SUMMARY OF TPA TECHNOLOGY
(PHASE I AND II)

PRESENTED TO MFAC PANEL XV

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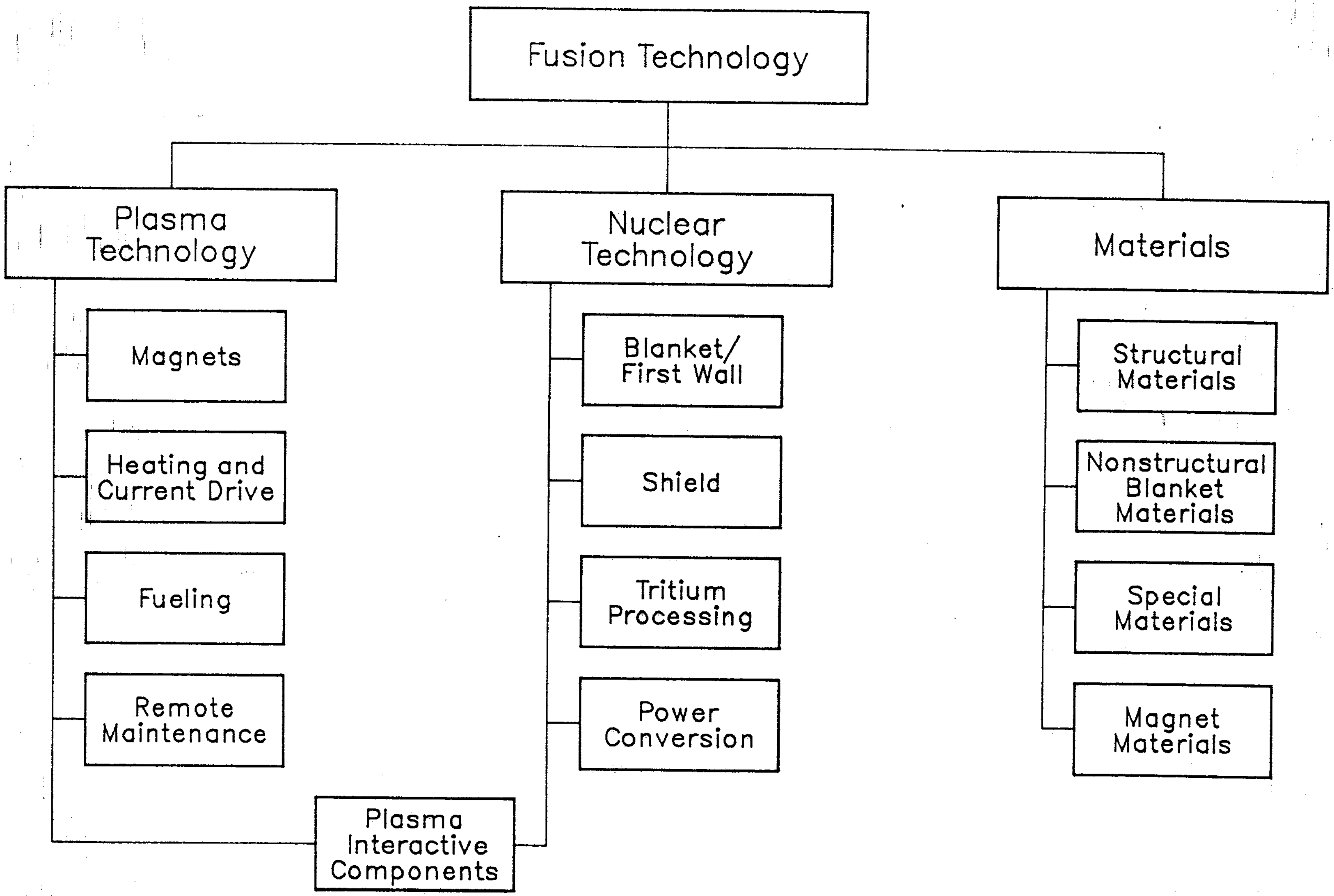
13 MAY 1986

OUTLINE

- ORGANIZATIONAL STRUCTURE
  (AND OTHER OBSERVATIONS)
- METHODOLOGY
- SUMMARY OF PHASE I: ISSUES & OBJECTIVES
- SUMMARY OF PHASE II: LOGIC DIAGRAMS
- PLANS FOR PHASE III


Fusion Technology
Plasma Technology
Nuclear Technology
Materials
Magnets
Heating and Current Drive
Fueling
Remote Maintenance
Plasma Interactive Components
Blanket/ First Wall
Shield
Tritium Processing
Power Conversion
Structural Materials
Nonstructural Blanket Materials
Special Materials
Magnet Materials

TPA TECHNOLOGY STEERING COMMITTEE

Mohamed A. Abdou, UCLA	(Chairman)
Richard F. Mattas, ANL	(Tech. Assistant to Chairman)
Lee A. Berry, ORNL	(Leader, Plasma Technology)
Dale L. Smith, ANL	(Leader, Materials)
John A. Bartlit, LANL	(Tritium)
Walter Bauer, SNLL	(PMI Interface)
David H. Berwald, Grumman	(Nuclear Technology)
James G. Crocker, EG&G	(Safety, System Interface)
Wilhelm B. Gauster, SNL	(PIC)
Carl D. Henning, LLNL	(Magnets)
John A. Schmidt, PPPL	(PIC)
Kenneth R. Schultz, GA	(Shield)
Herbert H. Woodson, UT, Austin	
Herbert Yoshikawa, HEDL	(Materials)

NOTES ON TPA TECHNOLOGY ORGANIZATIONAL STRUCTURE

- TPA Technology Steering Committee (TSC) members have collectively been responsible for the key aspects of the plan

- Three major areas have been led on a day-to-day basis as follows:

  - Plasma Technology: Lee Berry
  - Materials: Dale Smith
  - Nuclear Technology: Mohamed Abdou

- For each component, work has been performed by a Core Group of Technical Experts. Each group has been led by one or more TSC member.

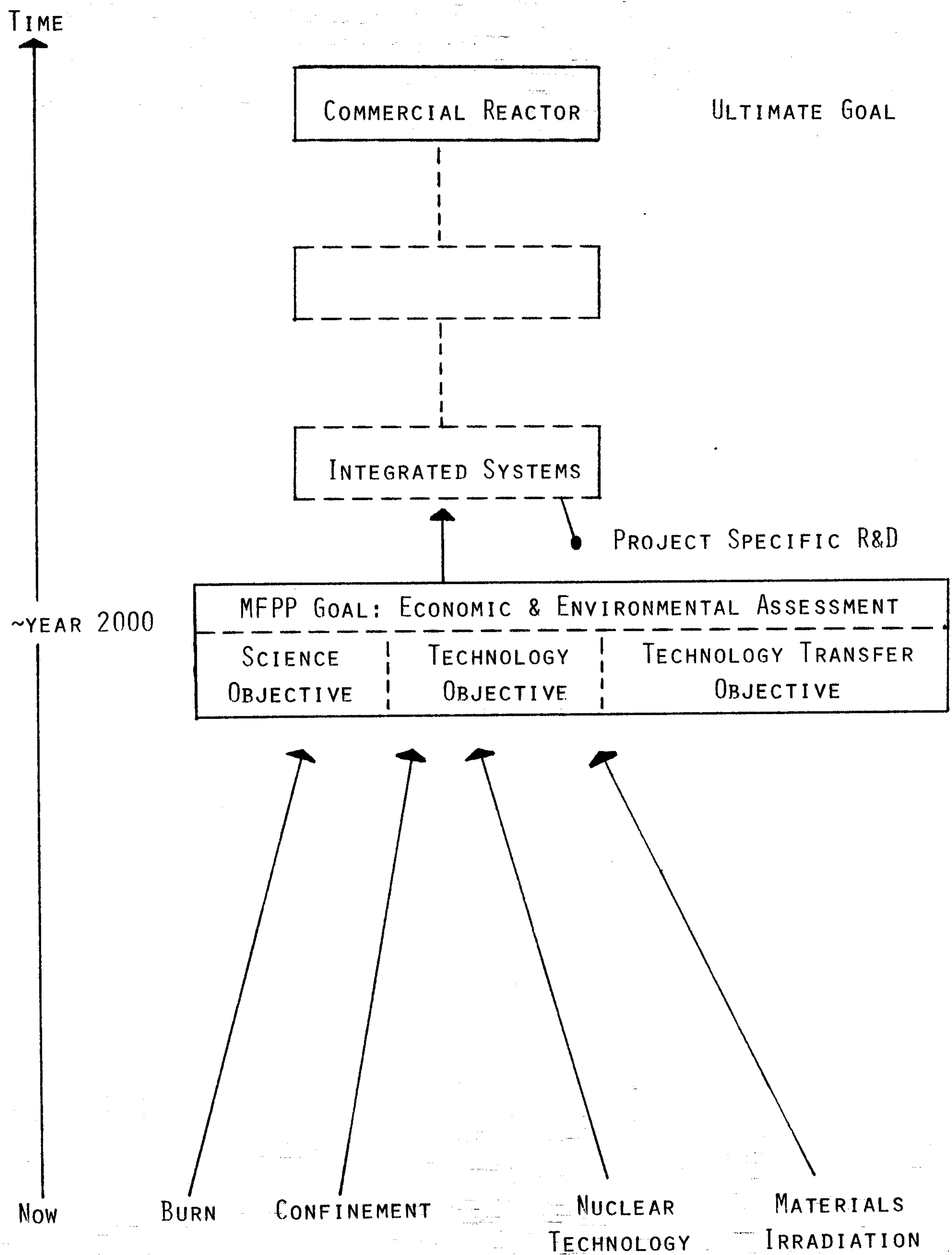
SOURCES OF INFORMATION AND COMMUNITY INVOLVEMENT

- A RELATIVELY LARGE NUMBER OF LEADING EXPERTS COVERING ALL TECHNICAL AREAS HAVE BEEN INVOLVED DIRECTLY IN TPA TECHNOLOGY.

- OTHER EXPERTS IN THE COMMUNITY HAVE BEEN CONSULTED. SPECIAL MEETINGS WERE HELD TO ADDRESS IMPORTANT TOPICS.

- INPUT FROM EXISTING PROJECTS, STUDIES, TASK GROUPS, ETC.
  - EXAMPLE: EXTENSIVE UTILIZATION OF FINESSE RESULTS FOR NUCLEAR TECHNOLOGY

FRAMEWORK (ONLY FOR ILLUSTRATION)



METHODOLOGY

- Benefits of Structured Methodology

- Considered a Methodology based on two parts:

  A) "FINESSE Type" Process for Developing Alternative Pathways

  B) "Analytic-Decision Making" Process for Comparing Alternative Pathways

- Such methodology requires considerable resources

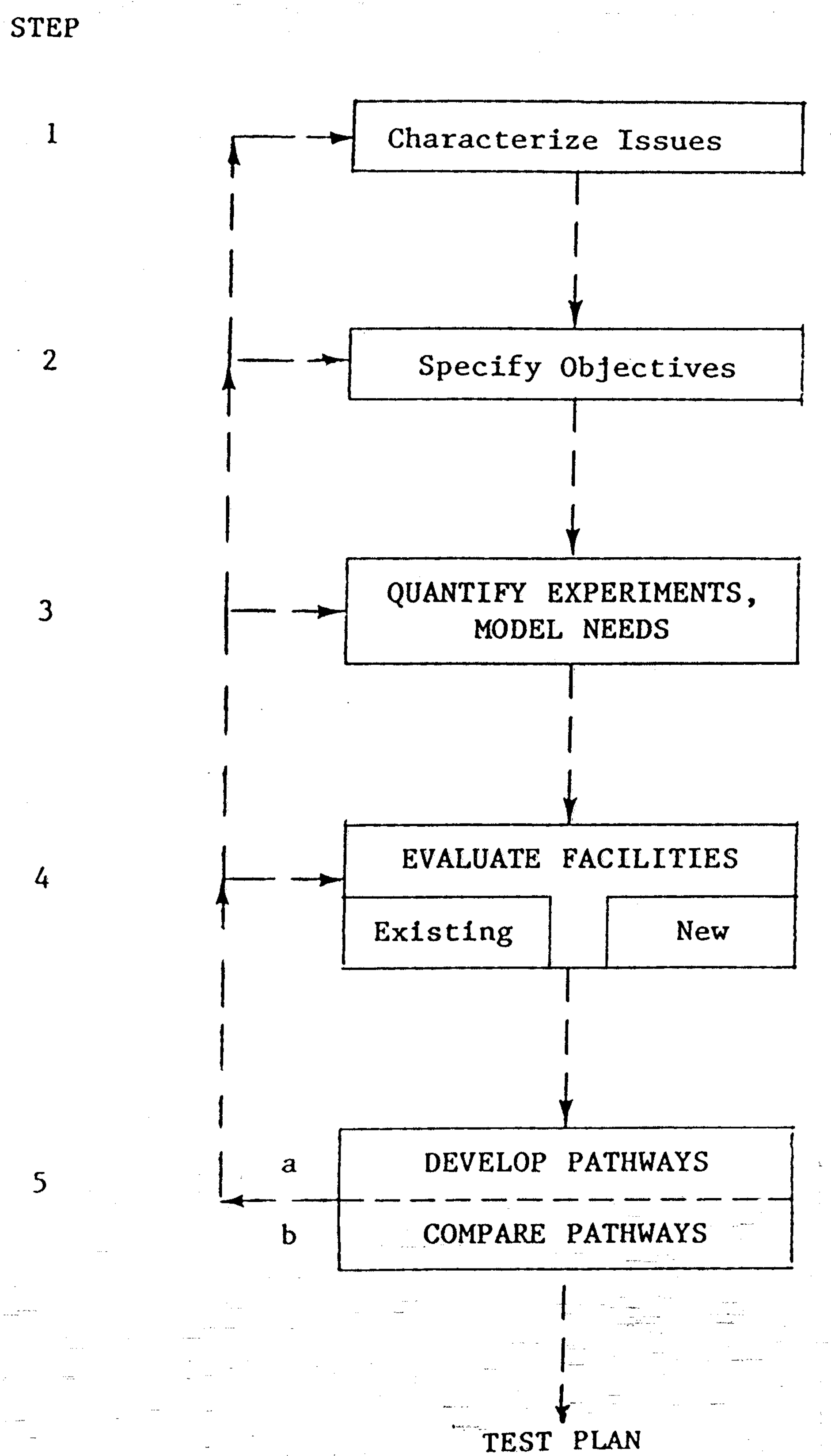
  - The degree to which Part A has been developed depends on component

  - Part B has not been formally addressed

- Major Complexity in Planning

  Dynamic Vs. Static Plan

TPA TECHNOLOGY METHODOLOGY STEPS



EXAMPLES OF ISSUES

ISSUE CHARACTERIZATION ITEMS IN TECHNOLOGY REPORT

1. DESCRIPTION

2. POTENTIAL IMPACT ON DESIGN

   - FEASIBILITY

   - ATTRACTIVENESS

3. DESIGN SPECIFITY

   HOW GENERIC/SPECIFIC RELATIVE TO

   - CLASS OF DESIGNS

   - TECHNOLOGY COMPONENT

   - CONFINEMENT CONCEPTS

4. OVERALL LEVEL OF CONCERN

   OVERALL IMPORTANCE TO FUSION

   COMPOSITE: BASED ON 2, 3 AND OTHER FACTORS

PRIMARY ISSUES FOR MATERIALS

- Radiation Effects on Materials Properties
  - Mechanical
  - Thermophysical
  - Thermochemical
  - Others
- Baseline (Unirradiated) Properties
  - Necessary for Scoping Prior to Irradiation
- Fabrication/Joining

PRIMARY ISSUES FOR BLANKET

Liquid Metal

- MHD Effects
- Compatibility
- Irradiation Effects
  Structure

Solid Breeder

- Tritium Recovery, Inventory
- Thermomechanical Interactions
- Irradiation Effects
  Structure/Breeder/M

- Fuel Self Sufficiency
- Tritium Extraction, Control
- Failure Modes and Effects

PRIMARY ISSUES FOR PLASMA INTERACTIVE COMPONENTS (PIC)

- Particle Exhaust, Recycling
- Erosion/Redeposition
- Energy Removal/Recovery
- Thermomechanical Loading and Response
- Radiation Effects
- Tritium Permeation and Inventory
- Fabrication

EXAMPLES OF OBJECTIVES

OBJECTIVE

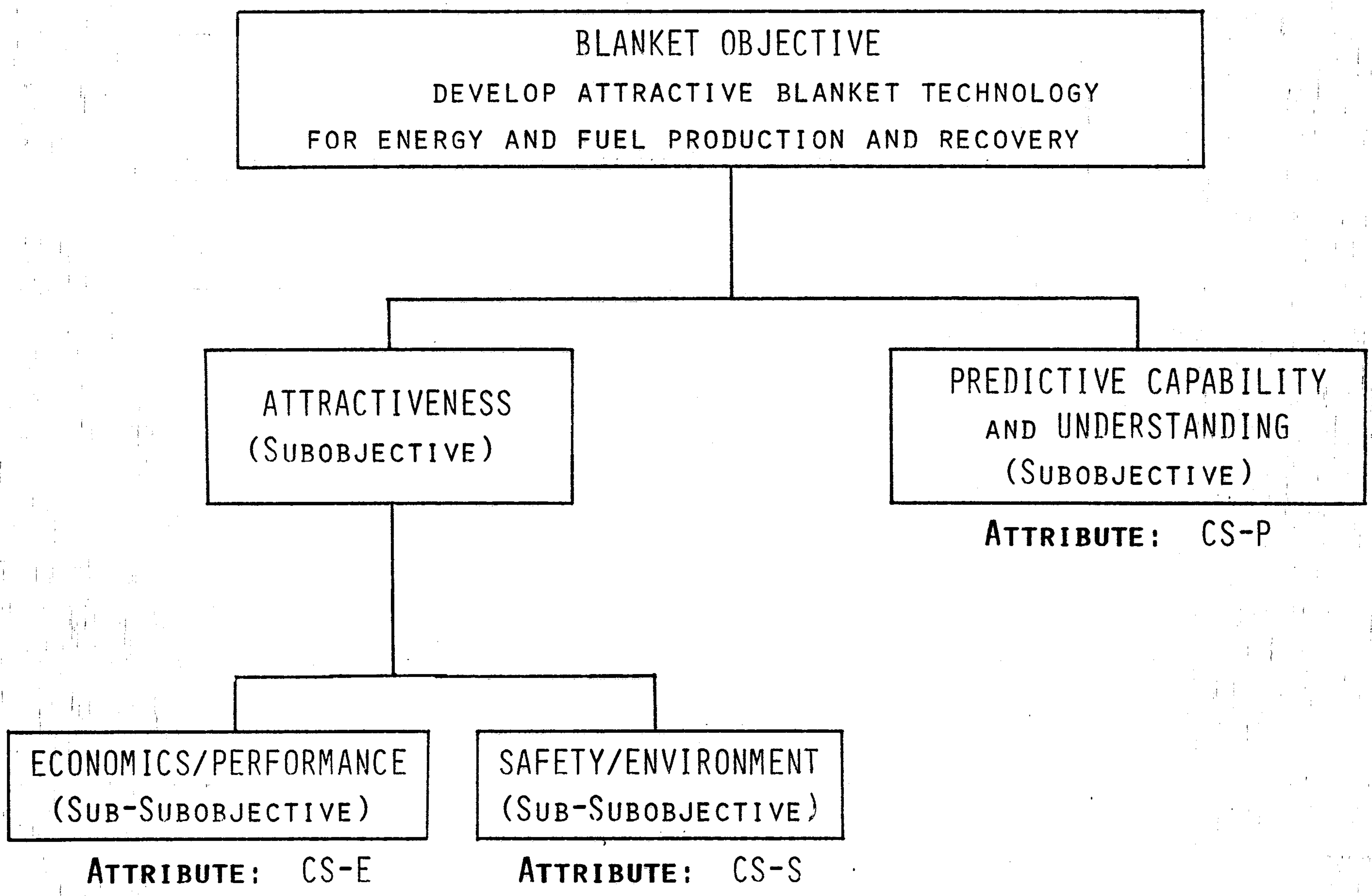
- Identifies what must be achieved and a direction for achievement

ATTRIBUTE

- A specific or quantifiable parameter to indicate the degree to which its associated objective is met

- Variety of Measurement Scales

  Natural, Proxy, or Constructed


BLANKET OBJECTIVE
DEVELOP ATTRACTIVE BLANKET TECHNOLOGY
FOR ENERGY AND FUEL PRODUCTION AND RECOVERY
ATTRACTIVENESS
(SUBOBJECTIVE)
PREDICTIVE CAPABILITY
AND UNDERSTANDING
(SUBOBJECTIVE)
ATTRIBUTE: CS-P
ECONOMICS/PERFORMANCE
(SUB-SUBOBJECTIVE)
ATTRIBUTE: CS-E
SAFETY/ENVIRONMENT
(SUB-SUBOBJECTIVE)
ATTRIBUTE: CS-S

BLANKET ATTRIBUTE
KEY PARAMETERS IN CONSTRUCTED SCALE

Economics/Performance

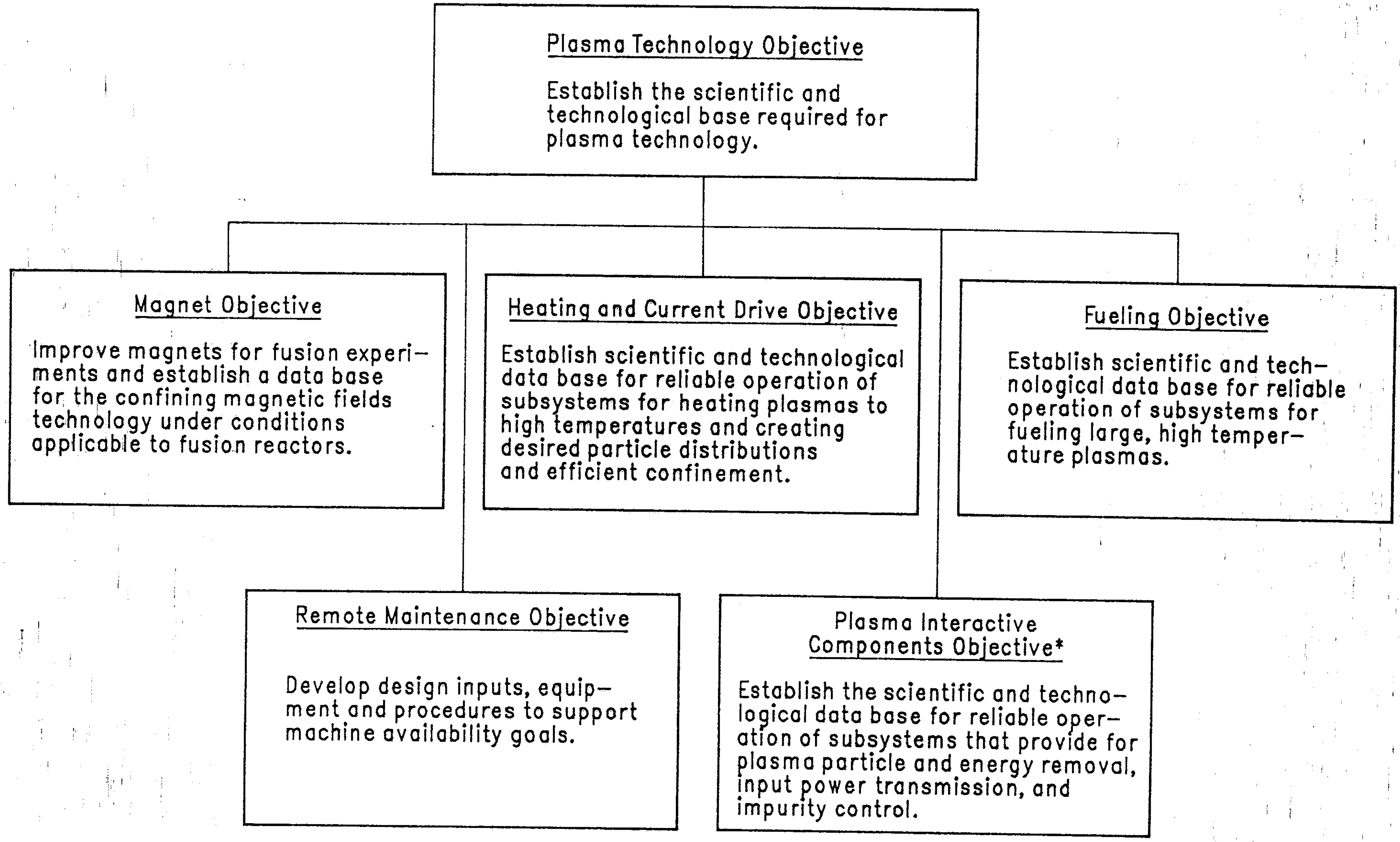
- Neutron Wall Load
- Surface Heat Flux
- Tritium Breeding
- Thermal Efficiency
- Energy Multiplication
- Blanket Thickness
- Reliability
- Lifetime
- Sector MTBF/MTTR
- Blanket/Transport Loop Cost

Safety/Environment

- Chemical Reactivity
- Response to Loss-of-Coolant
- Vulnerable Tritium Inventory
- Long-term Activation
- Afterheat
- Routine Radioactivity Release
- Others

Prediction/Understanding

- MHD
  - fluid velocity profile
  - pressure drop
  - heat transfer
  - corrosion
- Tritium Inventory
  - solubility
  - transport
  - etc.
- Materials Interactions
  - Breeder/Structure
  - Coolant/Structure
  - Purge/Breeder



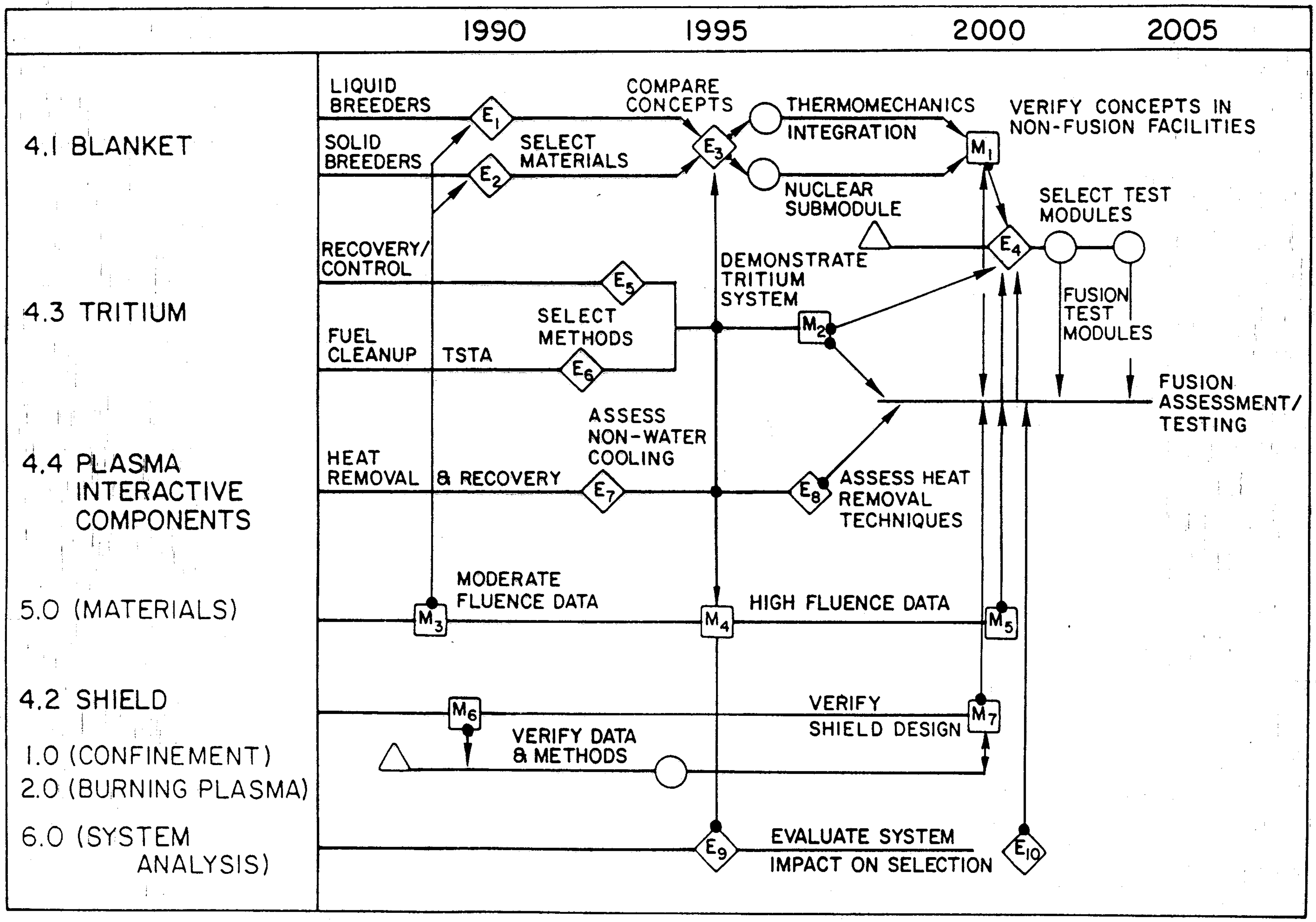
*Also shown under Nuclear Technology in Fig. 4.4-1.

EXAMPLES OF LOGIC DIAGRAMS

Table 1

TOP LEVEL OBJECTIVES FOR MFPP KEY TECHNICAL ISSUES

MFPP Key Issue	1985 - 1990	1990-1995	1995-2000	2000-2005	Overall Objective
• Confinement Systems	• Identify potentially attractive reactor concepts and perform experiments to address selected technical issues	• Resolve technical issues that support development of attractive reactor concepts and a predictive plasma science capability		• Operate leading confinement concept under fusion conditions	Demonstrate one or more confinement concepts (or commercially competitive fusion applications) and develop predictive plasma science capability
• Burning Plasmas	• Demonstrate scientific breakeven (Q ~ 1 in one concept)	• Demonstrate ignition in short pulses in one confinement concept	• Demonstrate ignition (or high Q) with long pulses in one confinement concept		Demonstrate ignition for high Q), long pulse burning plasma conditions in the leading confinement concept
• Nuclear Technology	• Conduct scoping nuclear technology experiments	• Acquire engineering data from interactive effects testing	• Verify selected nuclear technology concepts in non-fusion facilities	• Perform experiments of leading nuclear technology concepts and materials in fusion environment	Show that nuclear technology can be developed that leads to commercially competitive fusion applications
• Materials	• Develop scoping data on improved materials	• Acquire moderate fluence data on leading materials in non-fusion facilities	• Acquire high fluence data on leading materials in non-fusion facilities		Show that improved materials can be developed that lead to enhanced economic and environmental features for commercially competitive fusion applications

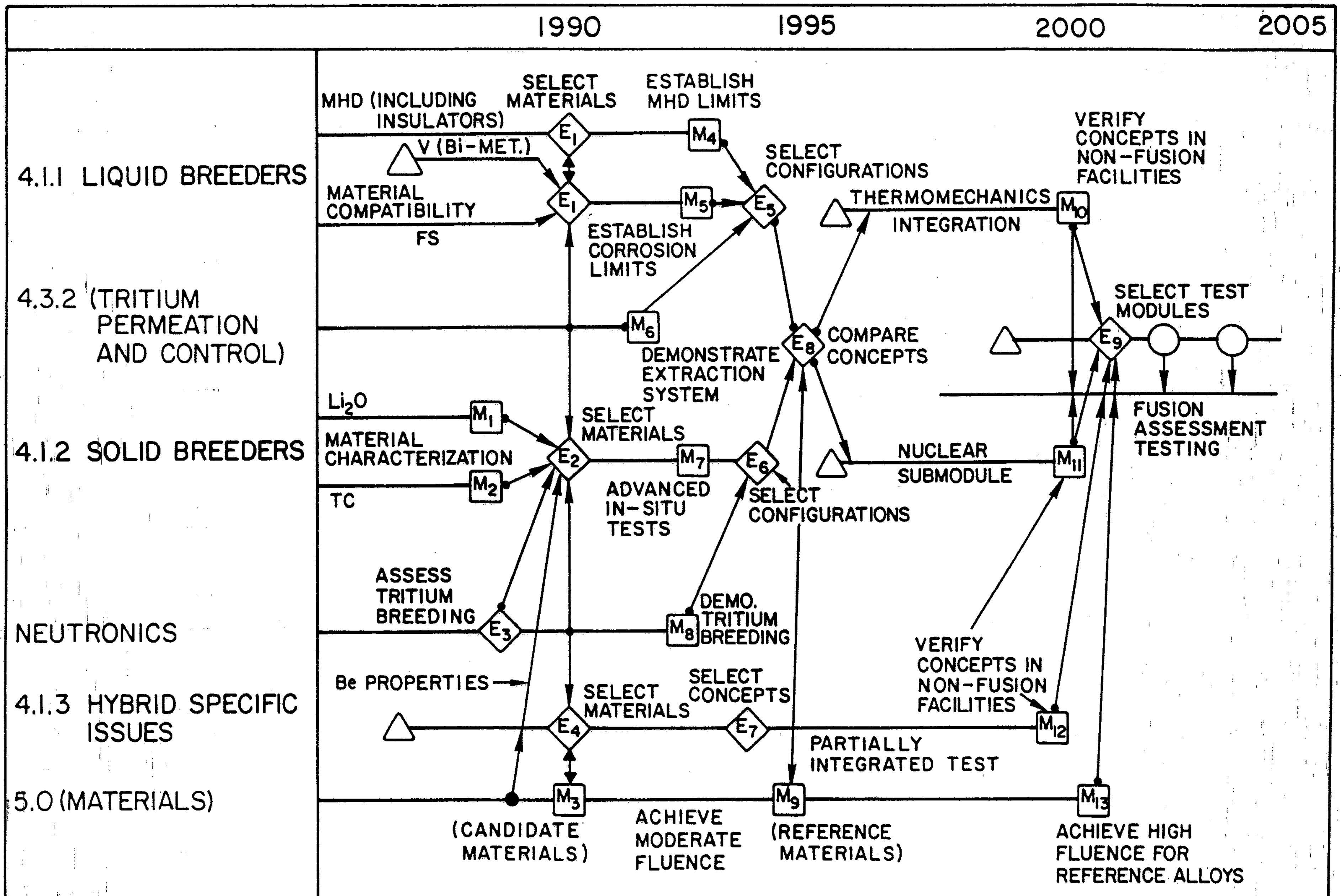


4.0 NUCLEAR TECHNOLOGY

Table 4-2

EVALUATION POINTS AND MILESTONES FOR NUCLEAR TECHNOLOGY

E_1	Select leading material combinations for liquid breeders.
E_2	Select leading material combinations for solid breeders.
E_3	Compare results for solid and liquid breeders. Select one breeder if possible. Select leading configurations.
E_4	Select primary design for experimental blanket test modules in fusion test.
E_5	Select tritium extraction and control methods.
E_6	Select method for fuel clean-up.
E_7	Assess feasibility of non-water cooling of PIC.
E_8	Assess heat removal techniques for PIC.
E_9	Evaluate system impact on selection of blanket concepts.
E_{10}	Evaluate system impact on selection of blanket test modules.
M_1	Verify blanket concepts in non-fusion facilities.
M_2	Demonstrate tritium system operation.
M_3	Achieve moderate fluence (30 dpa) for candidate alloys in non-fusion facilities.
M_4	Achieve moderate fluence (30 dpa) for reference alloys and high fluence (100 dpa) for candidate alloys in non-fusion facilities.
M_5	Achieve high fluence (100 dpa) for reference alloys in non-fusion facilities.
M_6	Verify data and methods for shield design.
M_7	Verify shield design effectiveness. Obtain data on component radiation protection criteria.

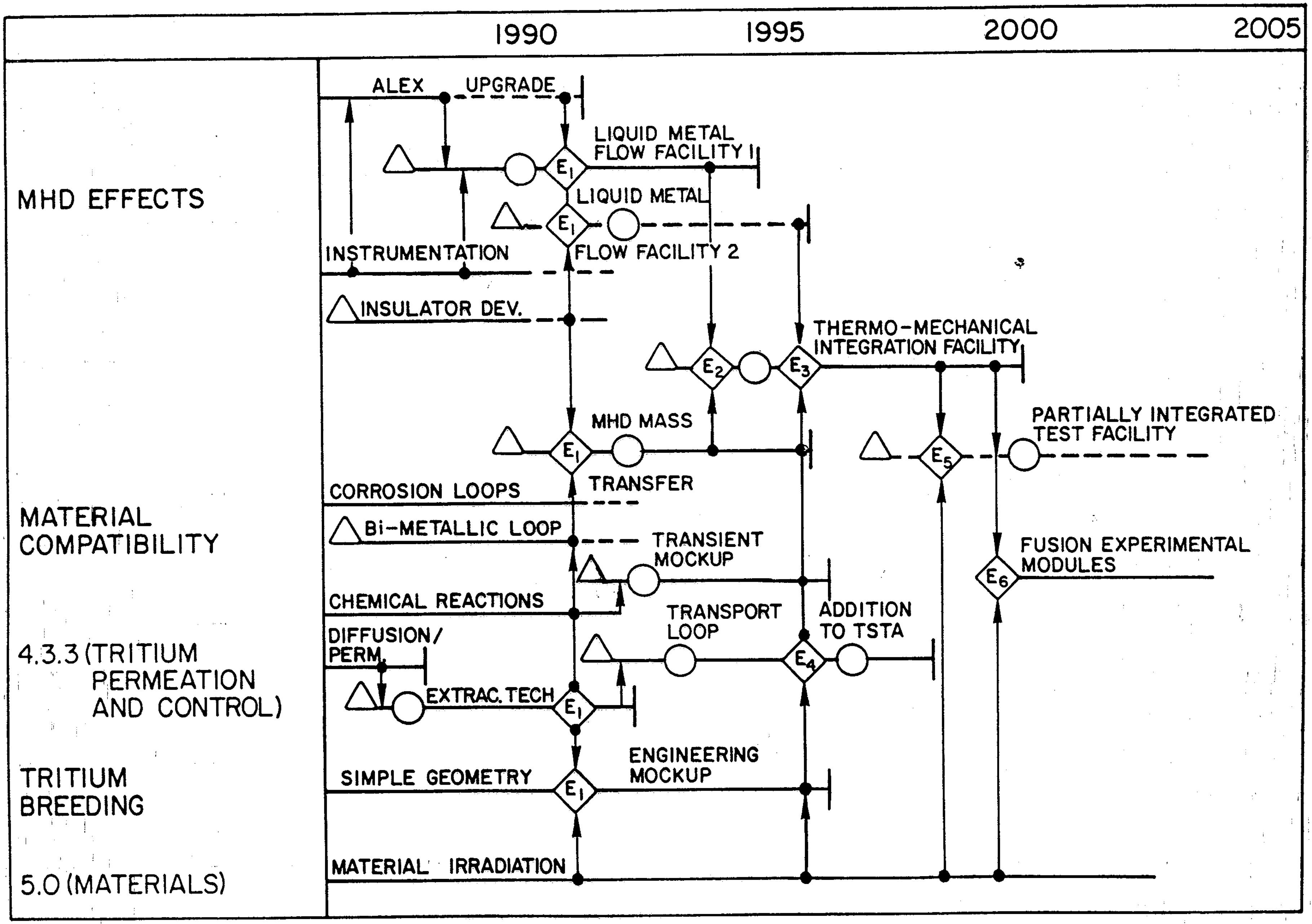


4.1 BLANKET/FW

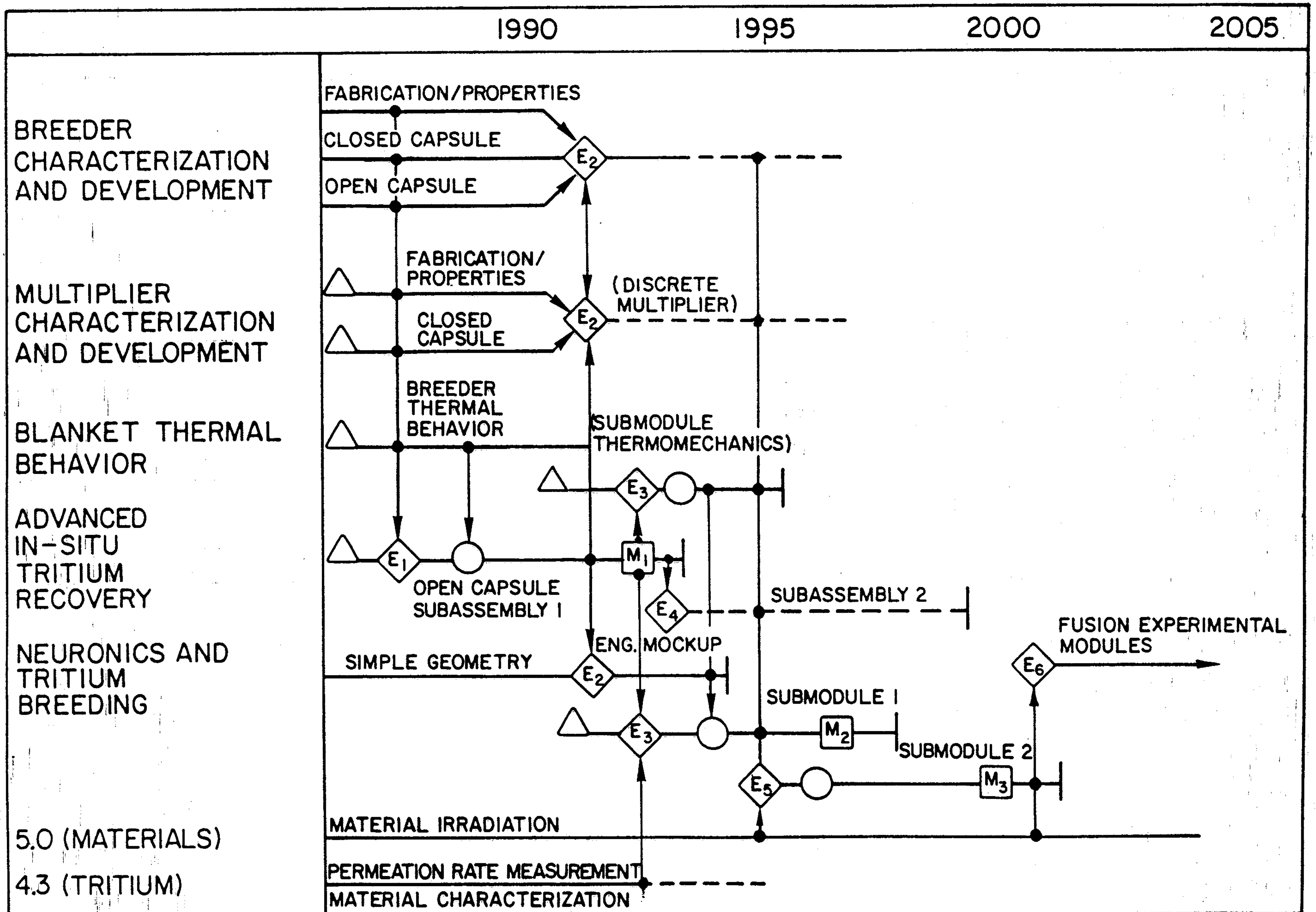
Table 4.1-2

BLANKET/FW EVALUATION POINTS AND MILESTONES

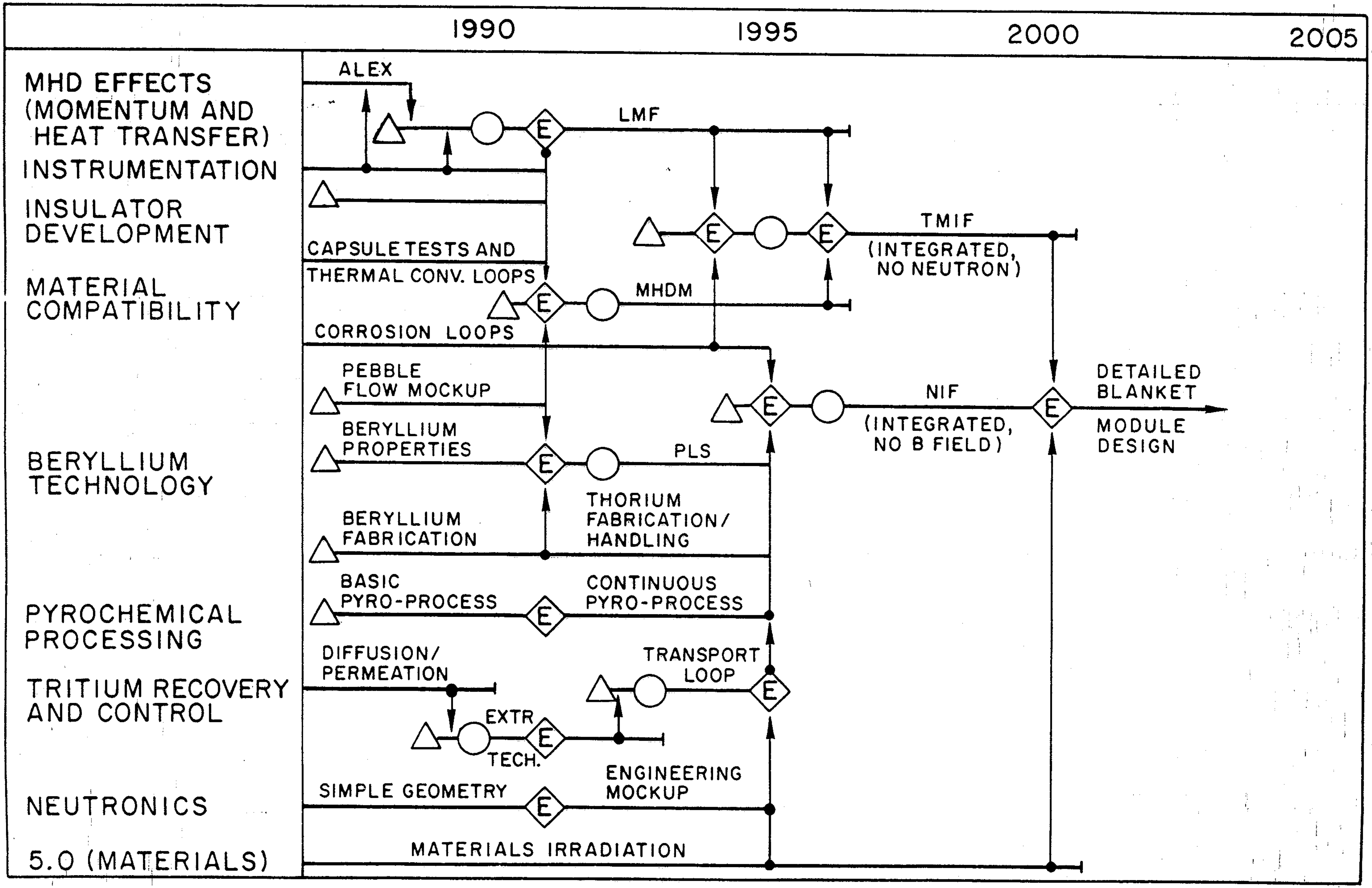
E_1	Narrow coolant/breeder and structural material options for liquid breeder blankets.
E_2	Narrow solid breeder/multiplier material options.
E_3	Assess tritium breeding potential of Li_2O.
E_4	Select fuel form and fuel processing methods.
E_5	Select material combinations and configurations for non-fusion concept verification testing of liquid breeder blankets.
E_6	Select material combinations and configurations for non-fusion concept verification testing of solid breeder blankets.
E_7	Select material combinations and configurations for non-fusion concept verification testing of hybrid blankets.
E_8	Compare solid breeder and liquid breeder concepts. Select a small number of concepts from one or both categories.
E_9	Select and design blanket modules for fusion testing.
M_1	Complete characterization of Li_2O ceramic breeders.
M_2	Complete characterization of ternary ceramic breeders.
M_3	Achieve moderate fluence for initial candidate alloys and select advanced reference alloys.
M_4	Complete MHD experiments. Establish feasibility of self-cooling and optimize cooling methods. Determine MHD design limits.
M_5	Complete basic material interaction experiments. Determine operating limits and demonstrate adequate impurity control techniques.
M_6	Demonstrate tritium extraction system for Li and/or LiPb.
M_7	Complete advanced in-situ tests.
M_8	Complete neutronics engineering mock-up tests. Demonstrate margin for achievable tritium breeding ratio.
M_9	Achieve moderate fluence non-fusion irradiation for reference alloys
M_{10}	Complete non-fusion concept verification for liquid breeder blankets.
M_{11}	Complete non-fusion concept verification for solid breeder blankets.
M_{12}	Complete non-fusion concept verification for hybrid blankets.
M_{13}	Achieve high fluence non-fusion irradiation for reference alloys.



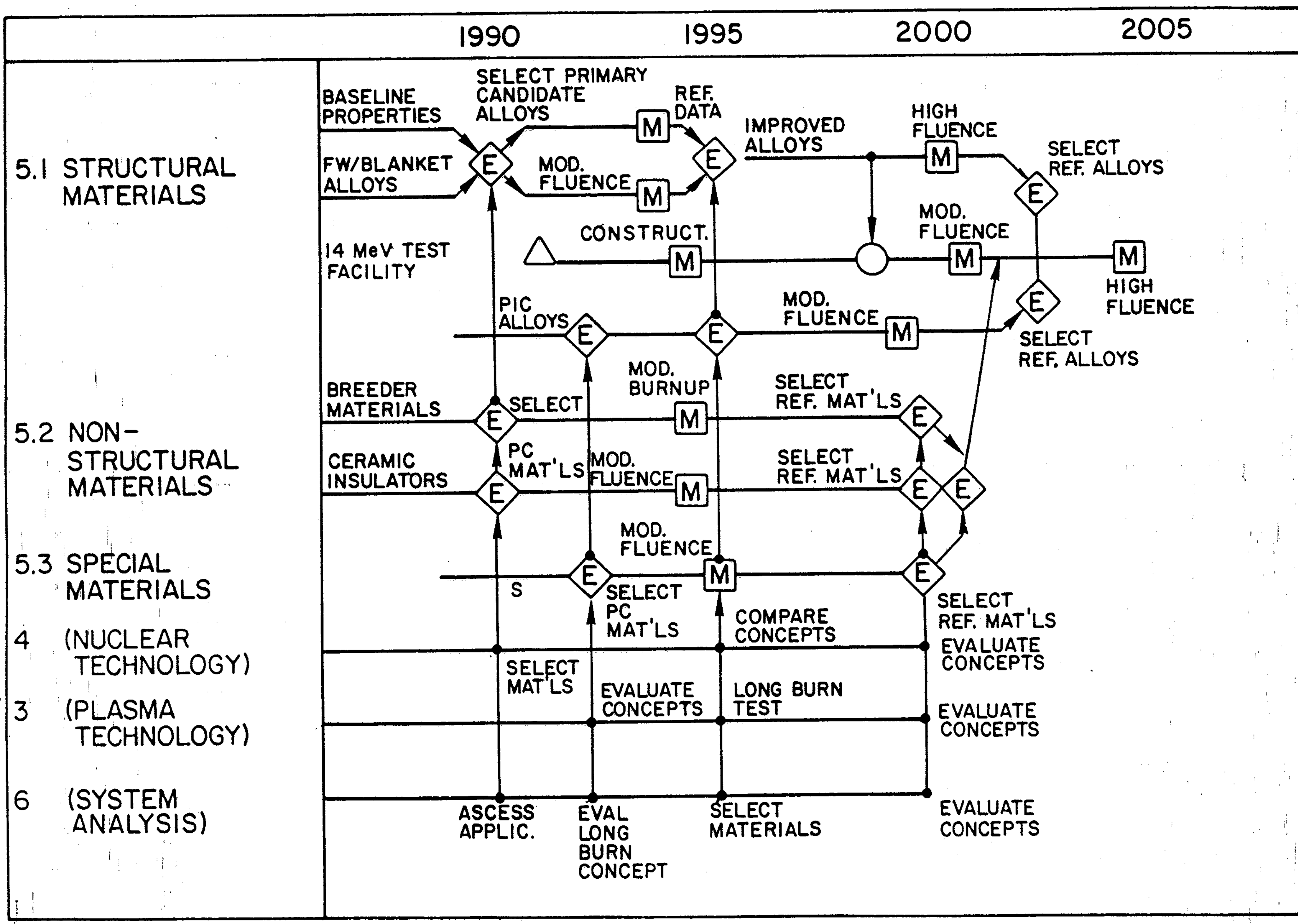
4.1.1 LIQUID BREEDER BLANKETS



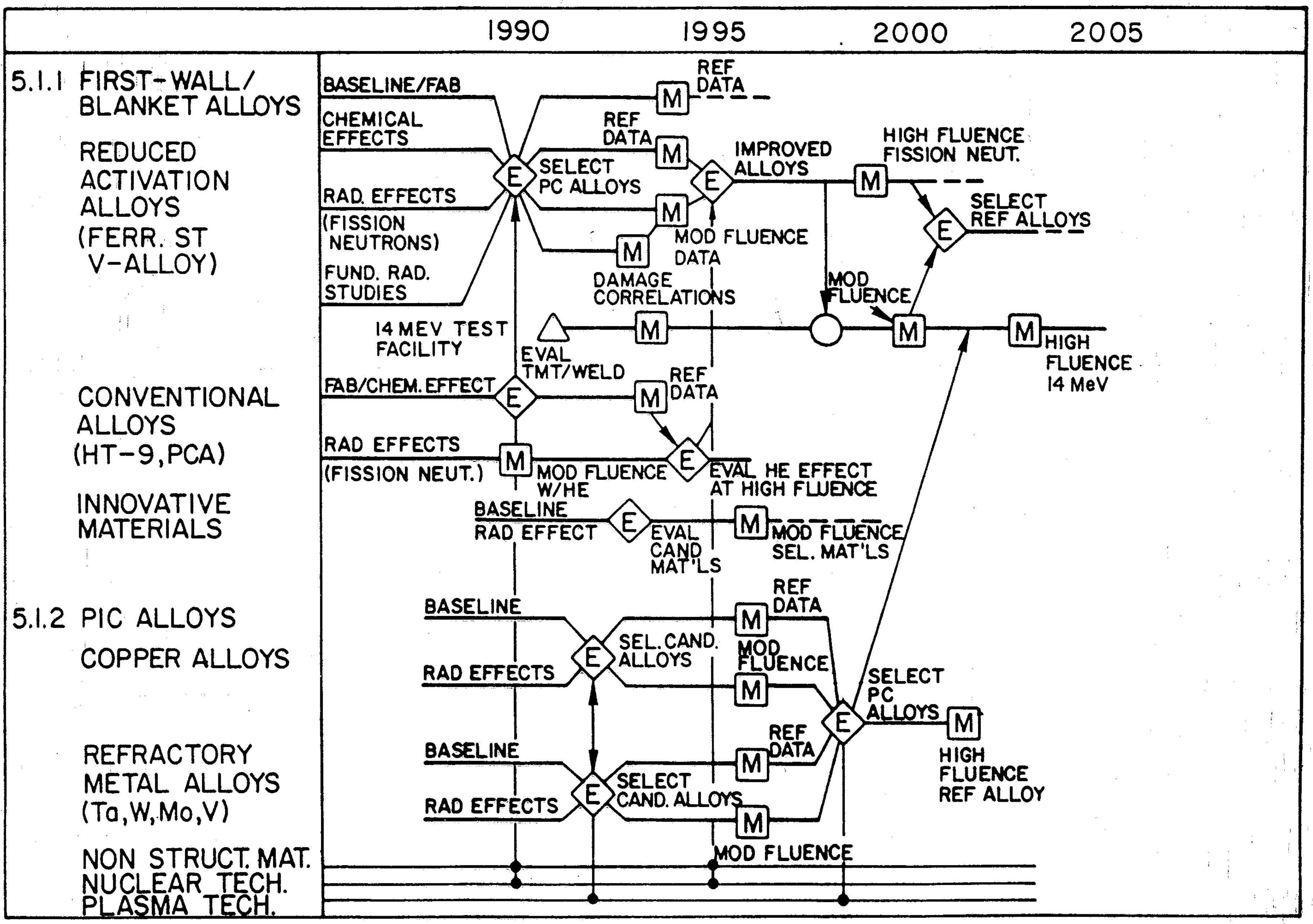
4.1.2 SOLID BREEDER BLANKETS



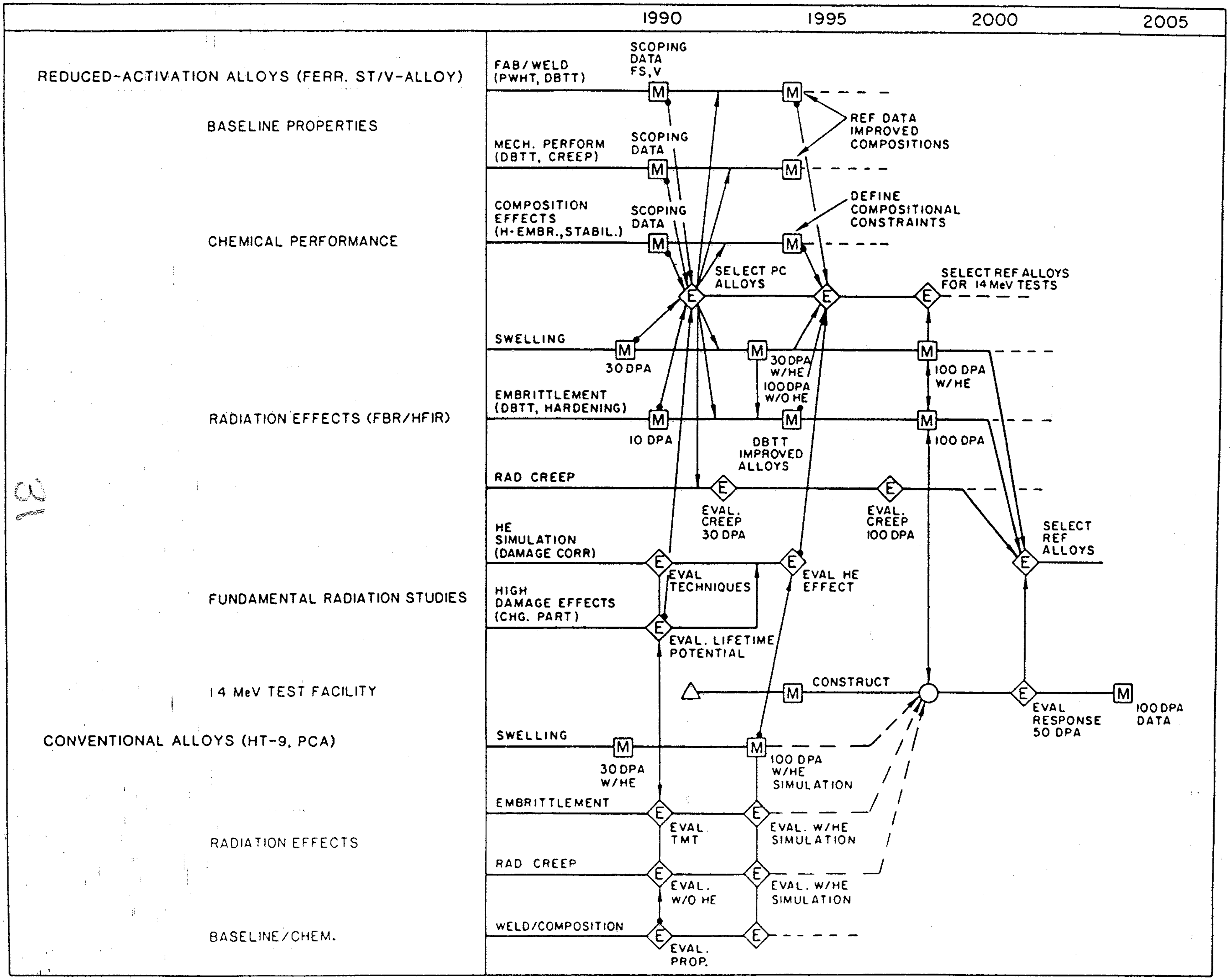
4.1.3 HYBRID BLANKETS (LIQUID METAL)



5.0 MATERIALS



5.1 STRUCTURAL MATERIALS

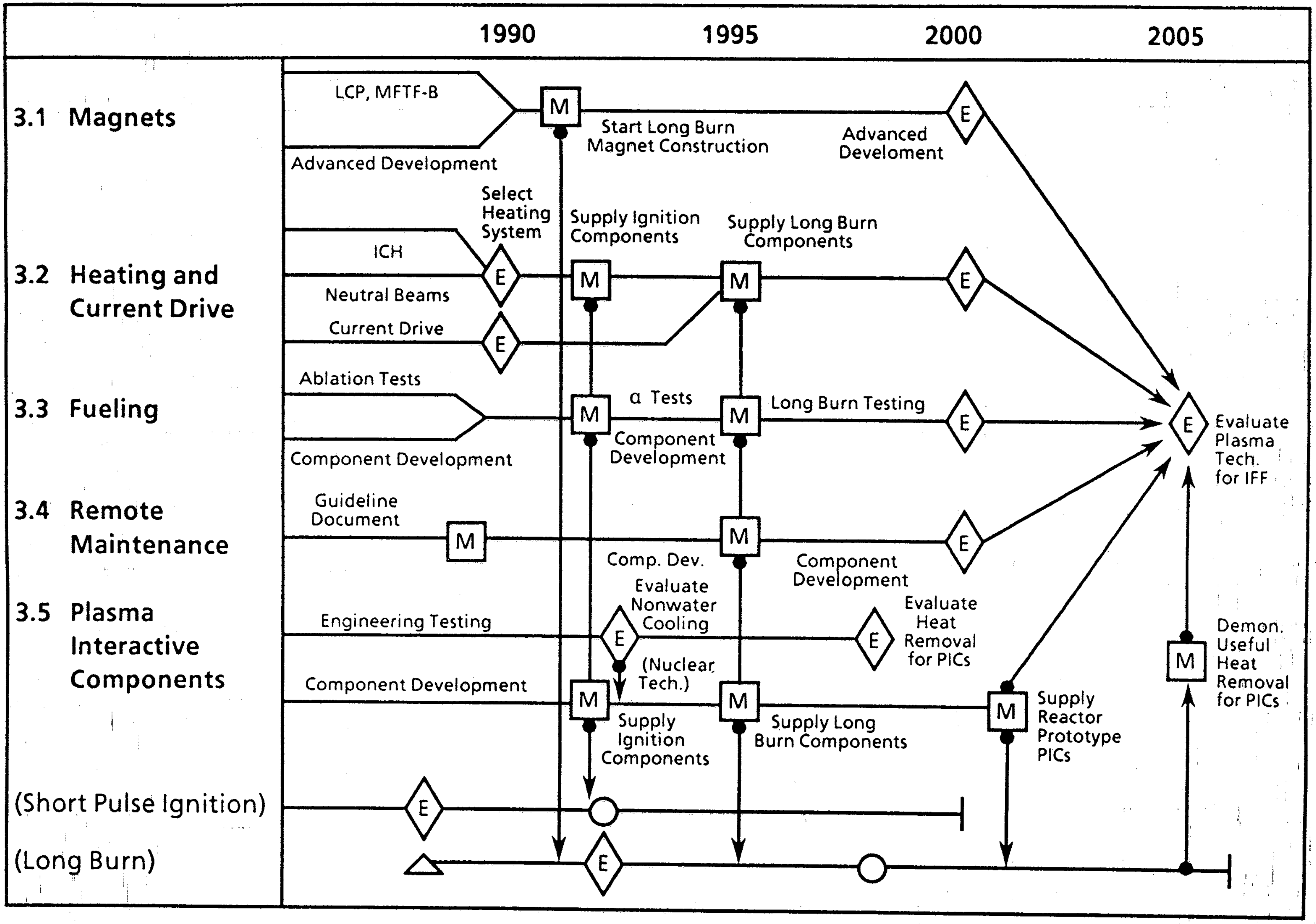


1990
1995
2000
2005
REDUCED-ACTIVATION ALLOYS (FERR. ST/V-ALLOY)
BASELINE PROPERTIES
CHEMICAL PERFORMANCE
RADIATION EFFECTS (FBR/HFIR)
FUNDAMENTAL RADIATION STUDIES
14 MeV TEST FACILITY
CONVENTIONAL ALLOYS (HT-9, PCA)
RADIATION EFFECTS
BASELINE/CHEM.
FAB/WELD (PWHT, DBTT)
SCOPING DATA FS,V
REF DATA IMPROVED COMPOSITIONS
MECH. PERFORM (DBTT, CREEP)
SCOPING DATA
COMPOSITION EFFECTS (H-EMBR., STABIL.)
SCOPING DATA
DEFINE COMPOSITIONAL CONSTRAINTS
SELECT PC ALLOYS
SELECT REF ALLOYS FOR 14 MeV TESTS
SWELLING
30 DPA
30 DPA W/HE
100 DPA W/O HE
100 DPA W/HE
EMBRITTLEMENT (DBTT, HARDENING)
10 DPA
DBTT IMPROVED ALLOYS
100 DPA
RAD CREEP
EVAL. CREEP 30 DPA
EVAL. CREEP 100 DPA
SELECT REF ALLOYS
HE SIMULATION (DAMAGE CORR)
EVAL TECHNIQUES
EVAL HE EFFECT
HIGH DAMAGE EFFECTS (CHG. PART)
EVAL. LIFETIME POTENTIAL
CONSTRUCT
EVAL RESPONSE 50 DPA
100 DPA DATA
SWELLING
30 DPA W/HE
100 DPA W/HE SIMULATION
EMBRITTLEMENT
EVAL. TMT
EVAL. W/HE SIMULATION
RAD CREEP
EVAL. W/O HE
EVAL. W/HE SIMULATION
WELD/COMPOSITION
EVAL. PROP.

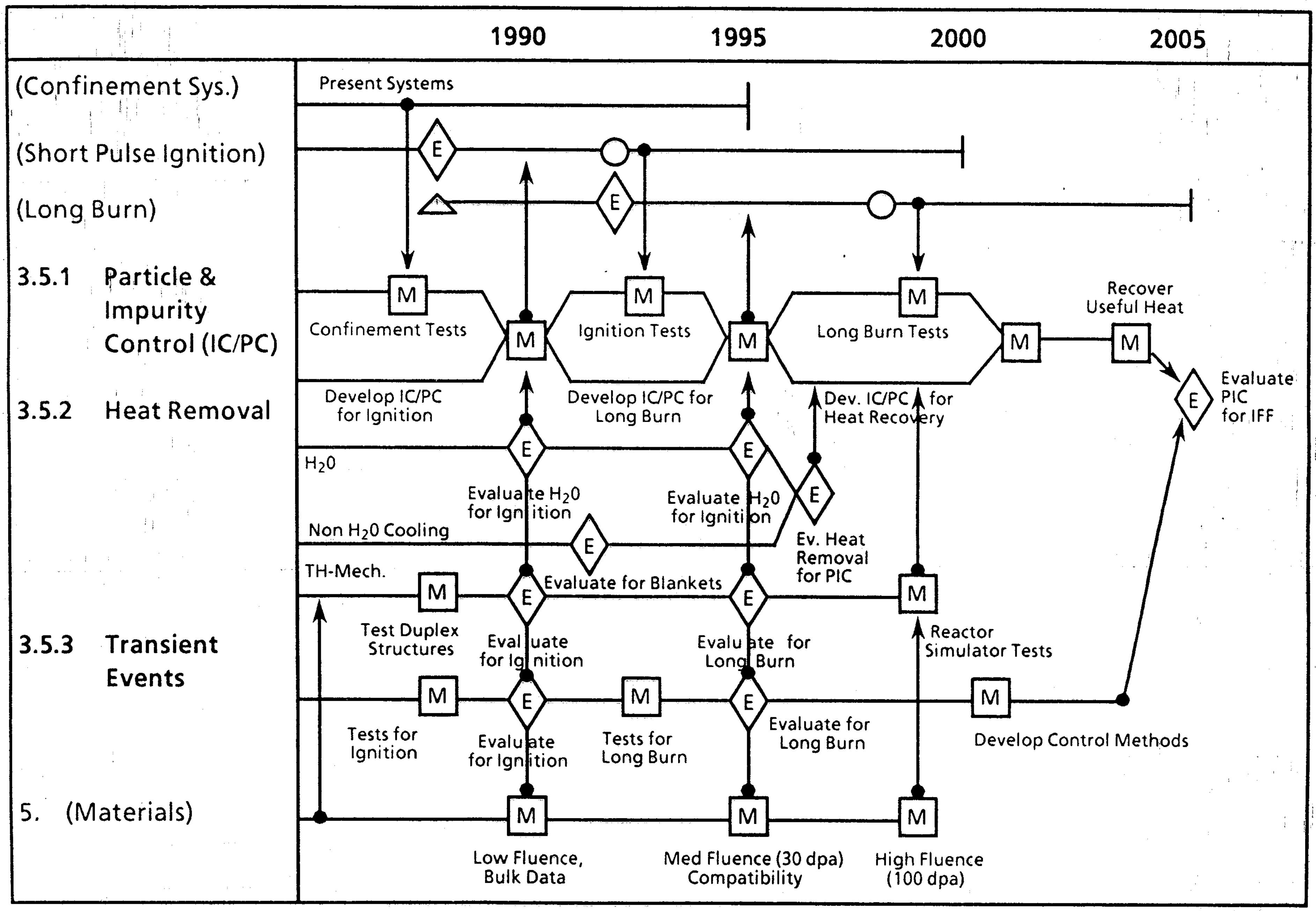
Table 3-1

CHARACTERIZATION OF PLASMA TECHNOLOGY TASKS

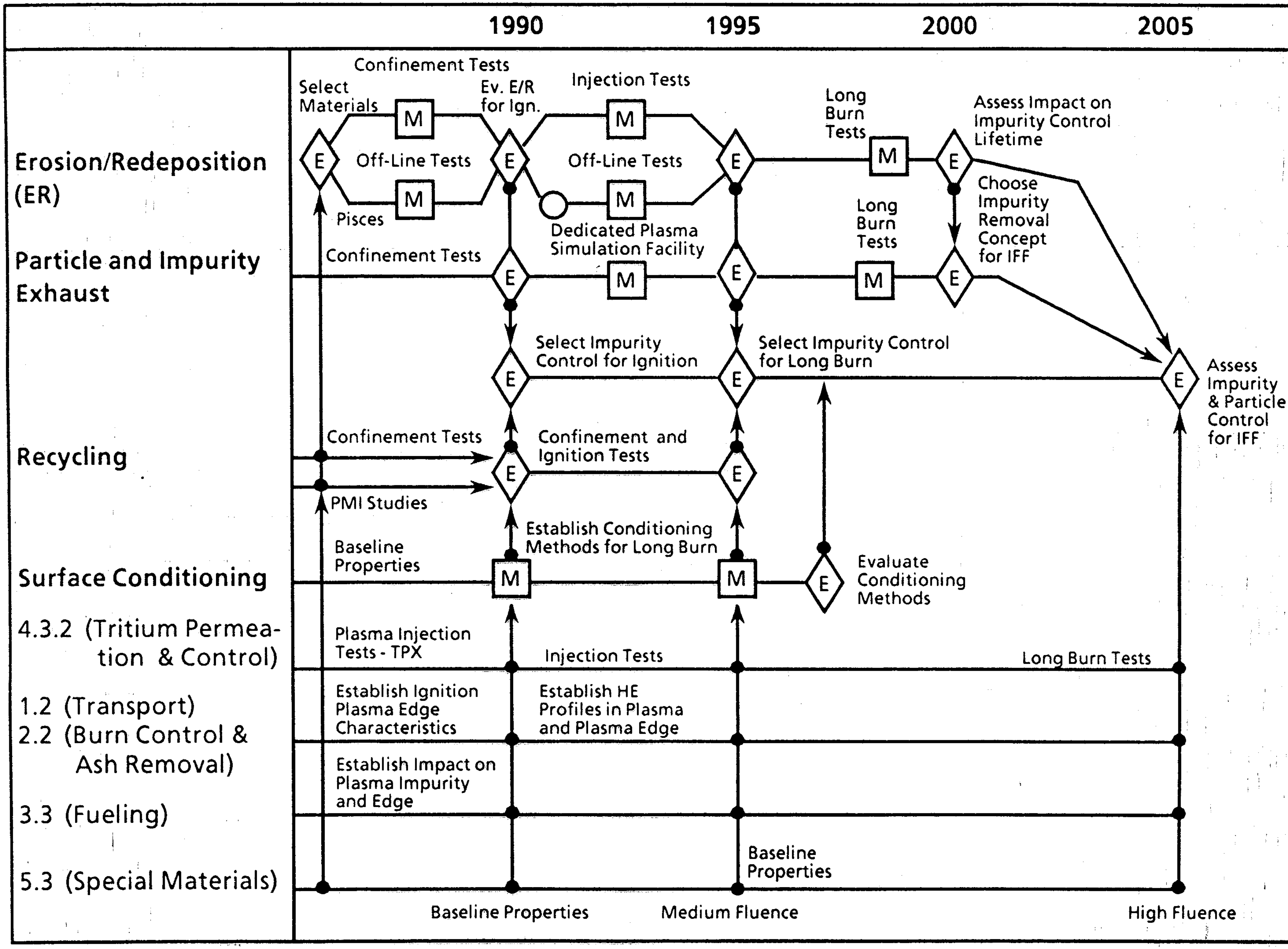
1985-1990	1990-1995	1995-2000	2000-2005
Subsystems feasibility tests on existing devices, component development for ignition	Testing on ignition device, evaluation of approaches to provide long burn design basis	Component development for long burn facility	Advanced development of systems based on quasi steady-state testing in fusion environment



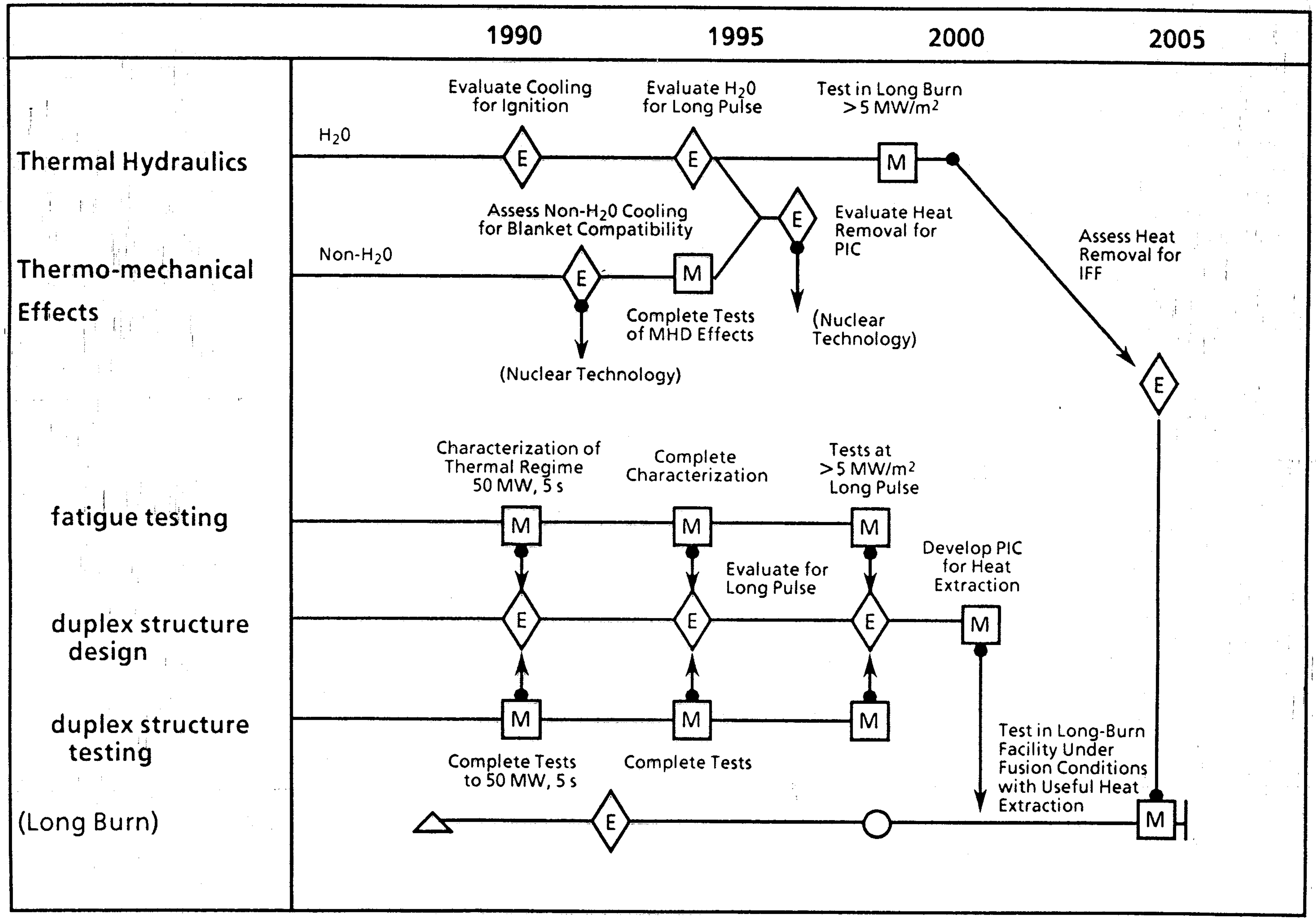
3. PLASMA TECHNOLOGY



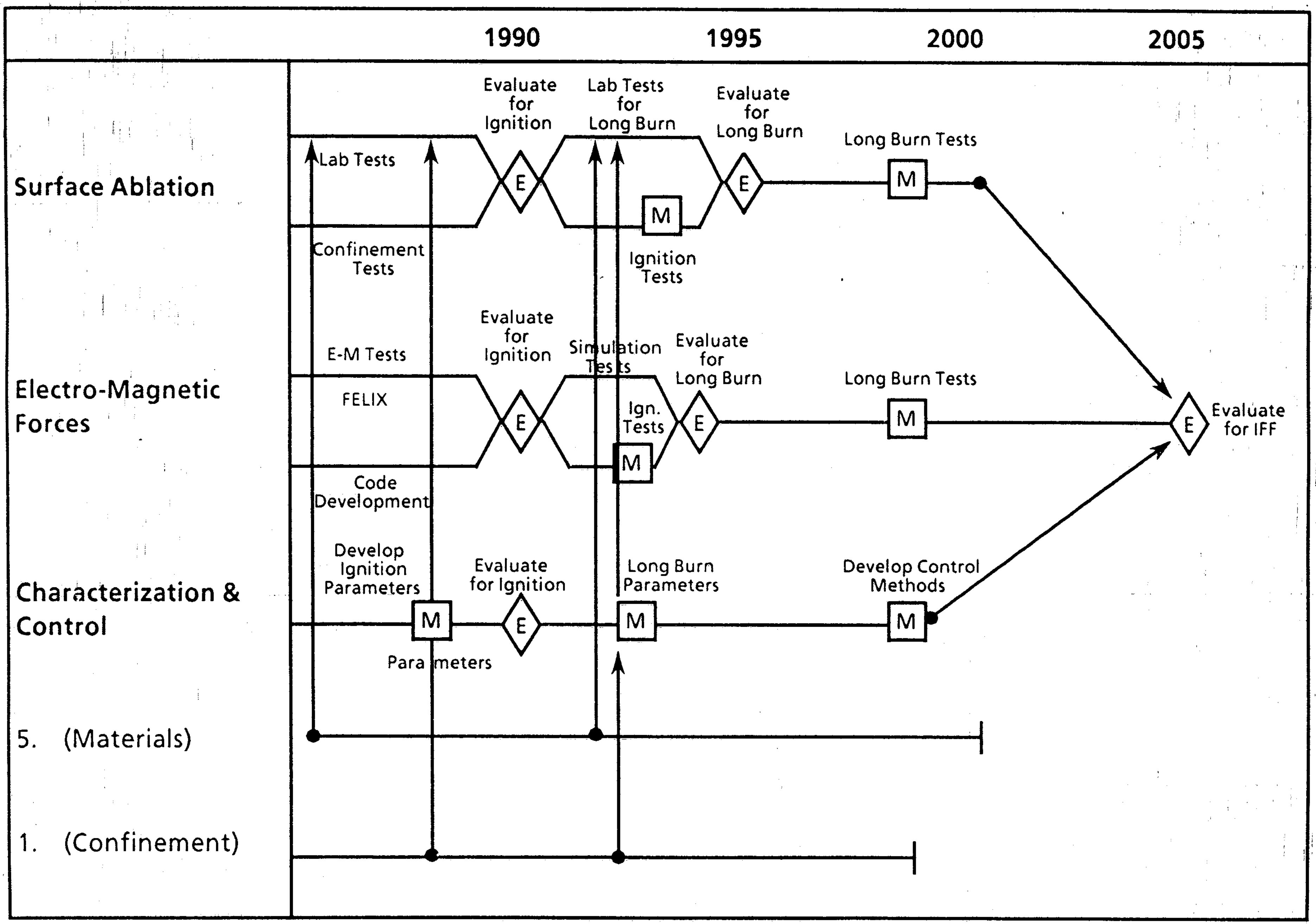
3.5 PLASMA INTERACTIVE COMPONENTS



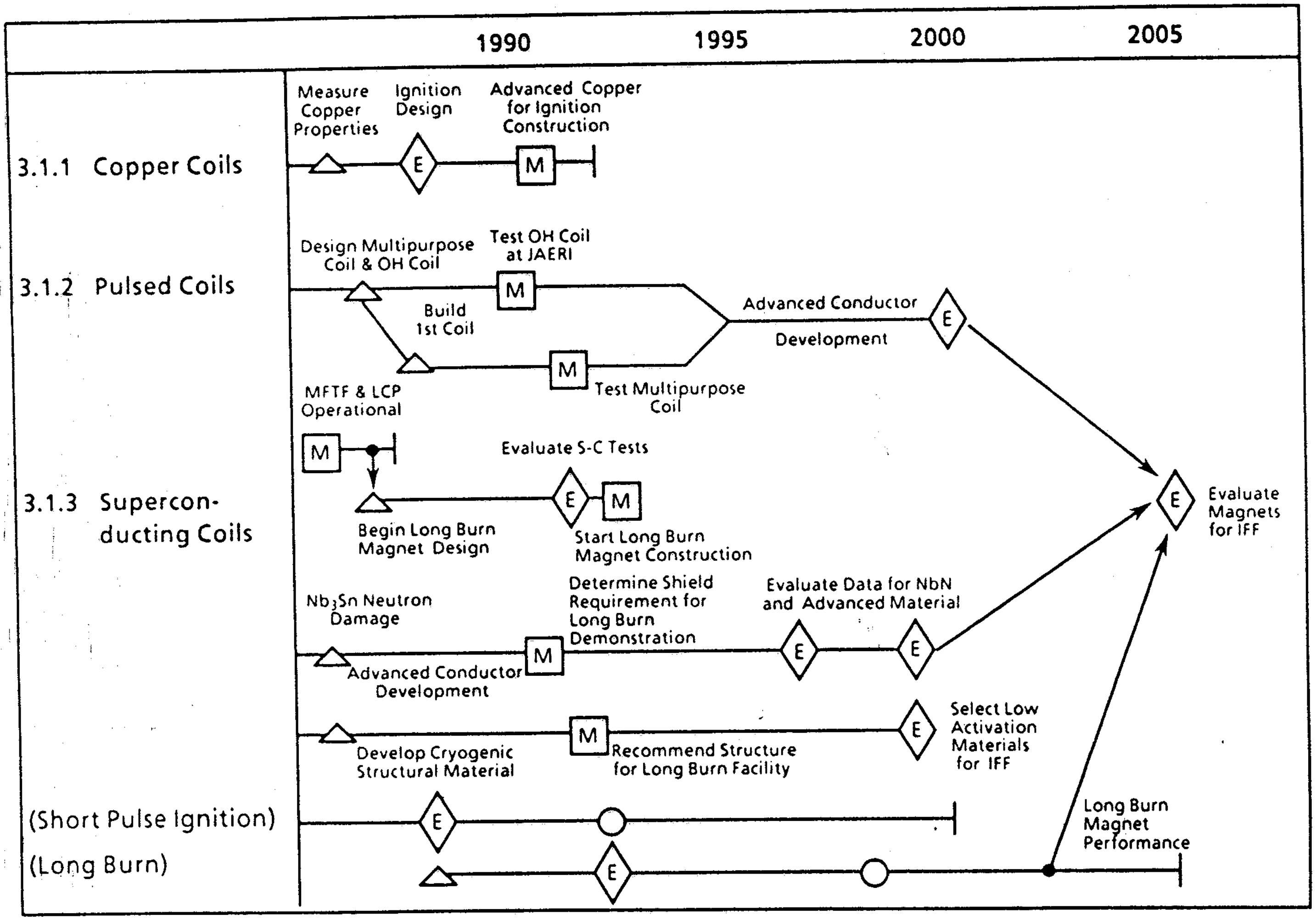
3.5.1 PARTICLE AND IMPURITY CONTROL



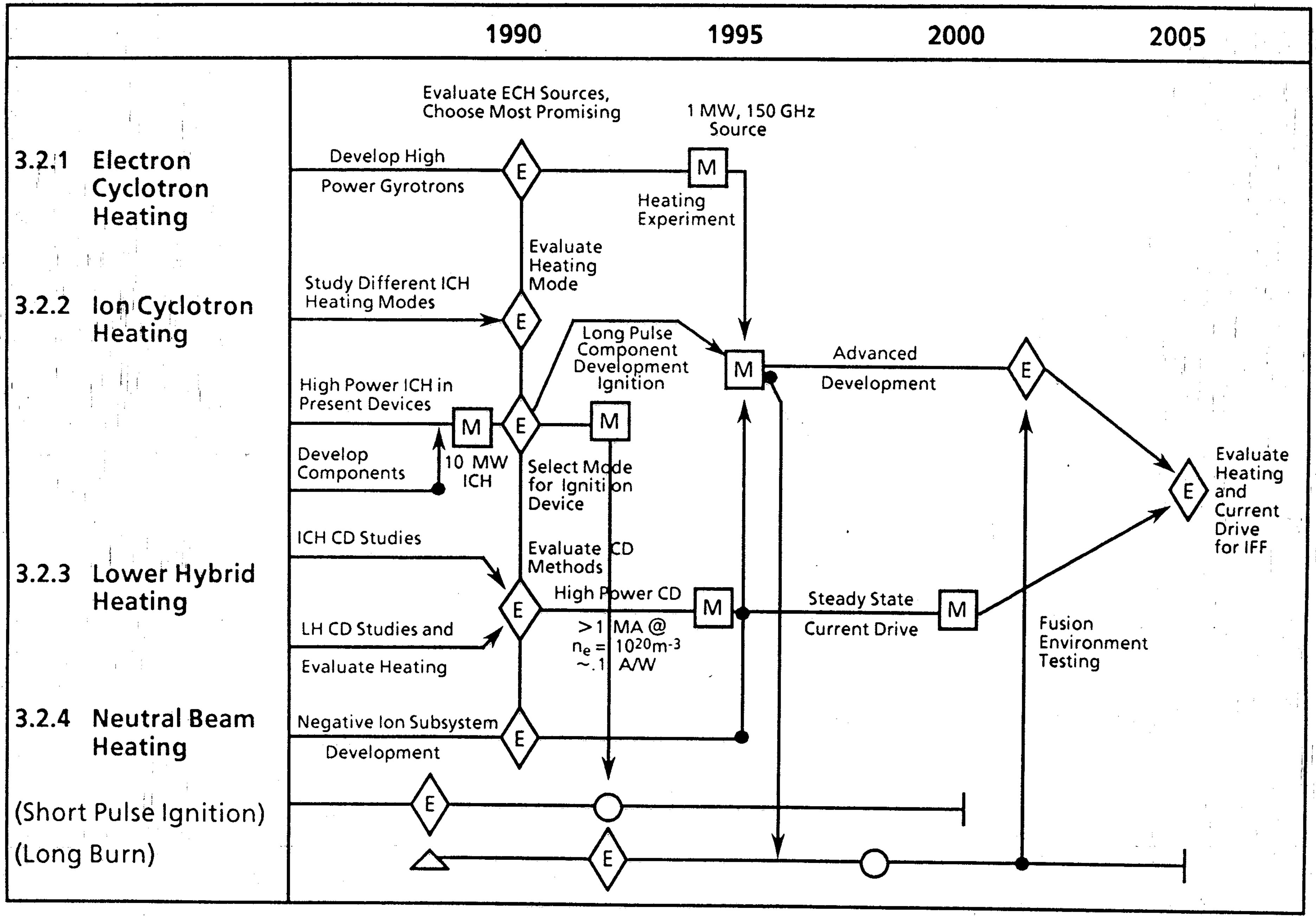
3.5.2 HEAT REMOVAL



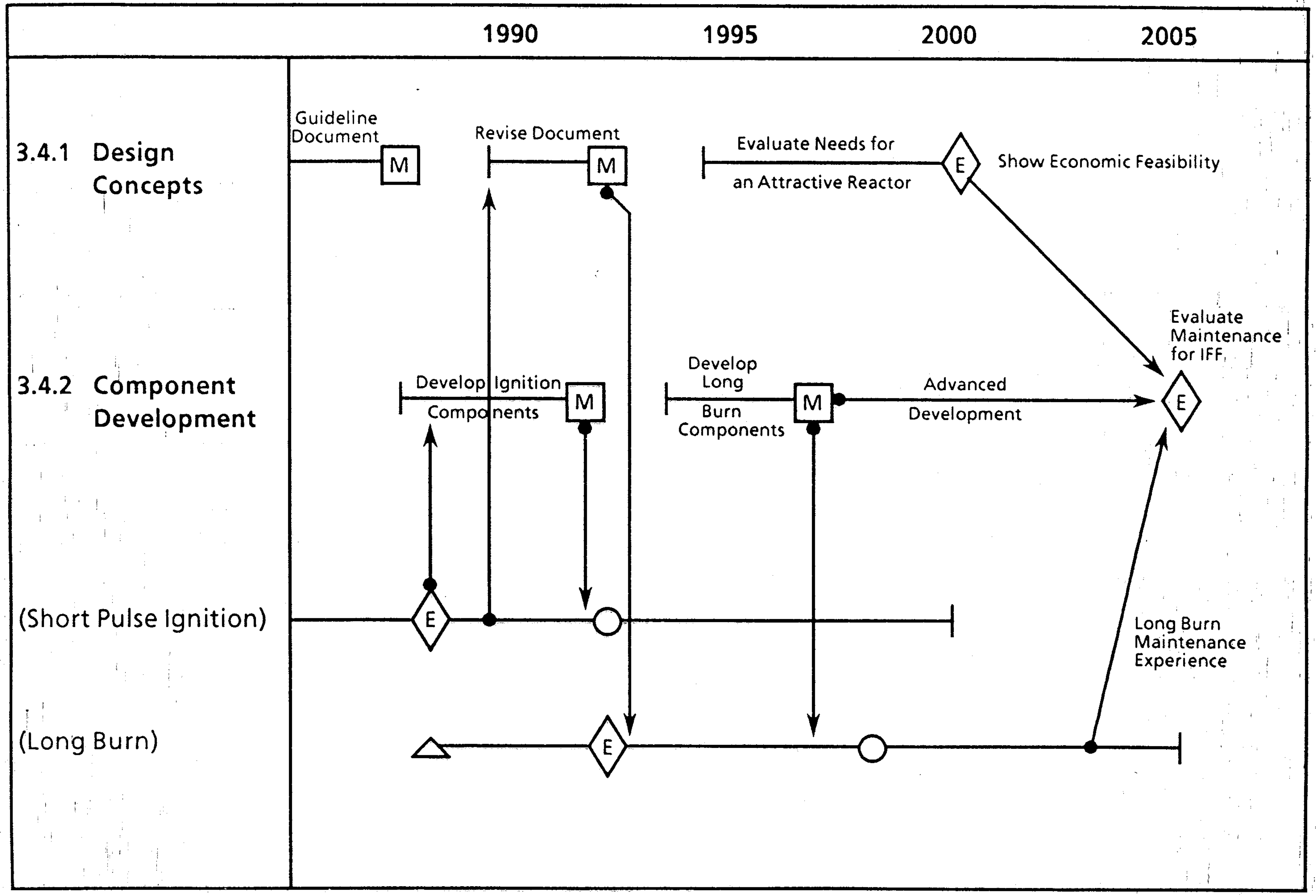
3.5.3 TRANSIENT EVENTS


1990
1995
2000
2005
3.1.1 Copper Coils
Measure Copper Properties
Ignition Design
Advanced Copper for Ignition Construction
3.1.2 Pulsed Coils
Design Multipurpose Coil & OH Coil
Test OH Coil at JAERI
Build 1st Coil
Advanced Conductor
Development
Test Multipurpose Coil
3.1.3 Supercon- ducting Coils
MFTF & LCP Operational
Evaluate S-C Tests
Begin Long Burn Magnet Design
Start Long Burn Magnet Construction
Evaluate Magnets for IFF
Nb_3Sn Neutron Damage
Determine Shield Requirement for Long Burn Demonstration
Evaluate Data for NbN and Advanced Material
Advanced Conductor Development
Select Low Activation Materials for IFF
Develop Cryogenic Structural Material
Recommend Structure for Long Burn Facility
(Short Pulse Ignition)
(Long Burn)
Long Burn Magnet Performance
M
E

3.1 MAGNETS



3.2 HEATING AND CURRENT DRIVE



3.4 REMOTE MAINTENANCE

PLANS FOR PHASE III

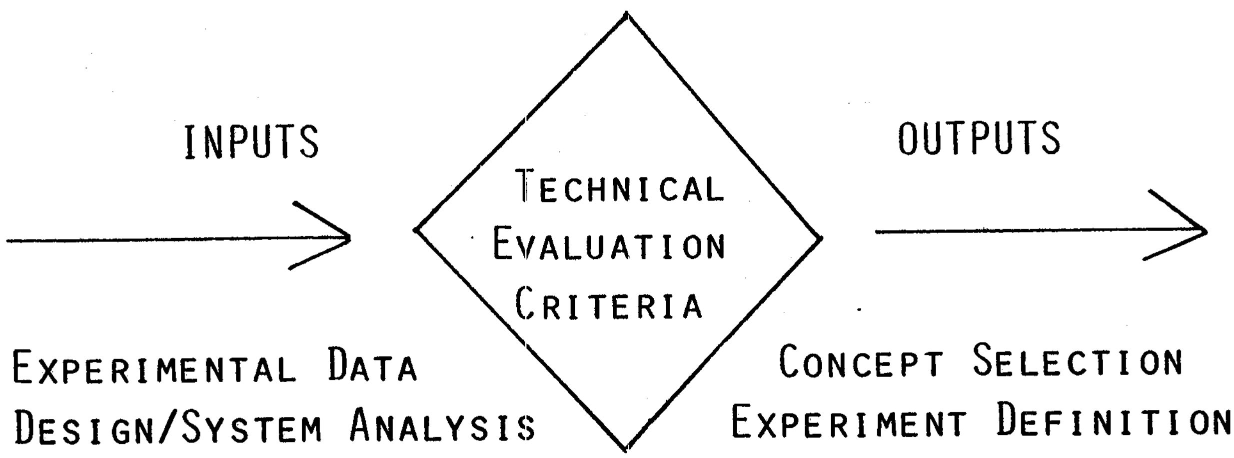
PHASE III

MAJOR FOCUS

- REVISION OF LOGIC DIAGRAMS
  - REVIEW LOGIC AND IMPLICATIONS
  - ELABORATE ON MAJOR DECISION POINTS AND EVALUATION CRITERIA
- DESCRIPTION OF MAJOR FACILITIES AND EXPERIMENTS
- ESTIMATE RESOURCE REQUIREMENTS

EXAMPLE OF DECISION POINT

1995 DECISION POINT
(NUCLEAR TECHNOLOGY/MATERIALS)



1995 NUCLEAR (BLANKET) EVALUATION/DECISION

DECISION DESCRIPTION

A) COMPARE AND SELECT PRIMARY BLANKET CONCEPTS
- MAJOR CLASSES (LIQUID, SOLID BREEDERS)
- MATERIALS (SPECIFIC BREEDERS, STRUCTURAL ALLOYS)
- CONFIGURATIONS

B) DEFINE POST-1995 MAJOR EXPERIMENTS AND FACILITIES
- FOR INTEGRATED NON-FUSION FACILITIES
- AND FOR TEST MODULES IN FUSION FACILITY

<u>TECHNICAL EVALUATION CRITERIA</u>

1. ATTRACTIVENESS

2. PREDICTABILITY

   - ATTRACTIVENESS, FOR COMMERCIAL REACTOR AND PREDICTABILITY BASED ON DATA AVAILABLE AT THE TIME THE DECISION IS MADE

   - EVALUATION CRITERIA
     SEE <u>ATTRIBUTES</u> FROM <u>PHASE I</u>
     (A COPY IS ATTACHED)

3. DEVELOPMENT FACTORS

   - TIME

   - COST

   - RISK
     - (REMAINING) REQUIRED TO DEVELOP OPTION

INPUTS

- DATA FROM MULTIPLE INTERACTION EXPERIMENTS (MHD FLUID FLOW, MATERIAL COMPATIBILITY, TRITIUM RECOVERY, TRITIUM BREEDING, NEUTRONICS, ETC.)
- MODERATE FLUENCE IRRADIATION DATA FOR STRUCTURAL ALLOYS
- DEFINITION OF PARAMETERS AND CHARACTERISTICS FOR REACTOR GOALS
  - NEUTRON WALL LOAD
  - SURFACE HEAT FLUX
  - MAGNETIC FIELD
  - LIKELY OFF-NORMAL EVENTS (DISRUPTIONS?, ETC)
  - END-USE APPLICATION CHARACTERISTICS

OUTPUTS

- SELECTION OF MAJOR CLASS OF DESIGN CONCEPTS (E.G., LM OR SB)
- FOR A GIVEN CLASS, SELECT REFERENCE MATERIALS AND DESIGN CONFIGURATION
- DEFINITION AND SELECTION OF
  - NON-FUSION INTEGRATED TESTING FACILITIES AND EXPERIMENTS
  - KEY DESIGNS FOR TEST MODULES FOR FUSION TESTING
- FEEDBACK TO INPUTS (ITERATION ON SYSTEMS FEATURES)

EXAMPLES OF EXPECTED OUTPUT
FOR FACILITY DESCRIPTION AND
RESOURCE ESTIMATE

(EXAMPLES TAKEN FROM FINESSE)

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

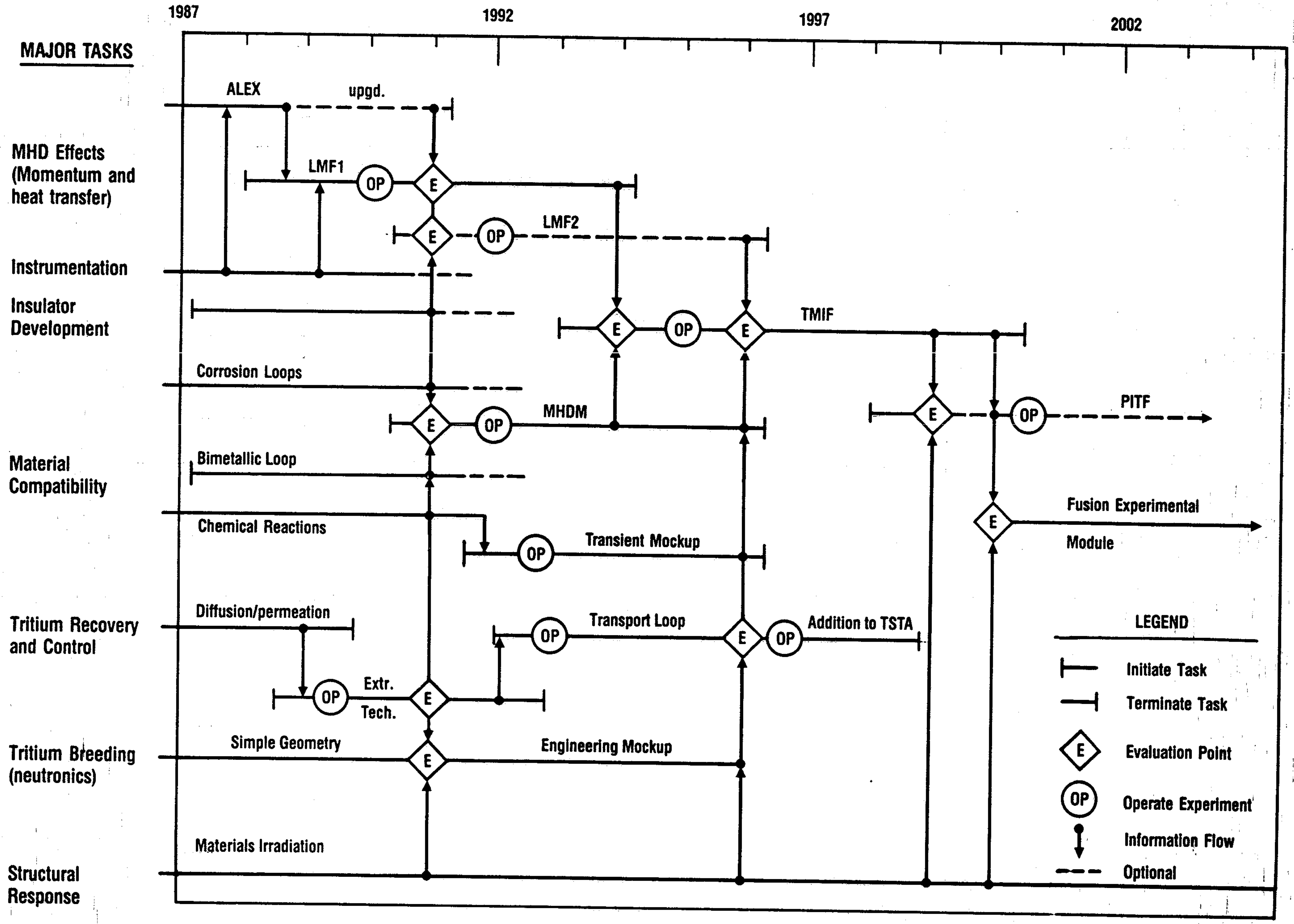
- Structural Response and Failure Modes

- Thermomechanics Integration Facility (TMIF)

- Partially Integrated Test Facility (PITF)

- Analysis and Model Development

LIQUID BREEDER BLANKET TEST PLAN



Features and Objectives of Major Liquid Breeder Experiments

		Magnetic Transport Phenomena Facilities			
	ALEX	LMF	MHDM	TMIF	PITF
Features of Experiments	• Simple Geometry of a channel • NaK	• Basic elements of relevant geometry	• Basic elements of relevant geometry • Relevant material combinations • Transport loop • Relevant T, ΔT, impurities, V • Long operating time per experiment	• Actual materials and geometry • Transport loop • Relevant environmental and operating conditions	• Prototypic blanket module • Transport loop • Prototypic environmental and operating conditions
	• Measure velocity profile, electric potential, pressure drop	• Measure V and T profiles; pressure drop, temperature, electric potential	• Measure dissolution and deposition rates	• Measure integral quantities (ΔP, T, corrosion and deposition rates)	• Measure integral quantities
Objectives	• Develop and test velocity profile instrumentation in NaK environment • Validate MHD in simple geometry (basic heat transfer data may be possible in upgrade	• Develop and test instrumentation • Validate MHD heat transfer • Design data (ΔP, T) for configuration screening • Explore techniques to reduce ΔP and enhance heat transfer	• Develop and test instrumentation in relevant environment • Design data on MHD heat and mass transfer • Verify techniques to reduce corrosion and corrosion effects	• Design data for blanket test module • Confirm and refine configurations	• Engineering design data • Reliability data in non-fusion environment