BLANKET MATERIAL AND ENGINEERING ISSUES AND REQUIREMENTS FOR EXPERIMENTS AND FACILITIES

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CRITERIA FOR BLANKET MATERIAL AND CONFIGURATION SELECTION

- POTENTIAL FOR ATTRACTIVE REACTOR
  - ECONOMICS
  - SAFETY
- PREDICTABILITY
  - UNDERSTANDING
  - ESTIMATES OF UNCERTAINTIES
- R&D FACTORS
  - TIME
  - COST
  - RISK

Economics Considerations (e.g.)

- Neutron Wall Load
- Surface Heat Load
- Power Conversion Efficiency
- Material Cost
- Fabrication Cost
- Reliability
- Failure Rate
- Maintenance/Replacement Time

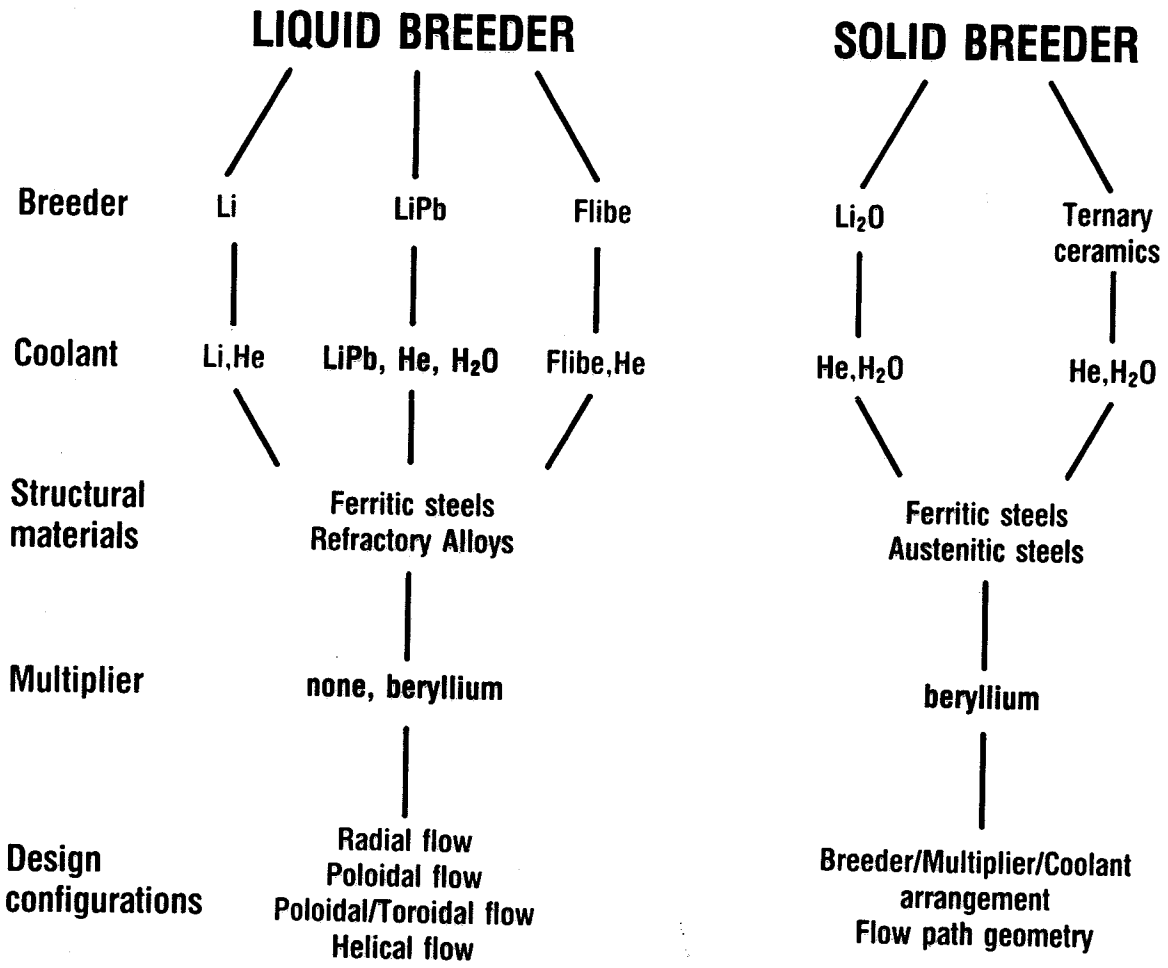
Safety Considerations (e.g.)

- Afterheat
- Short Term Activation
- Long Term Activation
- Chemical Reactivity

Representative Goal Ranges Considered in this Work
for Commerical Reactor Parameters

Parameter	Range
Neutron Wall Load, MW/m^2	4-6
Surface Heat Flux at First Wall, MW/m^2	0.2-1
Average Heat Flux in High Heat Flux Components (e.g., limiter/divertor), MW/m^2	5-10
Plasma Burn Time	very long/continuous
Magnetic Field Strength in Blanket Region, T	5-7
Reactor Availability, %	80
First Wall/Blanket Lifetime Fluence, $MW \cdot y/m^2$	15-20

Primary Options
For Blanket Materials and Configurations



—Further experimental work is required prior to selection.

What Have We Learned From Blanket Design Studies?

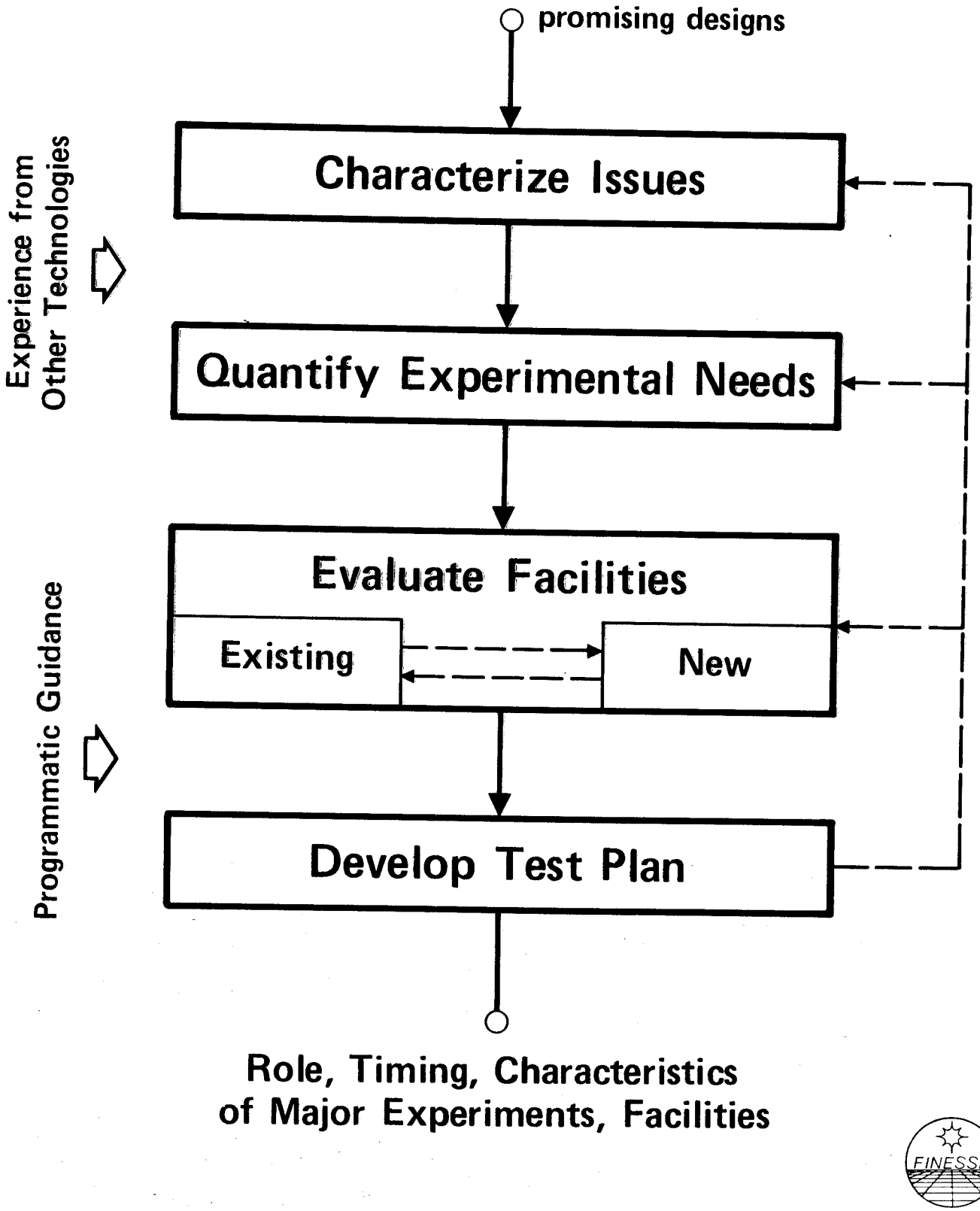
- Present Uncertainties Are Too Large To Permit Selection Of Only One Option
- Substantial Experimental Data Needed Before Selection

Problem of R&D Cost

- R&D Cost Is Greatly Affected By Number Of Options Pursued
- Similar Problems For Many Fusion Nuclear Components
- Need Carefully Planned Experiments

How Do We Plan An Effective Experimental Program?

FINESSE PROCESS For Experiment Planning



Generic Liquid Metal Blanket Issues

- Tritium Self-sufficency
- Magnetohydrodynamic (MHD) Effects
  —Fluid Flow (including pressure drop)
  —Heat Transfer
- Material Interactions (e.g., Corrosion)
- Structural Response in the Fusion Environment
  —Irradiation Effects on Material Properties
  —Response to Complex Loading Conditions
  —Failure Modes
- Tritium Recovery and Control

Effect of Coolant, Breeder and Structural Material Choices on Dominant Issues for Liquid Breeder Blankets

Liquid Metal Cooling	
Li or 17Li-83Pb	MHD effects (including viability of insulators)
	corrosion (including viability of inhibitors)
Coolant or Breeder	
Lithium	chemical reactivity
17Li-83Pb	tritium containment
Flibe	tritium containment
Helium	tritium containment
Structural Material	
Vanadium alloys	bimetallic mass transfer
	DBTT[a] (due to impurities, radiation, H, He)
Ferritic alloys	DBTT

[1]Ductile-to-Brittle Transition Temperature

UNCERTAINTIES IN LIQUID METAL CORROSION

- New Materials

  The Basic Materials Interactions are Poorly Understood and Poorly Quantified

- Unique Environment

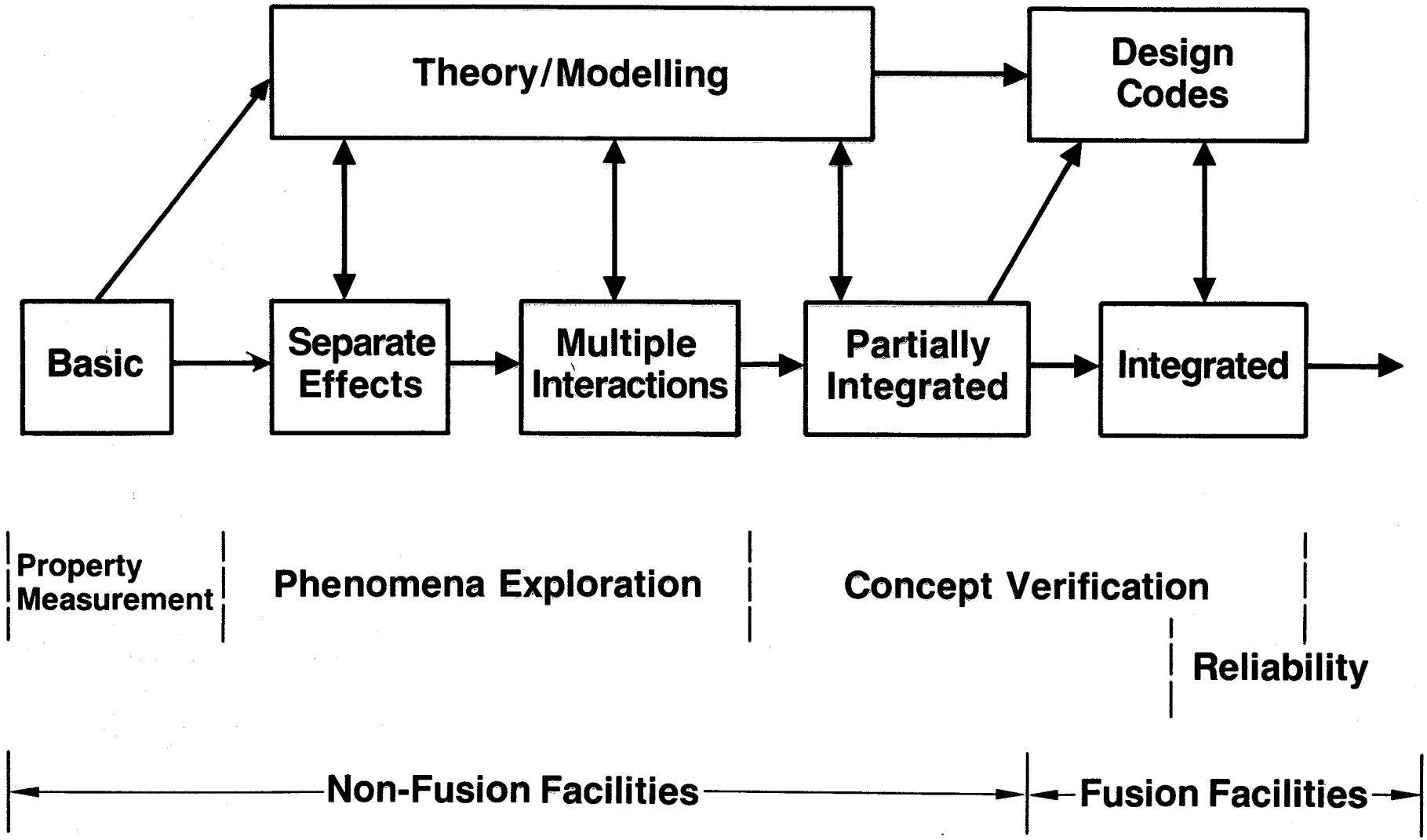
  MHD Effects (Coupled Heat, Mass, and Momentum Transport)

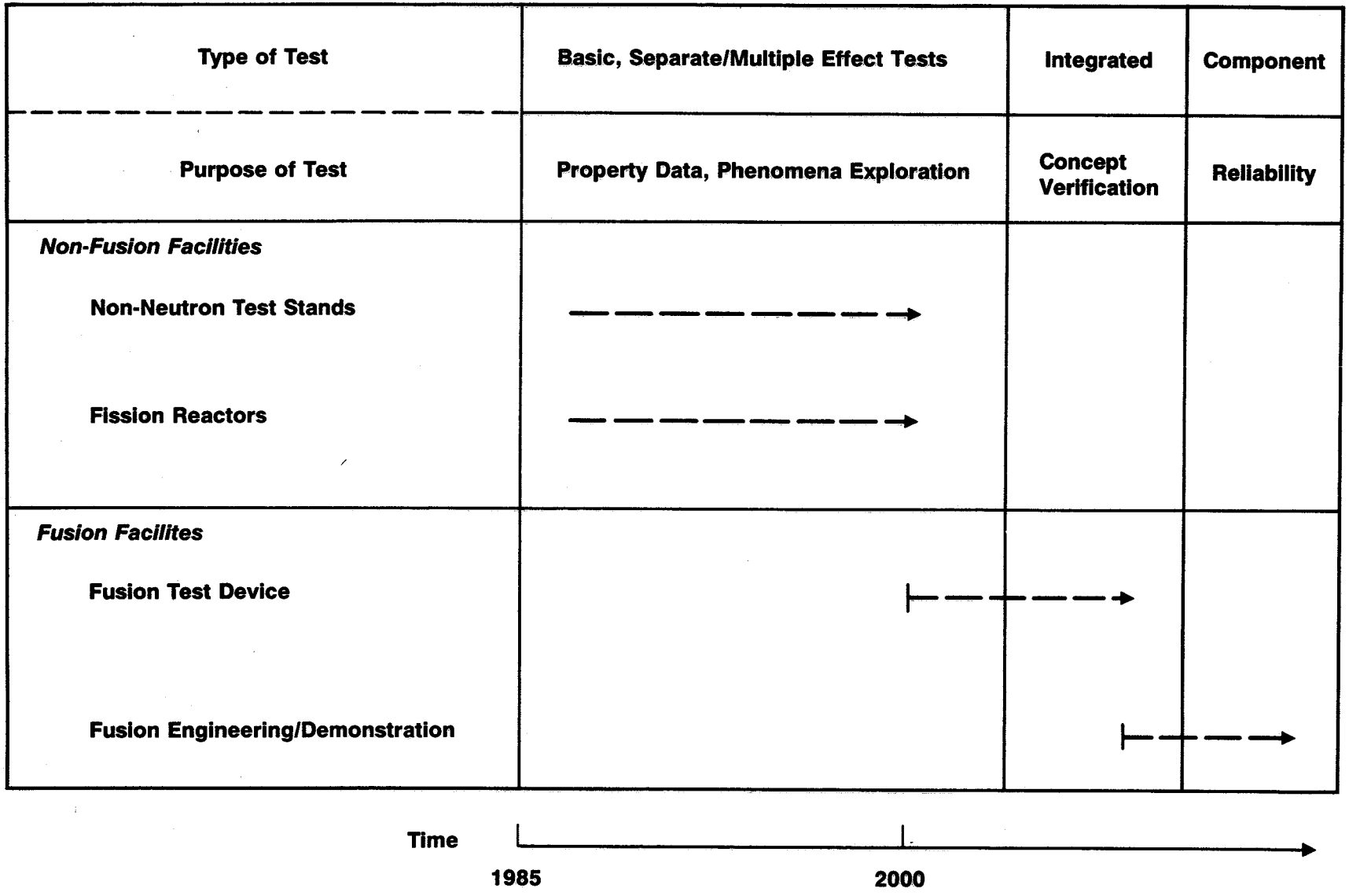
  Loop Effects

  Irradiation Effects

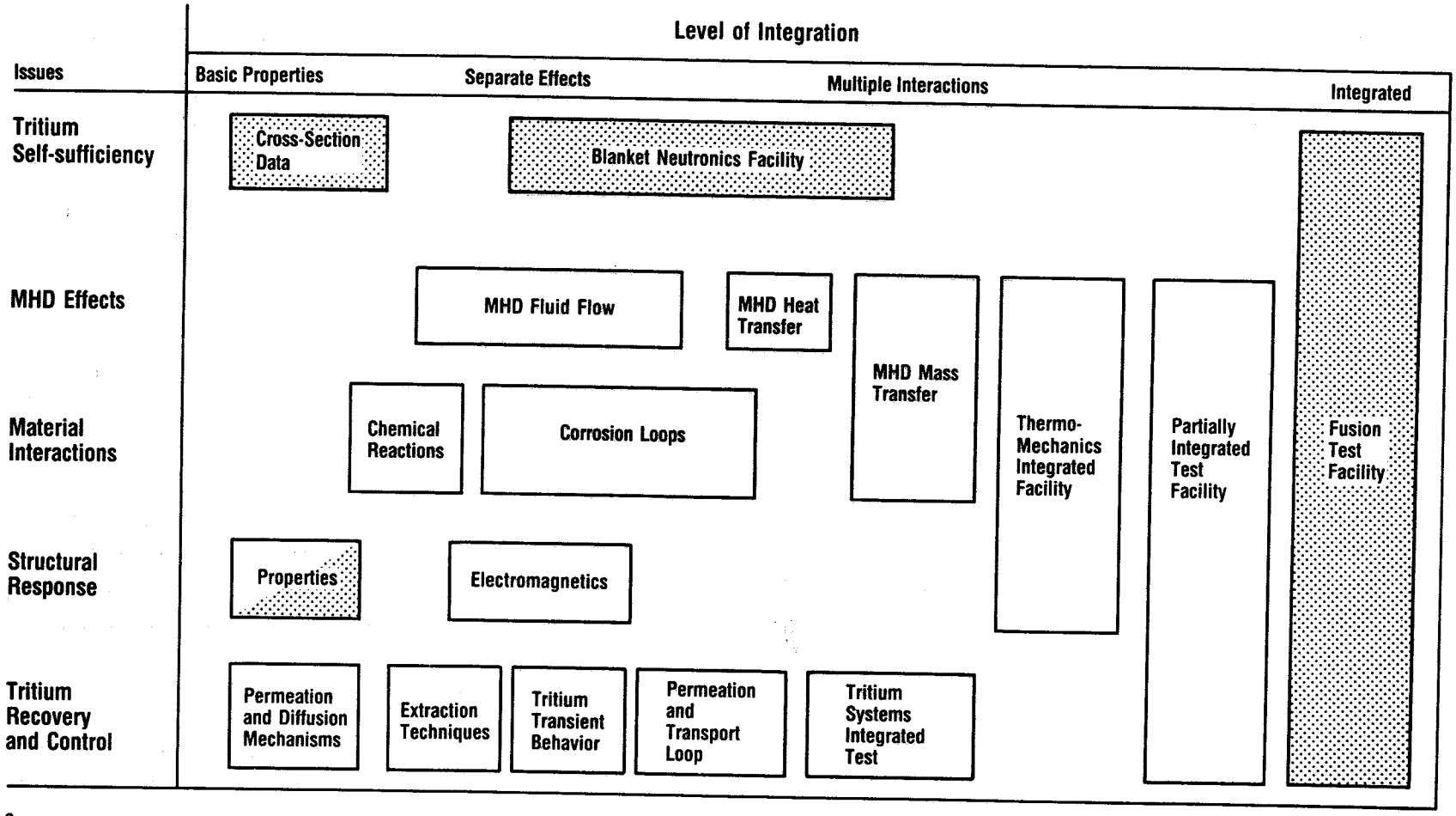
Generic Solid Breeder Blanket Issues

- Tritium Self-sufficiency
  —Achievable Breeding Ratio
  —Required Breeding Ratio
- Breeder/multiplier Tritium Inventory and Recovery
- Breeder/multiplier Thermomechanical Behavior
- Corrosion and Mass Transfer
- Structural Response and Failure Modes in Fusion Environment
- Tritium Permeation and Processing from Blanket


Theory/Modelling
Design Codes
Basic
Separate Effects
Multiple Interactions
Partially Integrated
Integrated
Property Measurement
Phenomena Exploration
Concept Verification
Reliability
Non-Fusion Facilities
Fusion Facilities


Type of Test
Basic, Separate/Multiple Effect Tests
Integrated
Component
Purpose of Test
Property Data, Phenomena Exploration
Concept Verification
Reliability
Non-Fusion Facilities
Non-Neutron Test Stands
Fission Reactors
Fusion Facilites
Fusion Test Device
Fusion Engineering/Demonstration
Time
1985
2000

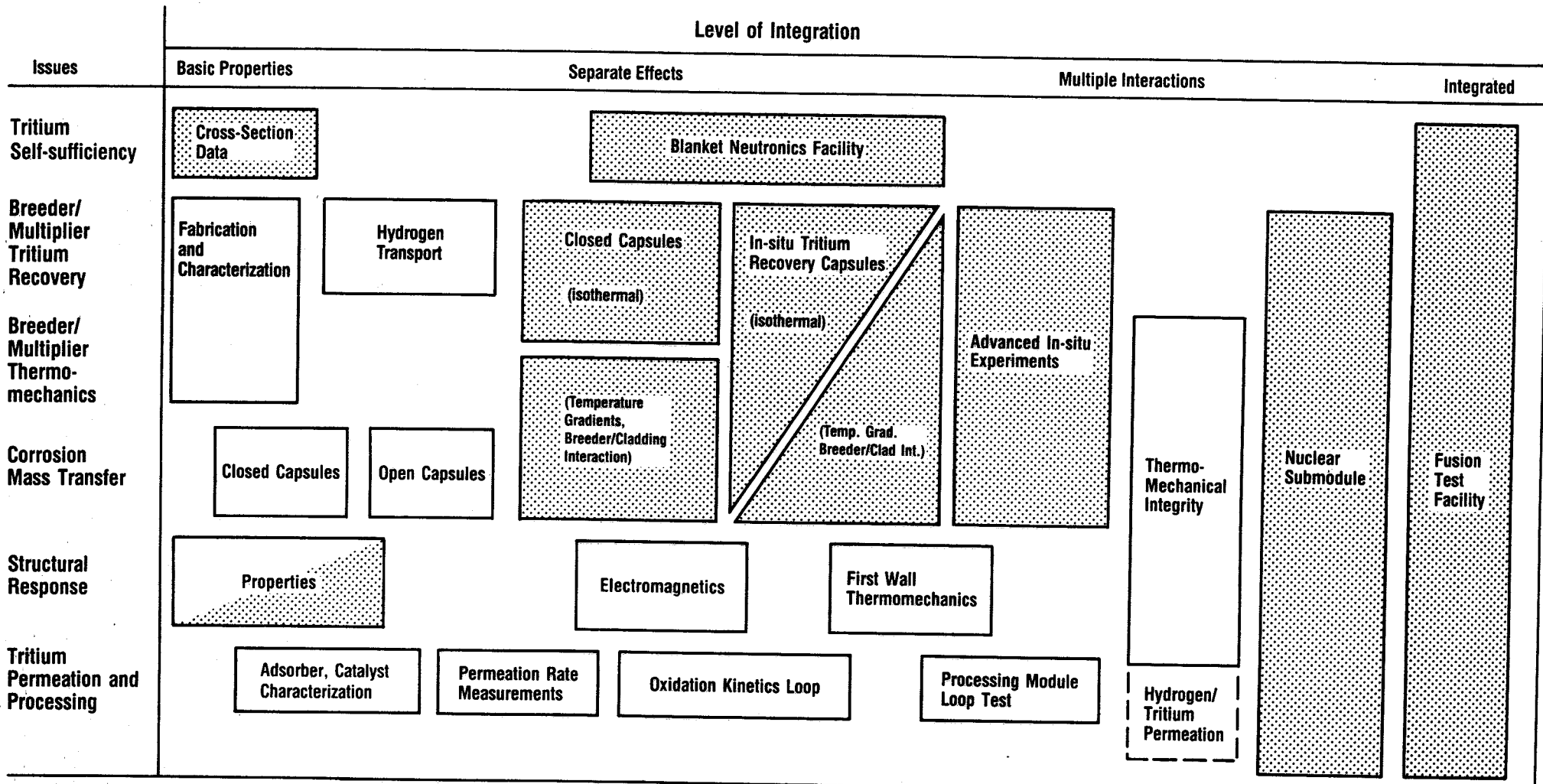
TYPES OF EXPERIMENTS AND FACILITIES FOR LIQUID METAL BLANKETS[a]



[a] Some experiments or facilities already exist

Neutron test.

TYPES OF EXPERIMENTS AND FACILITIES FOR SOLID BREEDER BLANKETS[a]

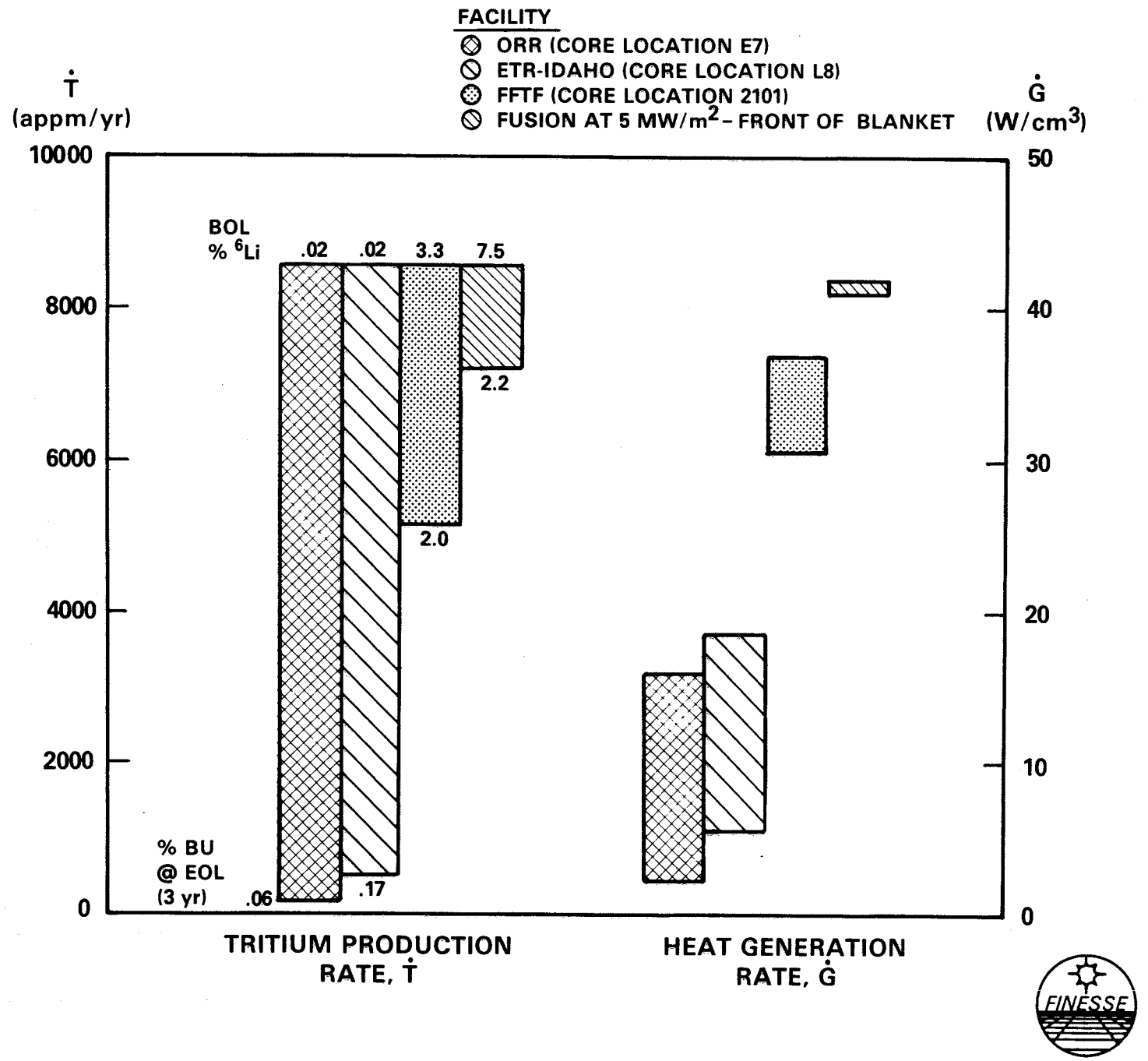


[a] Some Experiments and Facilities Exist

Neutron Test

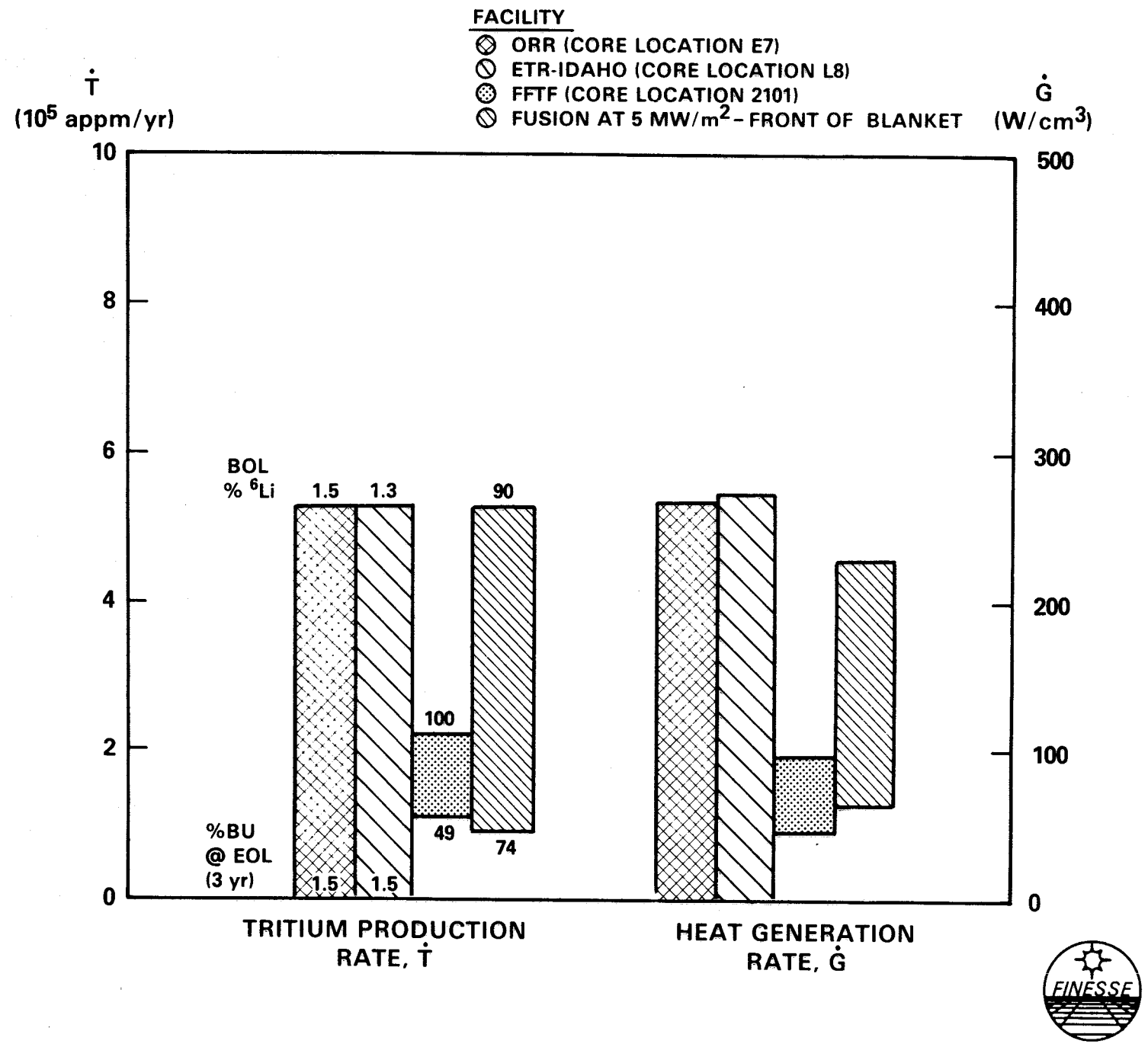
FISSION/FUSION IRRADIATION COMPARISON FOR Li_2O/He/HT-9 SYSTEM

Li_2O SOLID BREEDER

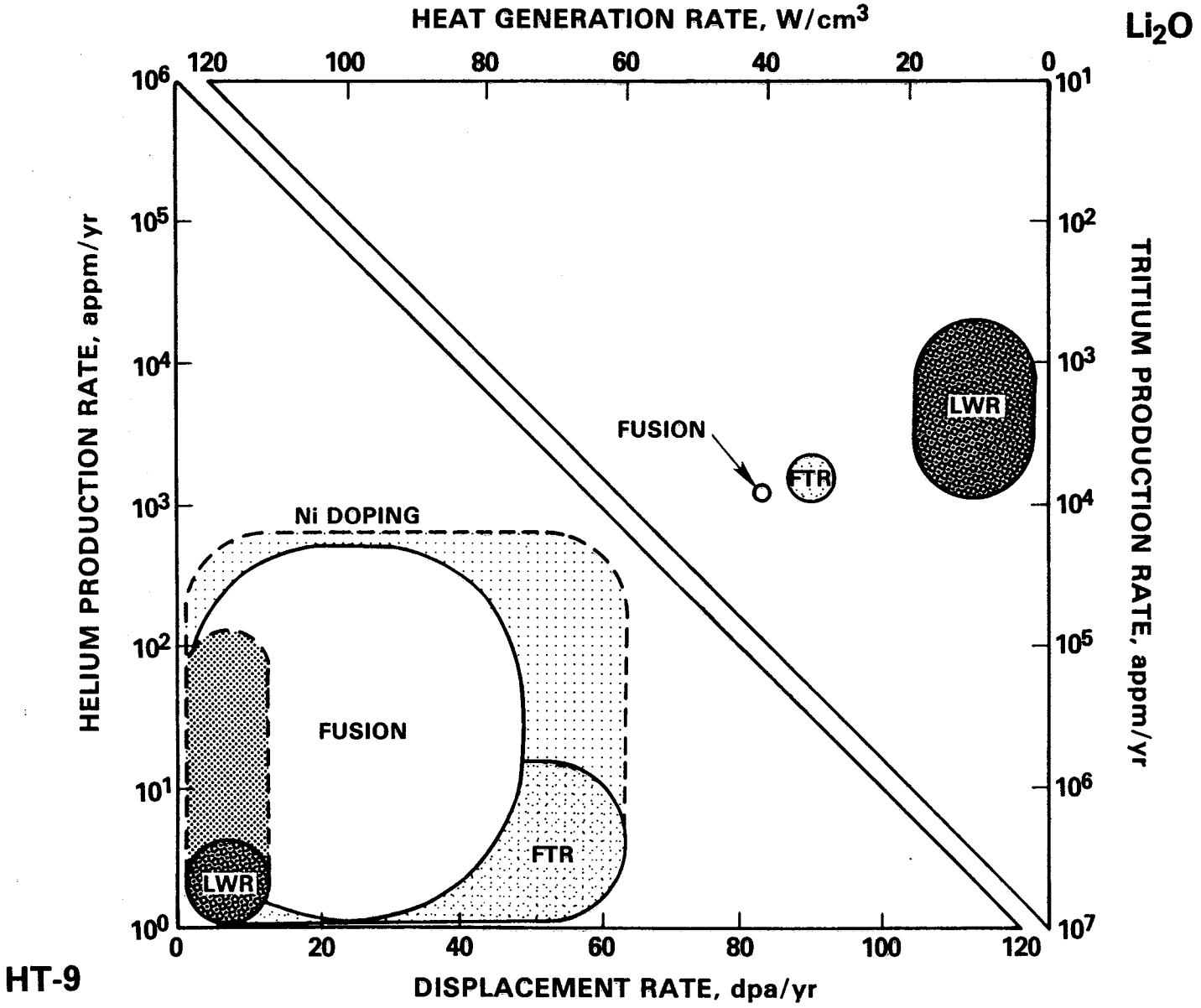


FISSION/FUSION IRRADIATION COMPARISON FOR $LiAlO_2/H_2O$/HT-9/Be SYSTEM

$LiAlO_2$ SOLID BREEDER



FISSION/FUSION REACTOR COMPARISON OF Li_2O/He/HT-9 SYSTEM



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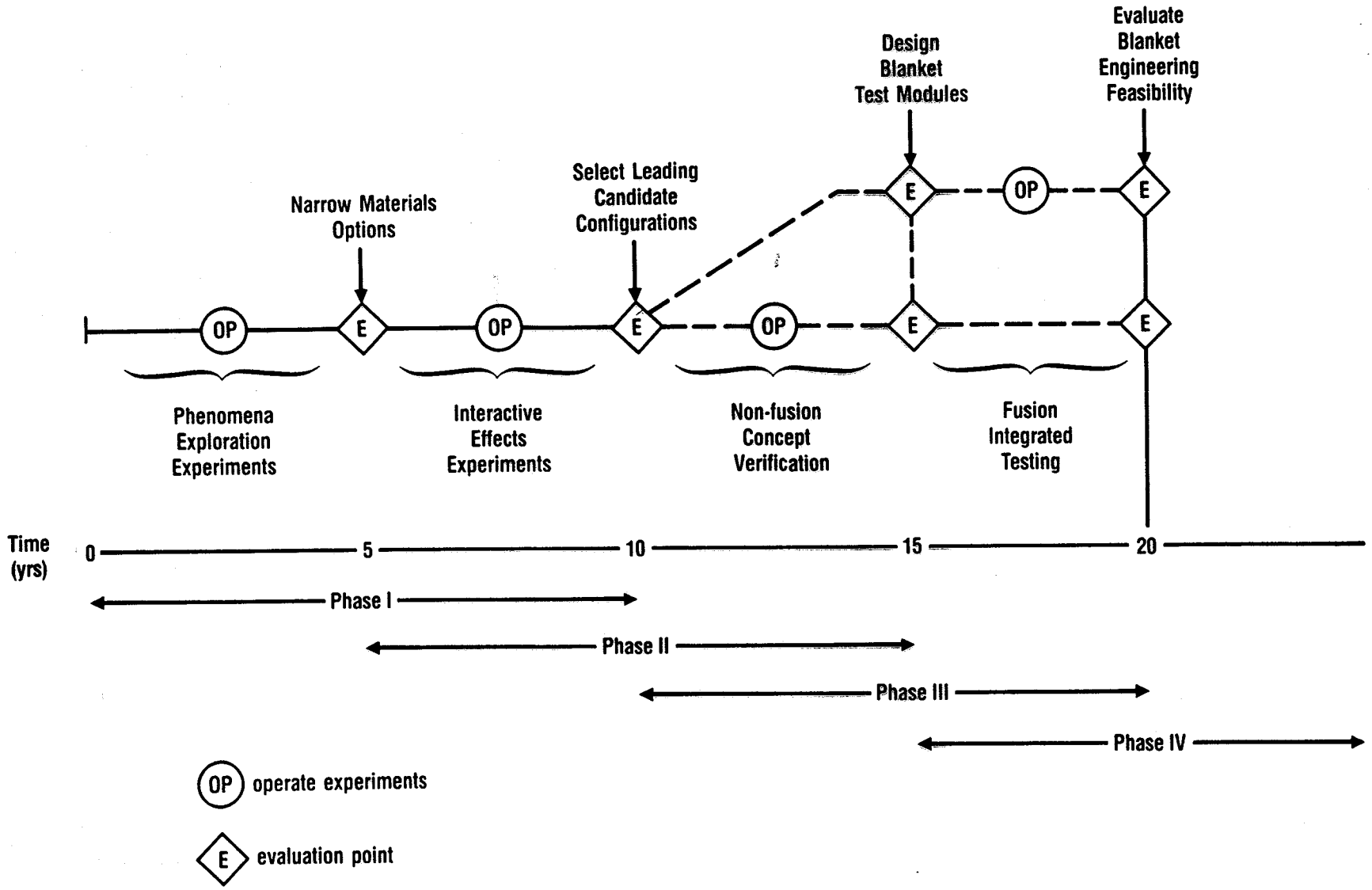


Figure 2-2. Overall objectives and phases of blanket test plan

Major Tasks for Liquid Breeder Blankets

- MHD Effects
  —Momentum and Heat Transfer Facilities (LMF1, LMF2)
  —Instrumentation Development
  —Insulator Development

- Material Compatibility
  —Corrosion Loops
  —MHD Mass Transfer Facility (MHDM)

- Tritium Recovery and Control
  —Tritium Extraction Tests
  —Tritium Transport Loop

- Tritium Breeding

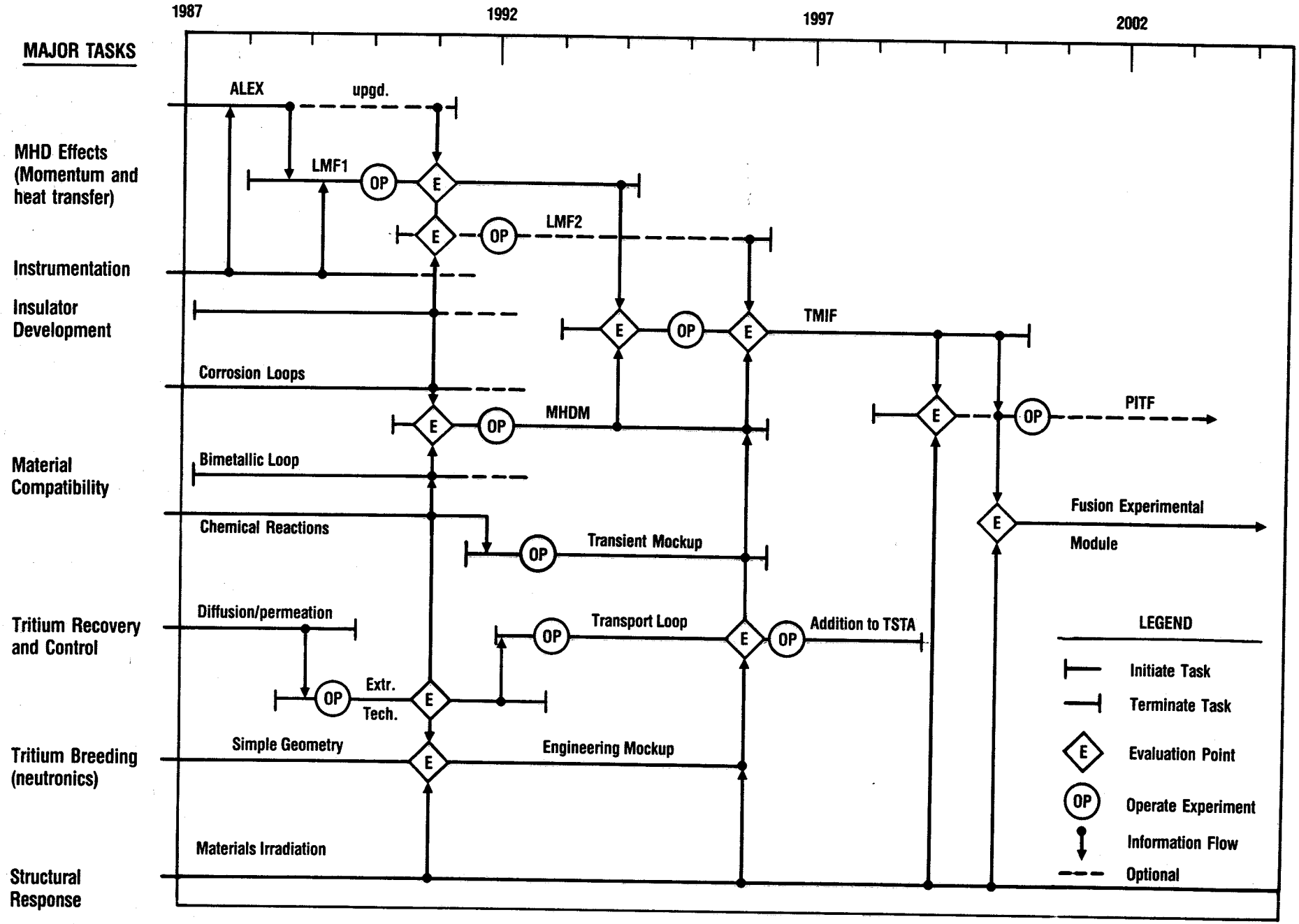
- Structural Response and Failure Modes

- Thermomechanics Integration Facility (TMIF)

- Partially Integrated Test Facility (PITF)

- Analysis and Model Development

LIQUID BREEDER BLANKET TEST PLAN



Major Tasks for Solid Breeder Blankets

- Solid breeder material development and characterization
  - —Tritium retention and release
  - —Thermophysical and thermomechanical properties
  - —Fabrication and recycling techniques.

- Multiplier material development and characterization
  - —Swelling in beryllium
  - —Tritium retention and release.
  - —Irradiation creep and mechanical properties

- Blanket thermal behavior
  - —Corrosion, mass transfer and chemical interaction kinetics
  - —Breeder/multiplier temperature profile and thermomechanical effects of breeder/cladding interaction
  - —Non-neutron blanket (sub)module thermomechanical integrity

- Neutronics and tritium breeding
  - —Simple geometry mockups
  - —Engineering mockups

- Advanced in-situ tritium recovery
  - —Two or more instrumented and purged assemblies with multiple capsules

- Nuclear submodule experiments
  - —Two or more nuclear submodule assemblies

Table 2-7. Parameters for Major Integrated Non-fusion Irradiation Experiments

	Advanced In-situ Tritium Recovery	Nuclear Submodule
Test geometry	Subassembly with multiple capsules	Blanket breeder section or unit cell
Material	Multiple	One per submodule
Temperature, °C	350-1200°C	Reactor blanket profile
Temperature gradients, °C/cm	100-1000	100-1000
Breeder thickness, cm	0.5-5	0.5-5
Purge gas	Helium, plus O_2, H_2 and/or H_2O	Helium, plus O_2, H_2 and/or H_2O
Purge flow rate, $m^3/s\text{-}g^a$	0.01-0.1	0.01-0.1
Burnup, at.% Li	3-10	3-10
Heat generation, MW/m^3	30-100	30-100
Irradiation time, yrs	1-3	1-3
Tritium production, T/Li-yr	0.01-0.5	0.01-0.5

[a]Normalized per gram of solid breeder material

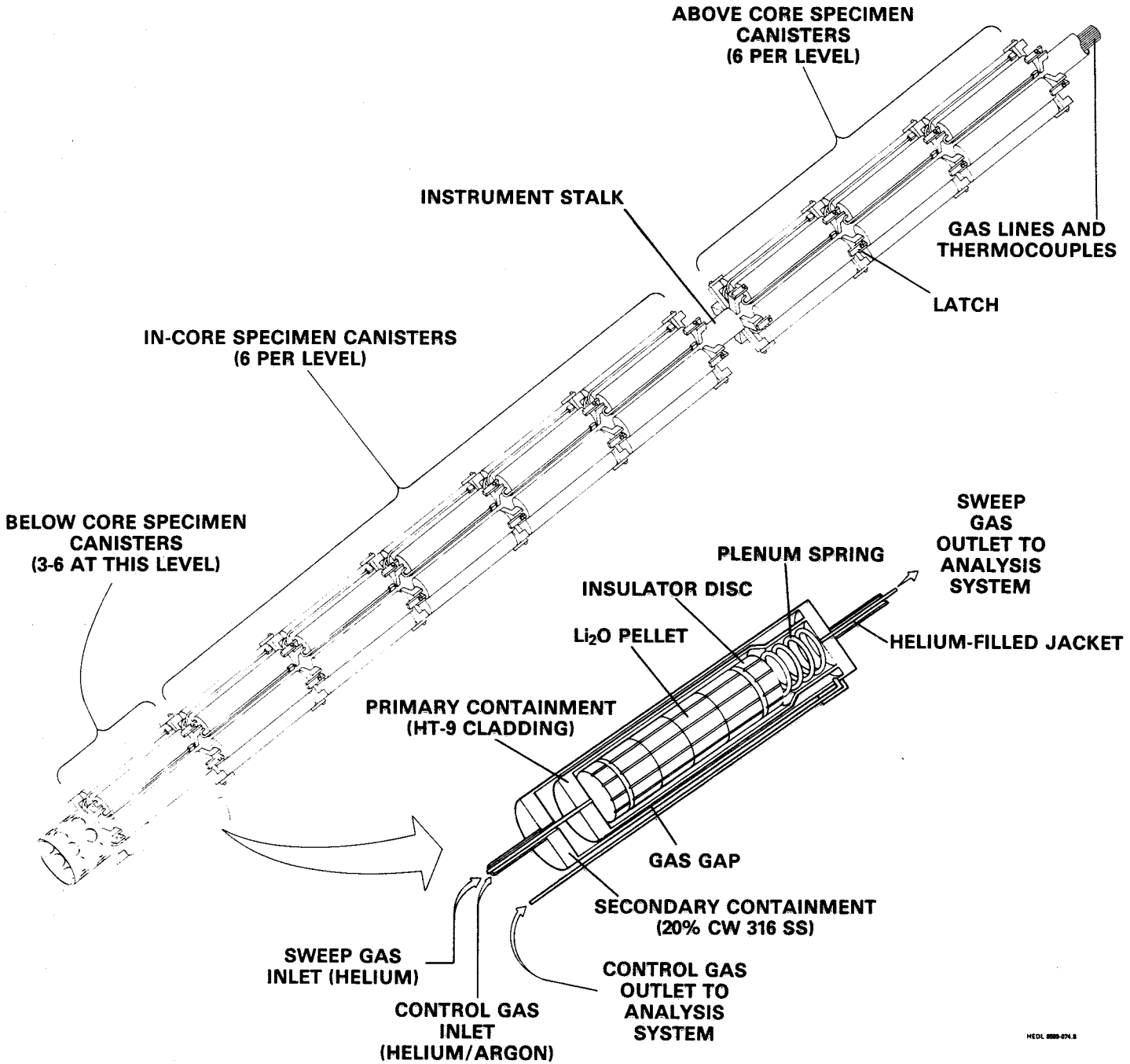


Figure 2-4. Representative advanced in-situ tritium recovery test assembly showing expanded view of a purged capsule

SOLID BREEDER BLANKET TEST PLAN