVAILABILITIES DEPEND ON:

- TESTING FLUENCE AT THE BLANKET TEST MODULE
- ACHIEVABLE MEAN TIME TO REPLACE (MTTR) FOR BLANKETS



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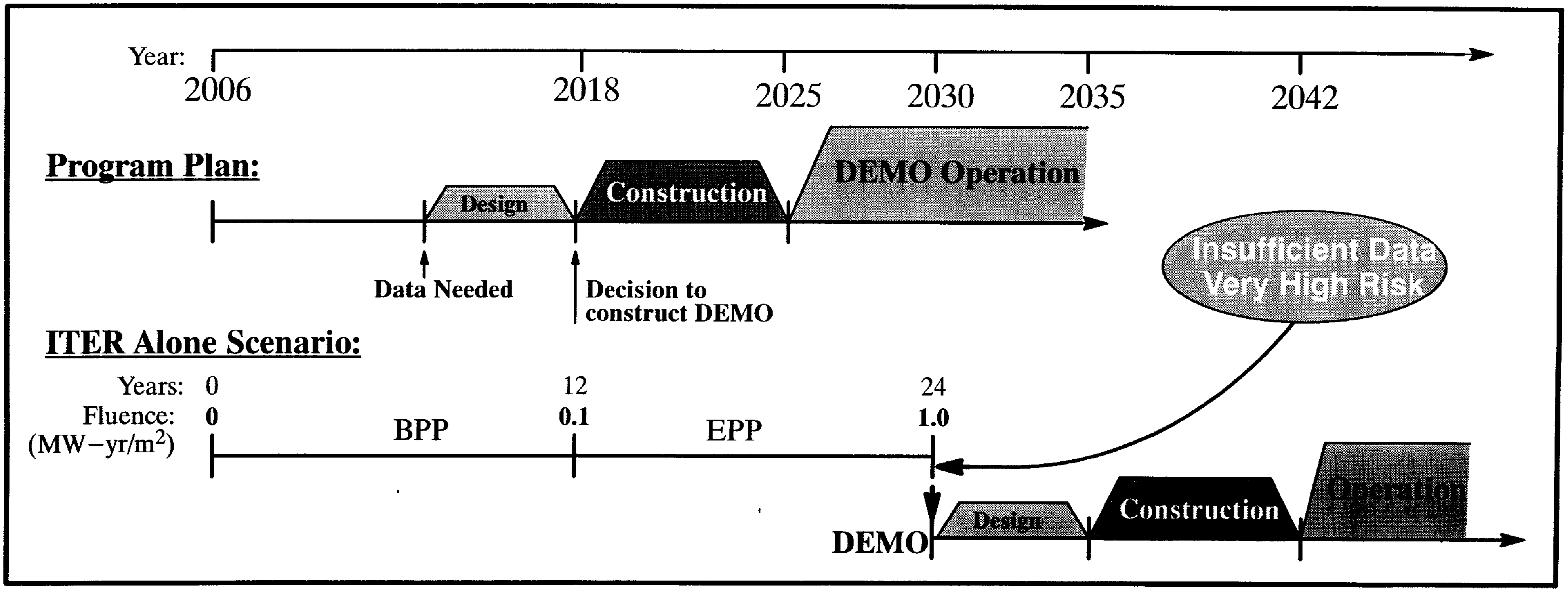
- Required Fluence > 6 MWy/m^2 • Required MTTR < 1 week

Can ITER Alone Provide Sufficient Data Base for DEMO ?

NO ! Because:

- **Pulsing Characterisitcs Not Suited to FNT Testing**
- **Fluence and Device Availability are Too Low**
- **Not Designed to Provide MTTR Data**
- **Conflict Between Physics Mission and FNT Testing Needs**



VNS IS NECESSARY

(1) To reduce the Risk to DEMO to Acceptable Levels
(2) To reduce the Technology Burden on ITER
(3) To meet the DEMO Time Schedule

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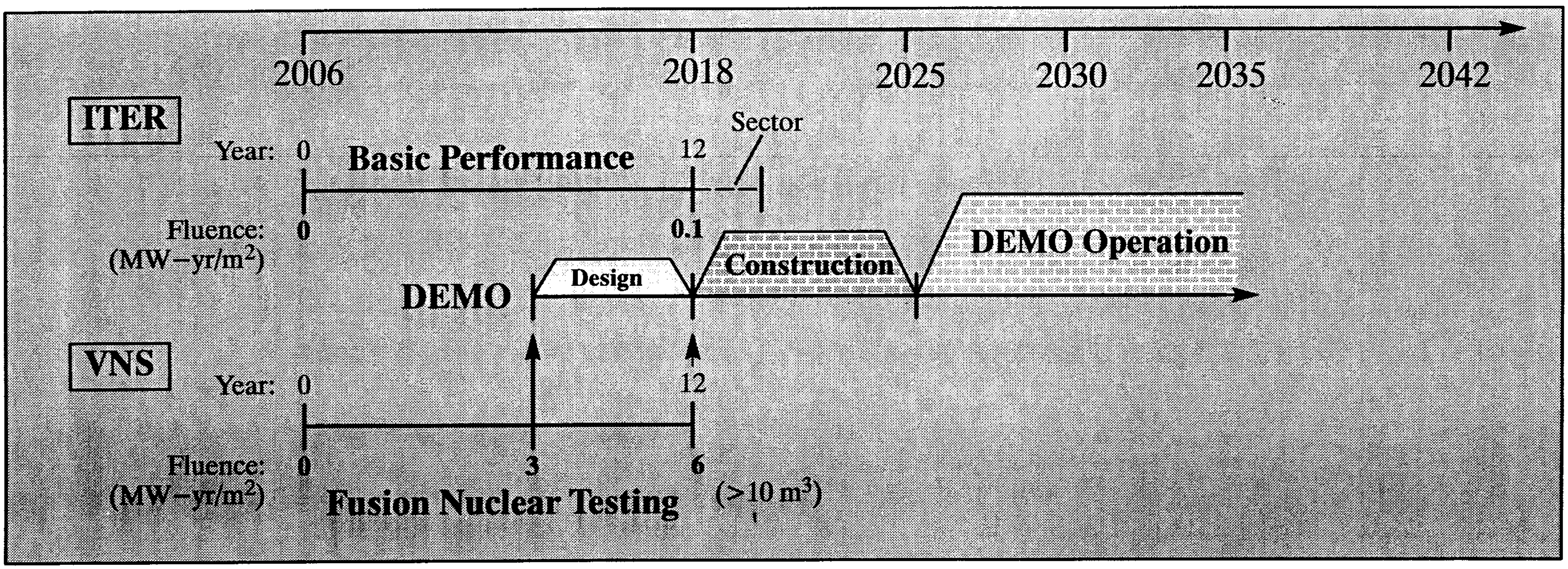
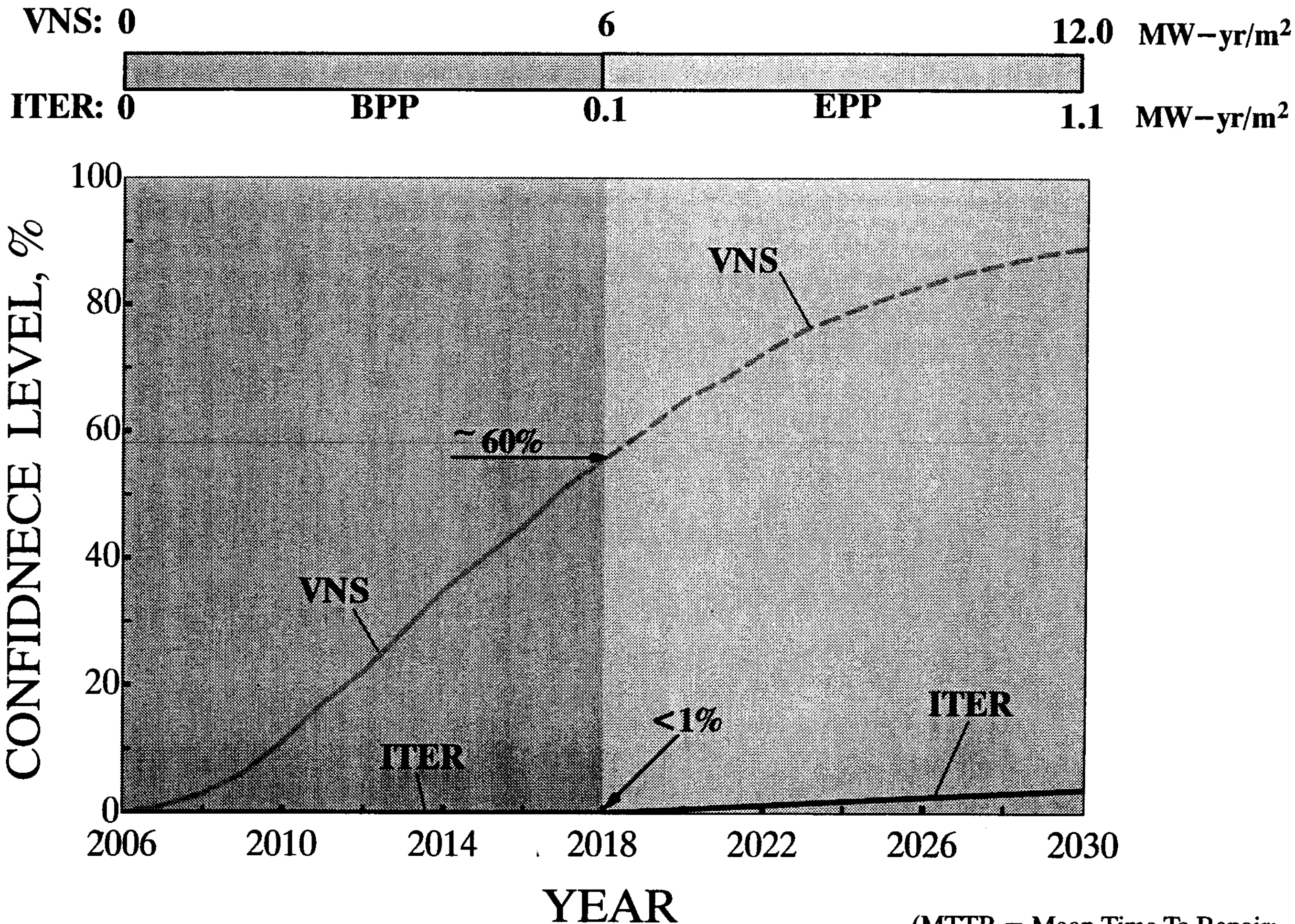
Parallel Fusion Facilities Scenario:



Confidence Level in DEMO

Obtainable with FNT Testing in VNS and ITER

(MTTR$_n$ = 1 week, MTBF$_n$ = 6.1 years)



(MTTR = Mean Time To Repair;
MTBF = Mean Time Between Failures)

Options for Tokamak VNS

	ITER	VNS		
		Super Conductor	Normal Conductor	Low A
Wall Load, MW/m^2	1	1	1-2	1-2
Inboard Shield, m	1.2	0.72	0.23	0.03
Major Radius, m	7.75	4.6	1.5-1.6	0.79-0.81
Minor Radius, m	2.8	1.05	0.6	0.6
Plasma Current, MA	24	6.4	6-7.1	9.4-10.4
Toroidal Field, T	6	7.7	4.3-5.5	2-2.4
Drive Power, MW	0	140	30-46	19-29
Fusion Power, MW	1500	360	82-172	32-65
Power Consumption, MW	400	370	540-700	130-180
First Wall Area, m^2	1300	290	62-65	30-31

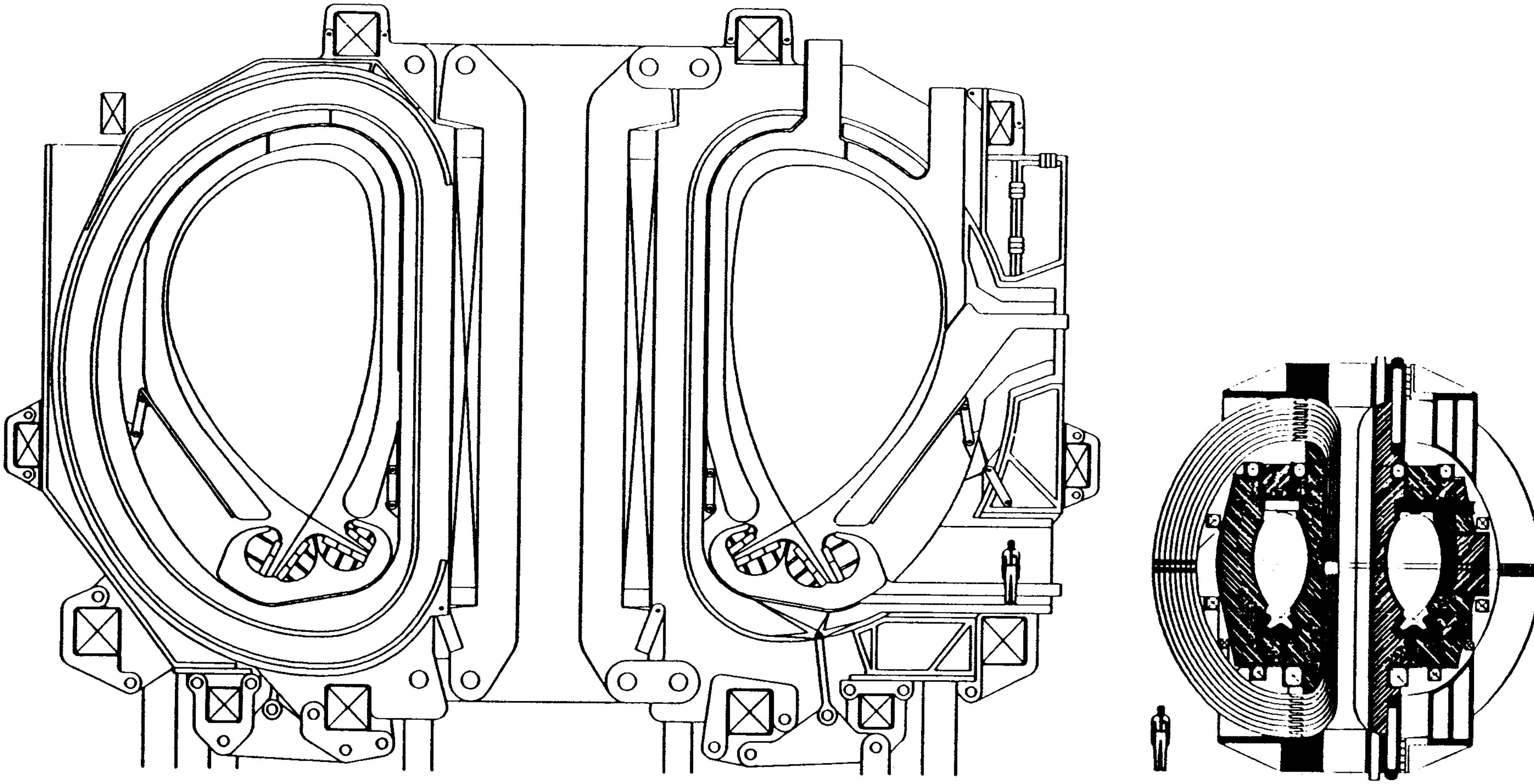


Figure 4. Elevation views for ITER [5] and a typical tokamak VNS with multi-turn normal conducting toroidal field coils (M-T N/C, Figure 1), depicted in same scale.

Comparison of Costs, Schedule and Confidence Level in DEMO for Scenarios with and without VNS

	ITER Alone (1 MW•y/m^2)	**ITER Alone** (3.3 MW•y/m^2)	**ITER (BPP) with VNS**
Capital Cost ($B)			
ITER	8	8	8
VNS	--	--	2
Operating Cost ($B)			
ITER (BPP + EPP)	4.8 + 4.8	4.8 + 4.8	4.8 + 0.0
VNS	--	--	3.0
Tritium Supply Cost ($B)			
ITER (BPP + EPP)	0.17 + 1.68	0.50 + 5.04	0.17 + 0.0
VNS	--	--	0.48
Total Cost ($B)	19.45	23.14	18.45
Confidence Level in DEMO in 2025	<1%	<10%	>70%
Year of DEMO Oper	after 2024 (??)	after 2042 (??)	2025

- **Without VNS-type device, the risk to DEMO is unacceptably high**
- **With VNS, risks to DEMO are reduced to acceptable levels**
- **Adding VNS <u>REDUCES</u> total cost to DEMO**

Increase in Expenditures in Early Years to Build VNS Parallel to ITER is Modest

- Consider Host Party X
  (Assume Host Party Pays 50%)

	Total Cost ($B)	ITER at X Site ($B)	VNS at X Site ($B)
ITER	8	4	1.33
VNS	2	0.33	1.0
IFMIF	0.8	0.13	0.13
Other	2	0.5	0.50
	12.8	5.0	3.0

- If Party X wins ITER site, VNS will add $330M over many years
- If Party X loses ITER and wins VNS, it will get Substantial Benefits at <u>lower cost</u>

Summary

- **The development of Fusion Nuclear Technology, particularly blanket is**

    - critical to realizing the promise of fusion
    - difficult: facilities, time

- **VNS is a facility to test, develop and qualify FNT Components for DEMO**

- **A Technically and Programmatically Sound World Strategy for Fusion R & D should include 3 Parallel Facilities**

    - ITER
    - VNS
    - IFMIF

- **VNS is Necessary**

    - To have reasonable confidence in successful DEMO
    - To reach DEMO in a reasonable time schedule

Summary (Cont'd)

- **Confidence in DEMO FNT Components:**

  With ITER alone : < 1%

  With VNS: > 60%

- **Adding VNS reduces total cost to DEMO**

  - Near Term Cost is not an issue if ITER and VNS are not sited in one country

- **There are attractive design options for VNS**

- **A small size (R<2m), low fusion power (~ 100 MW), driven tokamak (Q = 1-3) with steady state capabilities appears a particularly attractive option for VNS**