TPA TECHNOLOGY
STATUS REPORT

PRESENTATION TO MFAC

MOHAMED ABDOU

20 NOVEMBER 1985

TECHNOLOGY GROUP STEERING COMMITTEE

TECHNOLOGY/PHYSICS COORDINATION

PLASMA TECHNOLOGY

(Support Technology for Plasma Burn, Confinement Issue)

- Magnets
- Heating/Fueling
- Remote Maintenance
- PIC

NUCLEAR TECHNOLOGY

(MFPP Issue)

- Blanket/First Wall/Shield
- Tritium Processing
- Power Conversion
- Nuclear Elements of PIC

MATERIALS

(MFPP Issue)

- Structural Materials
- Non-Structural Blanket Materials
- Special Materials
- Magnet Materials

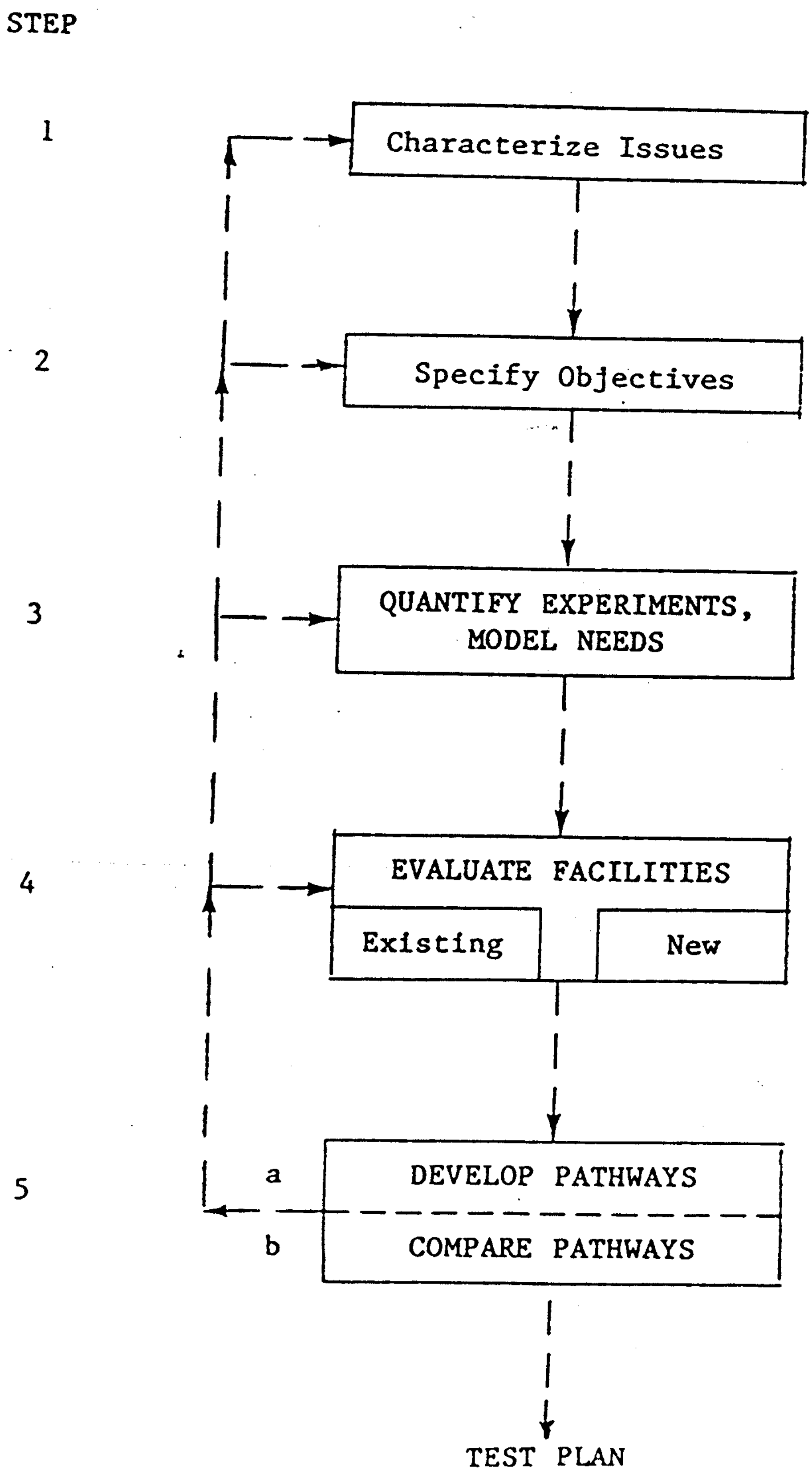
NUCLEAR TECHNOLOGY

- NUCLEAR SUBSYSTEMS
- PHENOMENA EXPLORATION
- MULTIPLE EFFECT TESTS
- INTEGRATED TESTS AND CONCEPT VERIFICATION
- ANALYTICAL AND COMPUTER MODELING
- EXPERIMENTS, FACILITIES FOR NUCLEAR TECHNOLOGY R & D

MATERIALS

- MATERIALS FOR REACTOR SUBSYSTEMS
- MATERIALS IRRADIATIONS
- BASIC MATERIALS PROPERTIES (PHYSICAL, CHEMICAL, MECHANICAL, AND NUCLEAR PROPERTIES) FOR ALL MATERIALS (STRUCTURE, MULTIPLIER, BREEDER, COOLANT, ETC.)
- RADIATION DAMAGE THEORY
- FACILITIES FOR MATERIALS IRRADIATION

TPA TECHNOLOGY METHODOLOGY STEPS



TPA TECHNOLOGY STATUS SUMMARY

- COMPLETED STEPS 1 AND 2
  - CHARACTERIZE ISSUES
  - SPECIFY OBJECTIVES
- INTERIM REPORT IS BEING REVIEWED
- PHASE II WILL FOCUS ON STEPS 3-5
  - MAJOR EXPERIMENTS AND FACILITIES
  - TECHNICAL LOGIC NETWORK

DEFINITION OF ISSUE?

- DIFFICULT TO DEVELOP PRECISE MEANING

- OFTEN USED TO CONVEY DIFFERENT MEANINGS:

  PROBLEM

  UNCERTAINTY WITH NEGATIVE CONSEQUENCE

  ELEMENT

  TECHNICAL AREA, TOPIC

- SELDOM USED TO MEAN POSITIVE

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

POTENTIAL IMPACT ON DESIGN

Feasibility Issues

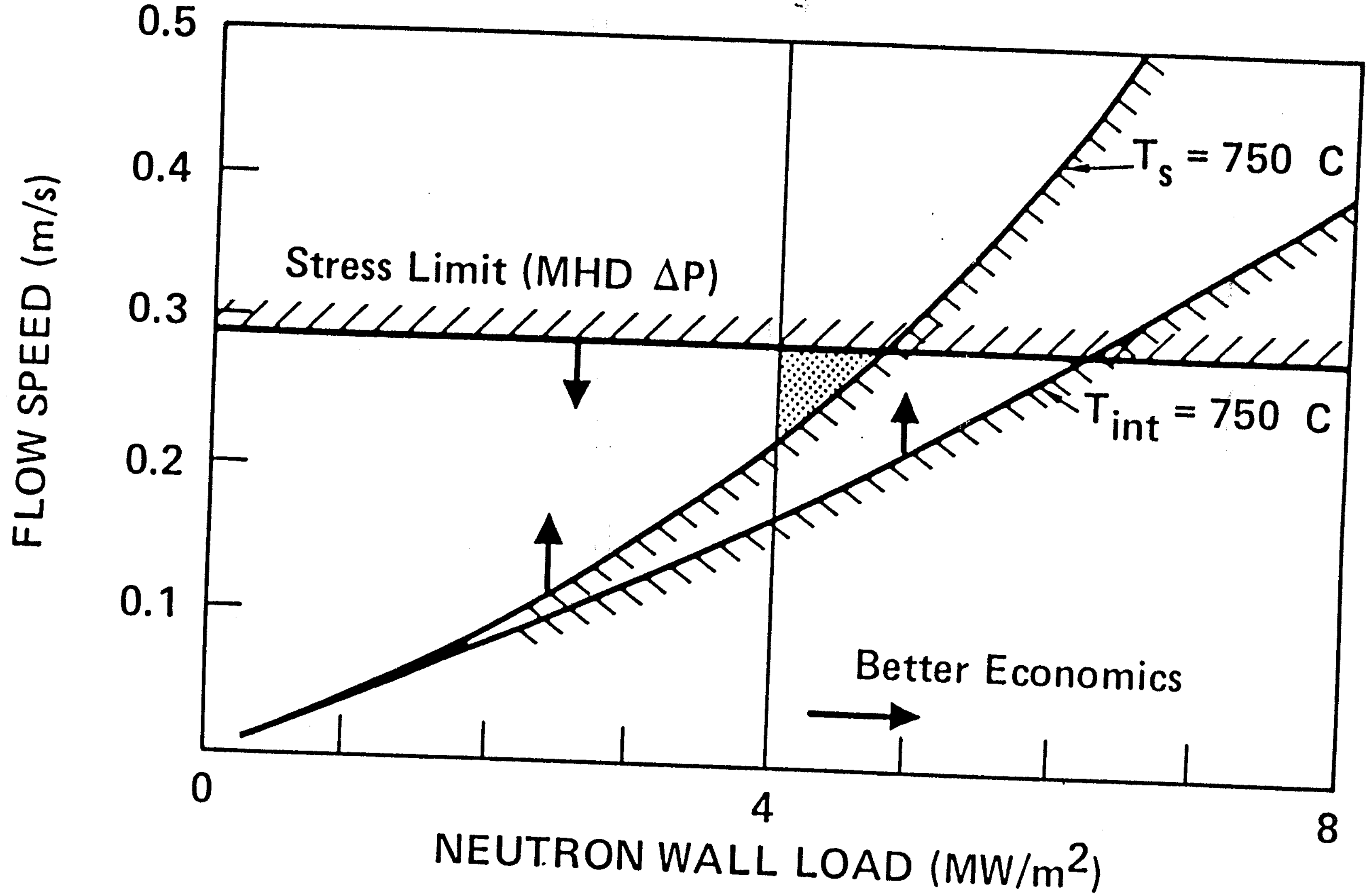
- May Close the Design Window
- May Result in Unacceptable Safety Risk
- May Result in Unacceptable Reliability, Availability or Lifetime

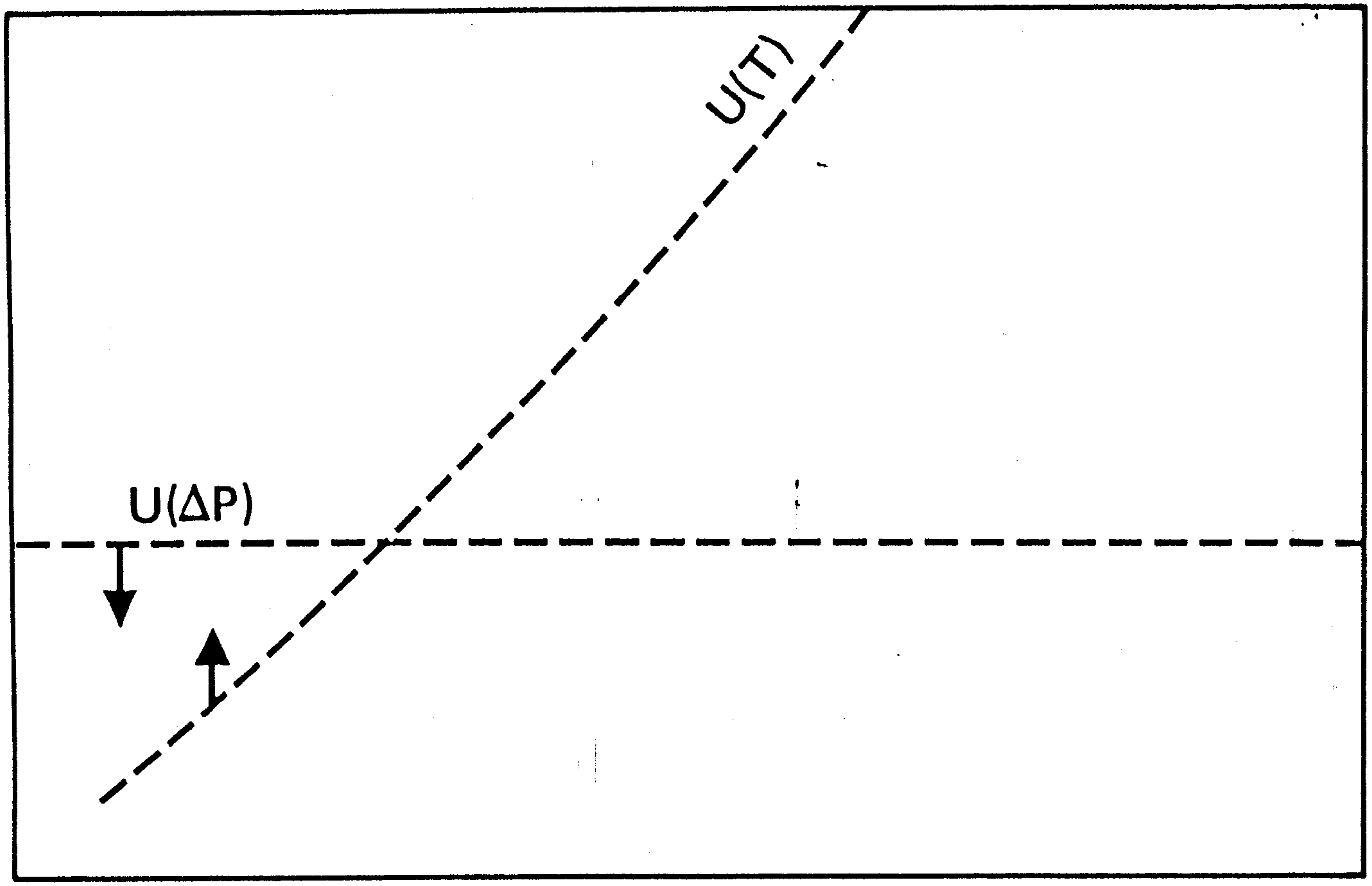
Attractiveness Issues

- Reduced System Performance
- Reduced Component Lifetime
- Increased System Cost
- Less Desirable Safety or Environmental Impact

FINESSE

Design Window EXAMPLE





U(T): Any of:
T_s = 650 C
T_{int} = 550 C
h_m = 0.7h

Uncertainties in MHD, Corrosion, Heat Transfer, Radiation Effects Represent Major Issues

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 MATERIALS

STRUCTURAL MATERIALS
(FW/B/PIC = ALLOYS AND CERAMICS)

Embrittlement and loss of fracture toughness as they affect the mechanical performance

Radiation-induced swelling and creep that affect dimensional stability

Property changes that result from compositional or phase changes

Baseline properties of developmental materials required for selection

Fabrication/Joining

NON-STRUCTURAL BLANKET MATERIALS
Solid Breeder Materials

Basic understanding and data on tritium solubility and transport, and microstructure

Swelling and creep that affect dimensional stability or mechanical integrity

Changes in thermal conductivity and chemical stability at high fluence/Li burnup that affect thermal performance

Liquid Breeders/Coolants

Radiolytic decomposition of molten salts and organic coolants

Ceramic Insulators

Fracture strength and thermal shock resistance to withstand thermal transients

Degradation of electrical properties by radiation

Swelling and creep that affect dimensional stablity

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 , ND EFFECTS

PRIMARY ISSUES FOR TRITIUM PROCESSING

- Tritium Monitoring and Accountability
- Impurity Removal from D-T Fuels
- Tritium Removal from Water Coolant, Room Atmosphere
- Tritium Processing System Safety and Reliability

PRIMARY ISSUES FOR RADIATION SHIELDING

- Specification of Shield Design Guidelines
  - Data for Component Radiation Protection Criteria
- Verification of Shield Effectiveness

PRIMARY ISSUES FOR REMOTE MAINTENANCE

- Integration into Facility/Component Design
- Development of Specialized Equipment

PRIMARY ISSUES FOR INSTRUMENTATION AND CONTROL

- Accuracy, Decalibration in Fusion Environment
- Lifetime under Irradiation

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

PRIMARY ISSUES FOR FUELING

- SPECIFICATION OF OPTIMUM FUELING PROFILES
  - MAY VARY FROM ONE CONFINEMENT CONCEPT TO ANOTHER
  - TECHNOLOGY VIEWPOINT: LARGE PELLET IS EASIER THAN HIGH VELOCITY
- PELLET ABLATION MODELING
- PELLET INJECTOR PERFORMANCE
  - STATE OF THE ART FOR PELLETS:
    D ~ 4 MM   V = 2 KM/S   REPETITION RATE ~ 5-40 s^{-1}

PRIMARY ISSUES FOR HEATING AND CURRENT DRIVE

- Negative Ion Beam System Attractiveness
- Negative Ion Beam Component Performance
  - Ion Source
  - Accelerator
  - Neutralizer
- Identification of an Attractive Ion Wave Heating Mode
- Development of ICRH Components
  - Launchers
  - Feedthroughs
  - Matching Systems
  - Power Sources
- Understanding of LHH Power Deposition
- LHH Components
  - Launcher
  - Source
- ECH Tubes
- Identification of Efficient Current Drive Technique

PRIMARY ISSUES FOR MAGNETS

- Copper Coils
  - Strength of Copper
  - Demountable or Sliding Joints
- Pulsed Coils
  - OH Coil Development
  - High Field Coils
  - Energy Storage
- Superconducting Coils
  - Radiation Hardening of Conductors, Insulators and Structures
  - Superconducting Current Density
  - Structural Materials Strength and Toughness

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

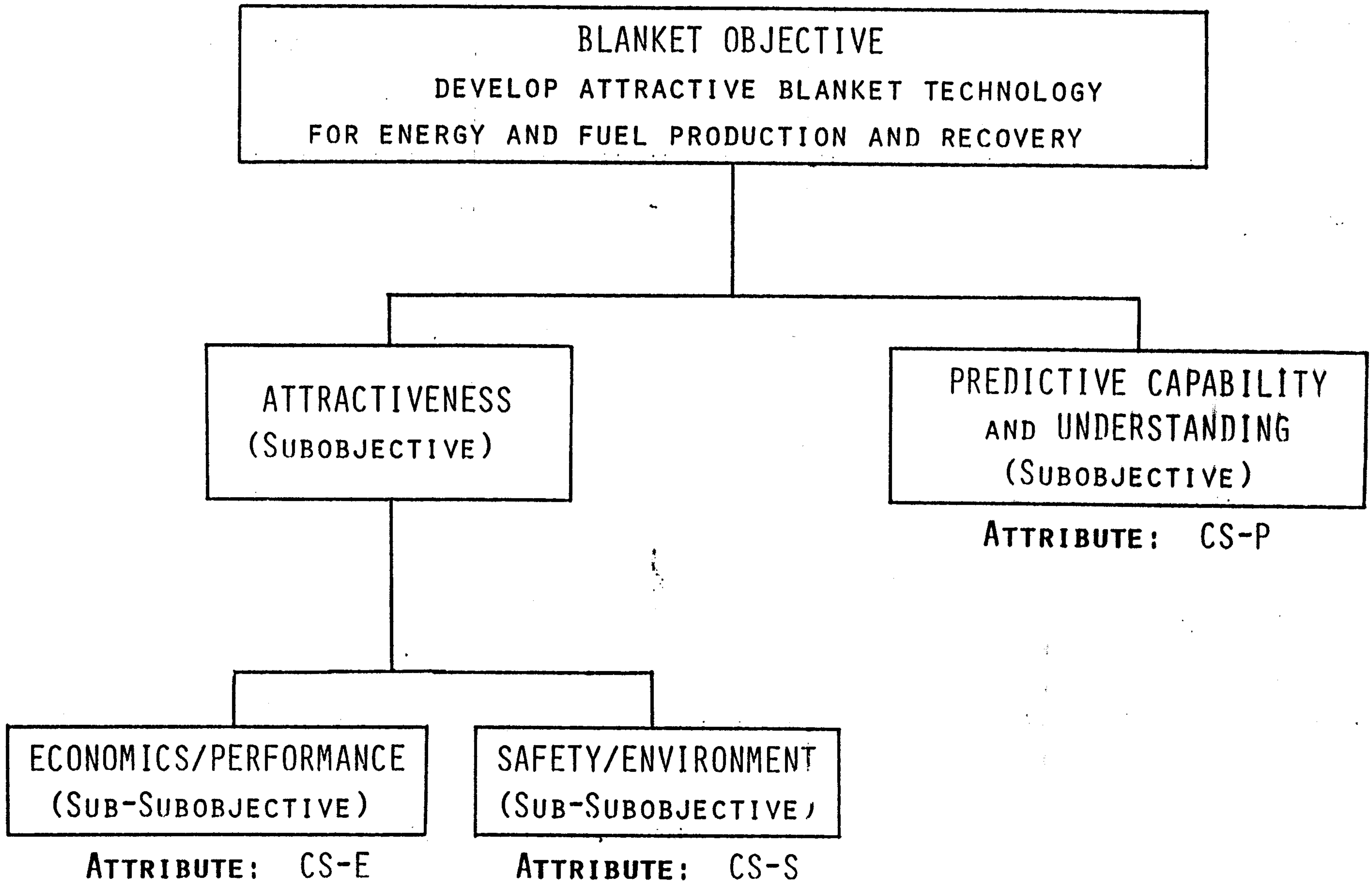
  NATURAL, PROXY, OR CONSTRUCTED

FUSION NUCLEAR TECHNOLOGY

OBJECTIVE

SHOW THAT IT WILL BE POSSIBLE TO DEVELOP ATTRACTIVE NUCLEAR TECHNOLOGY SUBSYSTEMS UNDER CONDITIONS RELEVANT TO FUSION ENERGY SOURCES.

PROVIDE A PREDICTIVE CAPABILITY WHICH CAN BE USED TO ASSESS THE PERFORMANCE OF FUSION NUCLEAR SUBSYSTEMS


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

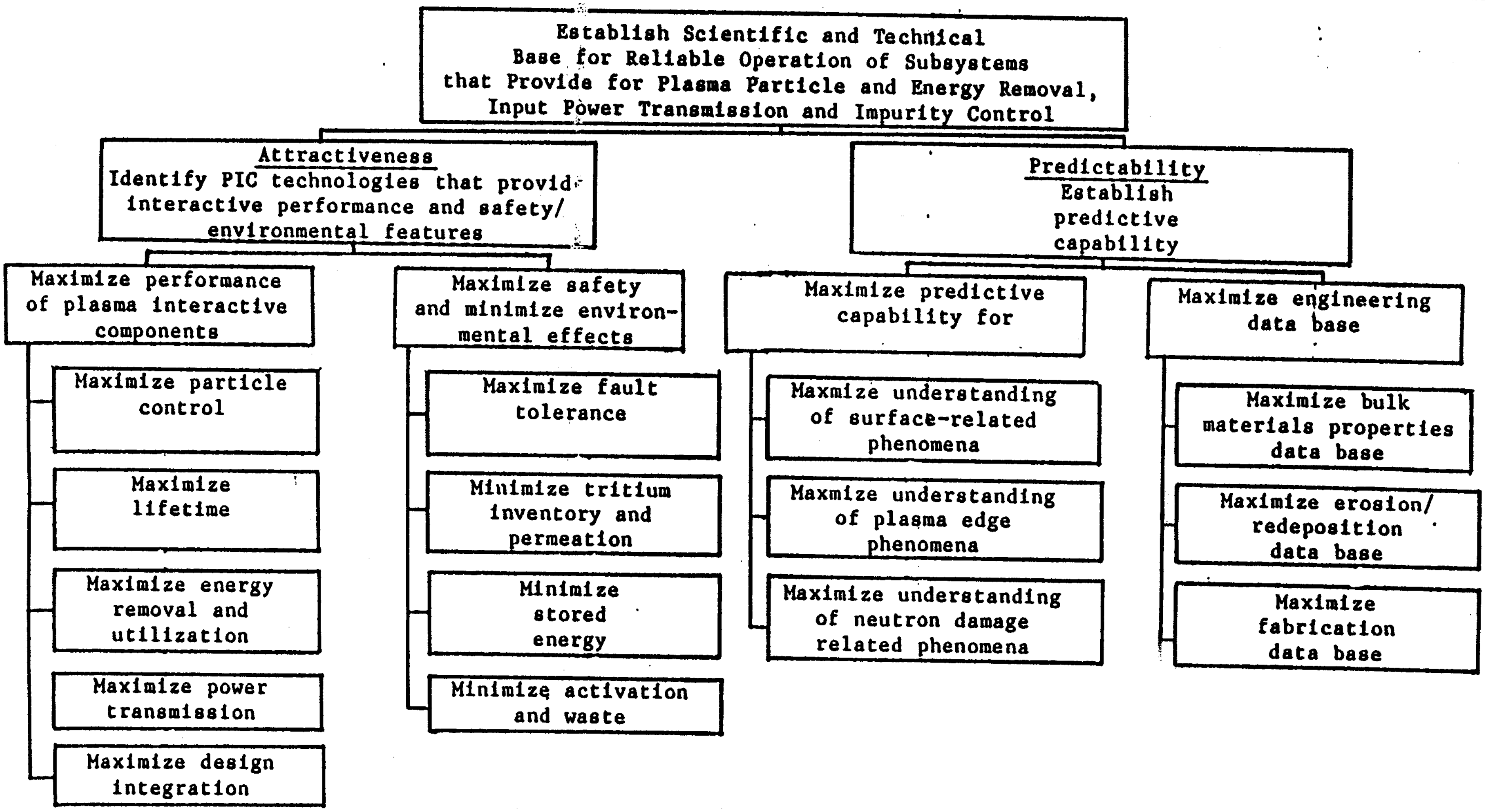
- Chemical Reactivity
- Response to Loss-of-Coolant
- Vulnerable Tritium Inventory
- Long-term Activation
- Afterheat
- Routine Radioactivity Release
- Others

Prediction/Understanding

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

Fig. 4.3-7

OBJECTIVES FOR PLASMA INTERACTIVE COMPONENTS (PIC)*



* Important factors for specifying attributes are summarized in Table 4.3-1.

Fig. 4.3-5

OBJECTIVES AND ATTRIBUTES FOR FUELING

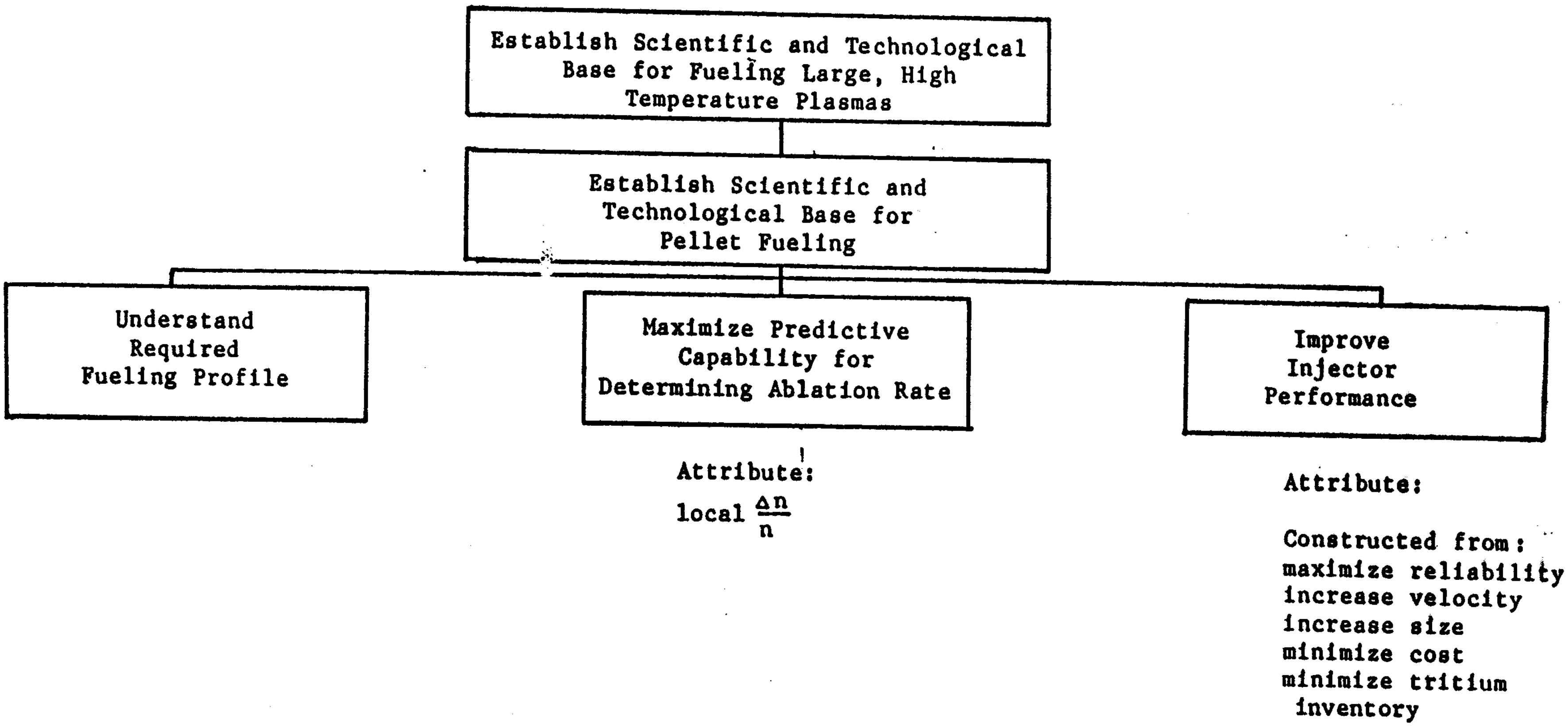
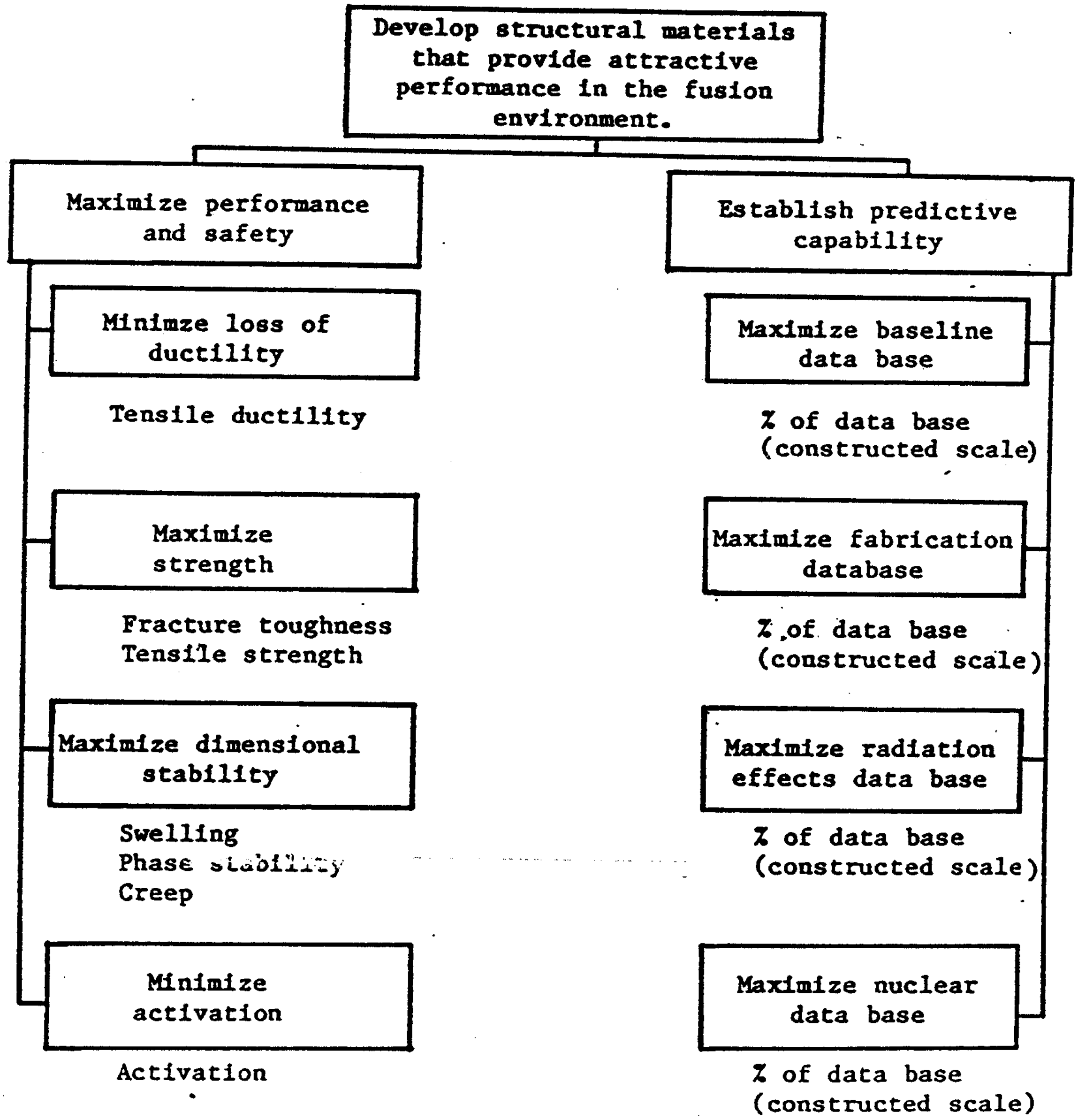
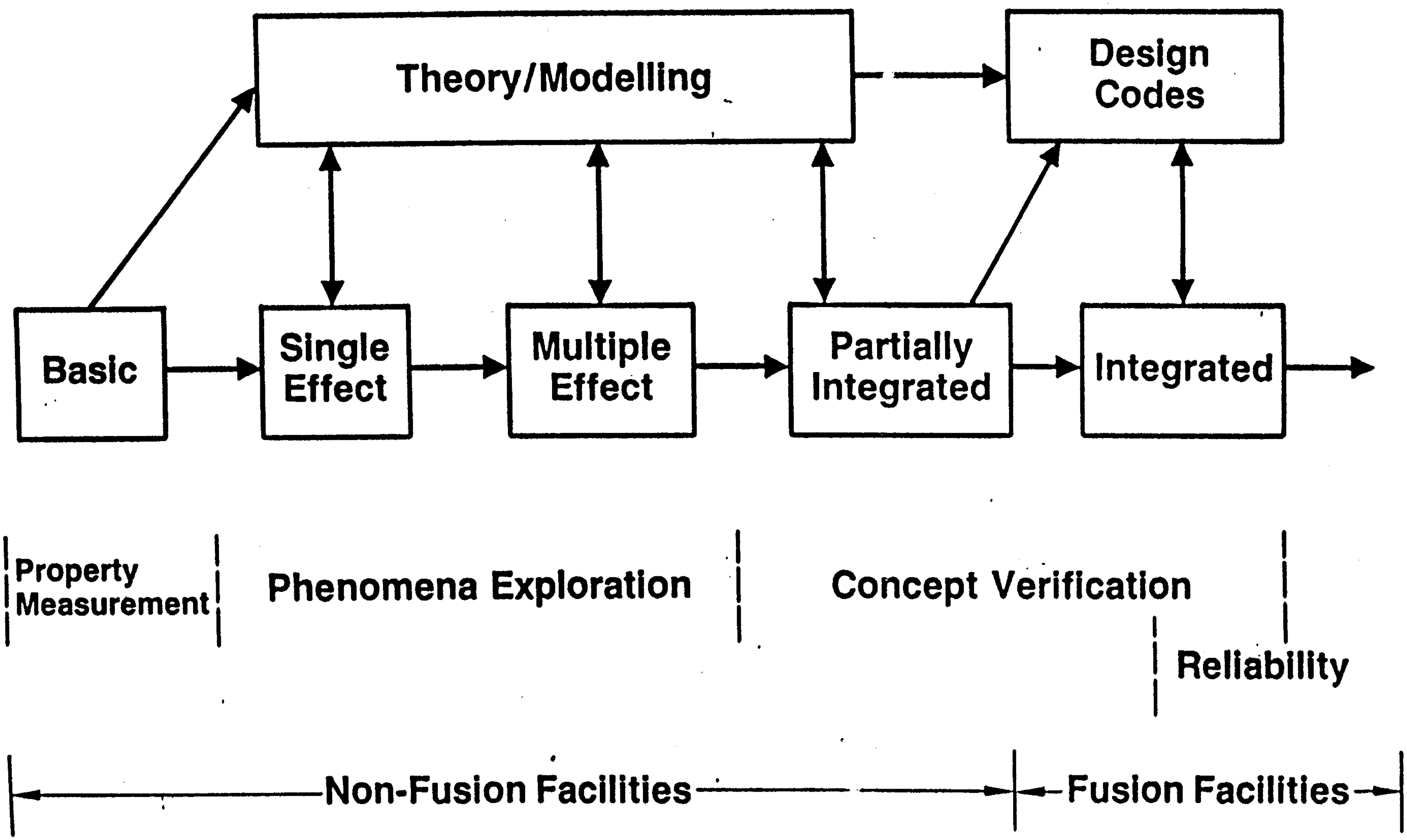


Fig. 4.3-13

OBJECTIVES AND ATTRIBUTES FOR STRUCTURAL MATERIALS




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

PLASMA-INTERACTIVE COMPONENTS (PIC)

INCLUDES:

LIMITERS, DIVERTORS, ETC.

IN-VESSEL ELEMENTS OF PLASMA HEATING (E.G. RF ANTENNA)

QUESTION

TPA GROUND RULE CONCERNING NEAR-TERM AND LONG-TERM R&D?

OPTION A

PIC WILL BE DEVELOPED ONLY AS REQUIRED FOR PLASMA EXPERIMENTS (I.E. ONLY NEAR-TERM, ROLL-FORWARD APPROACH)

OPTION B

PIC WILL HAVE TWO R&D ELEMENTS:

1) SUPPORT PLASMA-EXPERIMENTS

2) ADDRESS SELECTED KEY LONG-TERM ISSUES WHERE RESOLUTION IS CRITICAL FOR ECONOMIC AND ENVIRONMENTAL ASSESSMENT

EXAMPLES OF DIFFERENCES BETWEEN NEAR AND LONG-TERM PIC ISSUES

NEAR TERM	LONG TERM
PASSIVE COOLING SHORT PULSE EROSION NOT LIFE-LIMITING DISRUPTION A DRIVING FACTOR HEAT TRANSFER PRIMARY FACTOR TRITIUM PERMEATION NOT A KEY ISSUE IN-VESSEL RF ANTENNA ACCEPTABLE	ACTIVE COOLING LONG PULSE EROSION IS CRITICAL DISRUPTION SHOULD NOT BE A DRIVER THERMOMECHANICAL RESPONSE MAIN FACTOR TRITIUM PERMEATION A KEY ISSUE IN-VESSEL RF ANTENNA MAY NOT BE ACCEPTABLE
GRAPHITE SURFACE ACCEPTABLE WATER COOLING ACCEPTABLE	GRAPHITE TILES NOT ACCEPTABLE NEED TO EXPLORE LIQUID METALS

PIC PLANNING GROUNDRULE (NEAR- VS. LONG-TERM)

OPTION A (ONLY NEAR TERM)	OPTION B (NEAR AND LONG TERM)
ADVANTAGES - WORK COUPLED DIRECTLY TO PROJECTS - ENSURES NEAR-TERM NEEDS ARE MET - ELIMINATES THE NEED FOR A BROAD-BASED PROGRAM BASED ON UNCERTAIN PLASMA CONDITIONS - LOWEST NEAR-TERM COST	ADVANTAGES • PERMITS TIMELY FEEDBACK ON INTER-RELATIONS BETWEEN PIC, CONFINEMENT CONCEPT AND PIC, OTHER TECHNOLOGIES. • REDUCES LONG-TERM RISK • CAN POTENTIALLY SAVE TIME AND MONEY IF WORK ON LONG-TERM ISSUES HELPS WITH CHOICES IN NEAR-TERM
DISADVANTAGES - NEAR-TERM SOLUTIONS MAY NOT EXTRAPOLATE TO ATTRACTIVE CONDITIONS - HIGHEST RISK (MAY SERIOUSLY AFFECT THE OUTCOME OF FUSION ECONOMIC AND ENVIRONMENTAL ASSESSMENT)	DISADVANTAGES • REQUIRES LARGER FUNDING OR MORE BUDGET CONSTRAINTS ON NEAR-TERM EXPERIMENTS • MORE COMPLEX ORGANIZATIONAL PROBLEMS (IN THE FIELD, IN OFE)

BLANKET/FIRST WALL SHIELD GROUP

D. Berwald (Leader)	TRW
J. DeVan	ORNL
P. Gierszewski	UCLA
J. Grover	HEDL
R. Mattas	ANL
D. Morgan	MDAC
S. Piet	EG&G
K. Schultz (shield)	GAT
D. Sze	ANL
M. Tillack	UCLA

MAGNETIC GROUP

C. Henning (Leader)	LLNL
L. Berry	ORNL
P. Bonanos	PPPL
E. Dalder	LLNL
D. Larbalestier	UW
J. Luton	ORNL
B. Montgomery	MIT

TRITIUM GROUP

J. Bartlit (Leader)	LANL
P. Finn	ANL
W. Holtslander	ORNL
S. Piet	EG&G
M. Rogers	Mound
D. Sze	ANL
C. Walthers	LANL
K. Wilson	SNLL

PIC GROUP

W. Gauster (Co-Leader)	SNLA
J. Schmidt (Co-Leader)	PPPL
J. Cecchi	PPPL
J. Downing	LANL
P. Gierszewski	UCLA
D. Hoffman	ORNL
R. Mattas	ANL
R. Watson	SNLA

ALTERNATE POWER CONVERSION GROUP

C. Henning (Leader)	LLNL
B. G. Logan	LLNL
J. Maniscalco	TRW
G. Miley	UI
R. Moir	LLNL
L. Perkins	LLNL
H. Yoshikawa	HEDL

REMOTE MAINTENANCE

W. Gauster (Co-Leader)	SNLA
H. Yoshikawa (Co-Leader)	HEDL
J. Berger	HEDL
H. Conrads	PPPL
R. Harrigan	SNLA
C. Trachsel	MDAC