TPA TECHNOLOGY

STATUS REPORT

PRESENTATION TO OFE

MOHAMED ABDOU

DECEMBER 19, 1985

TPA FUSION TECHNOLOGY STATUS REPORT

Authors

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TPA FUSION TECHNOLOGY STATUS REPORT

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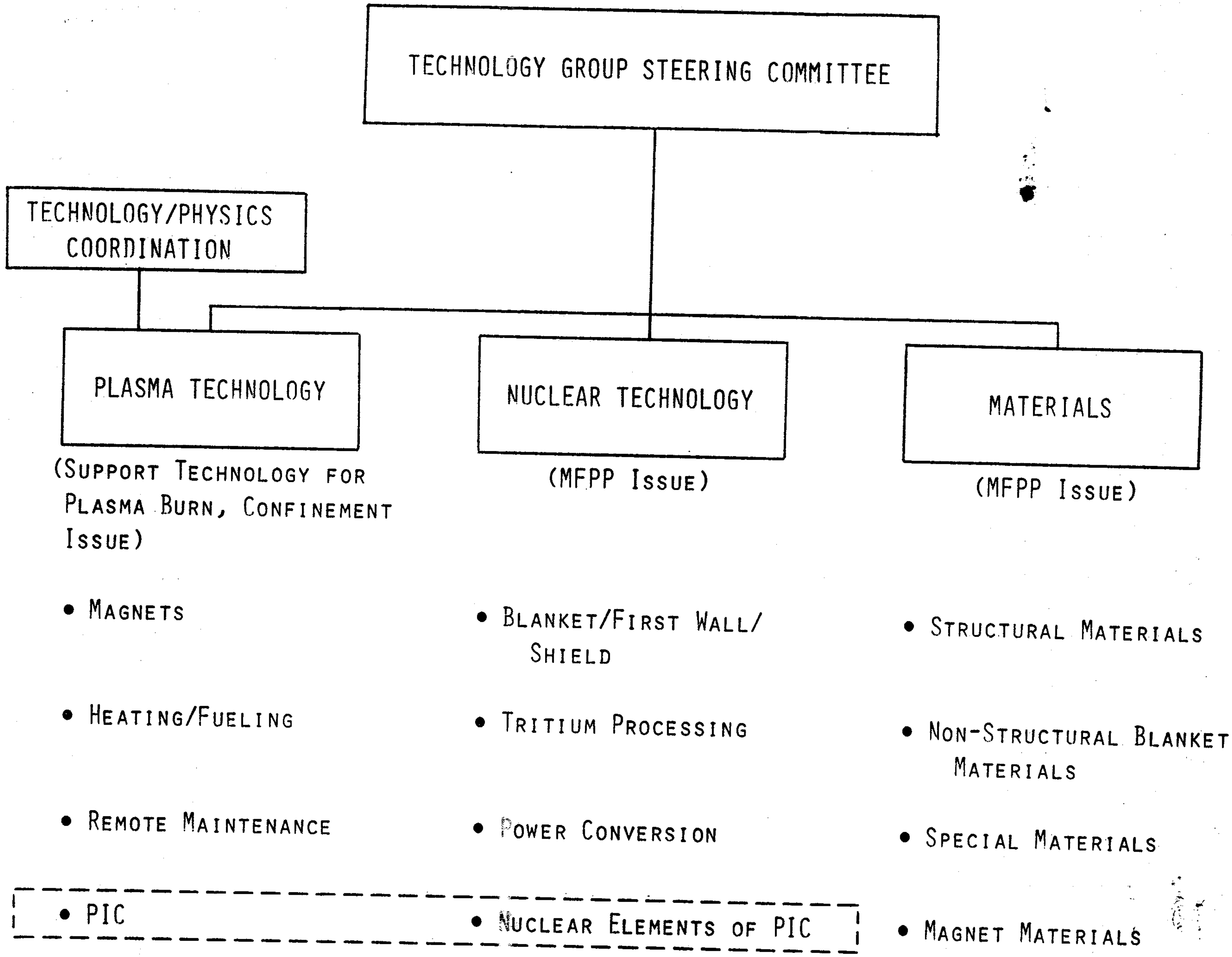
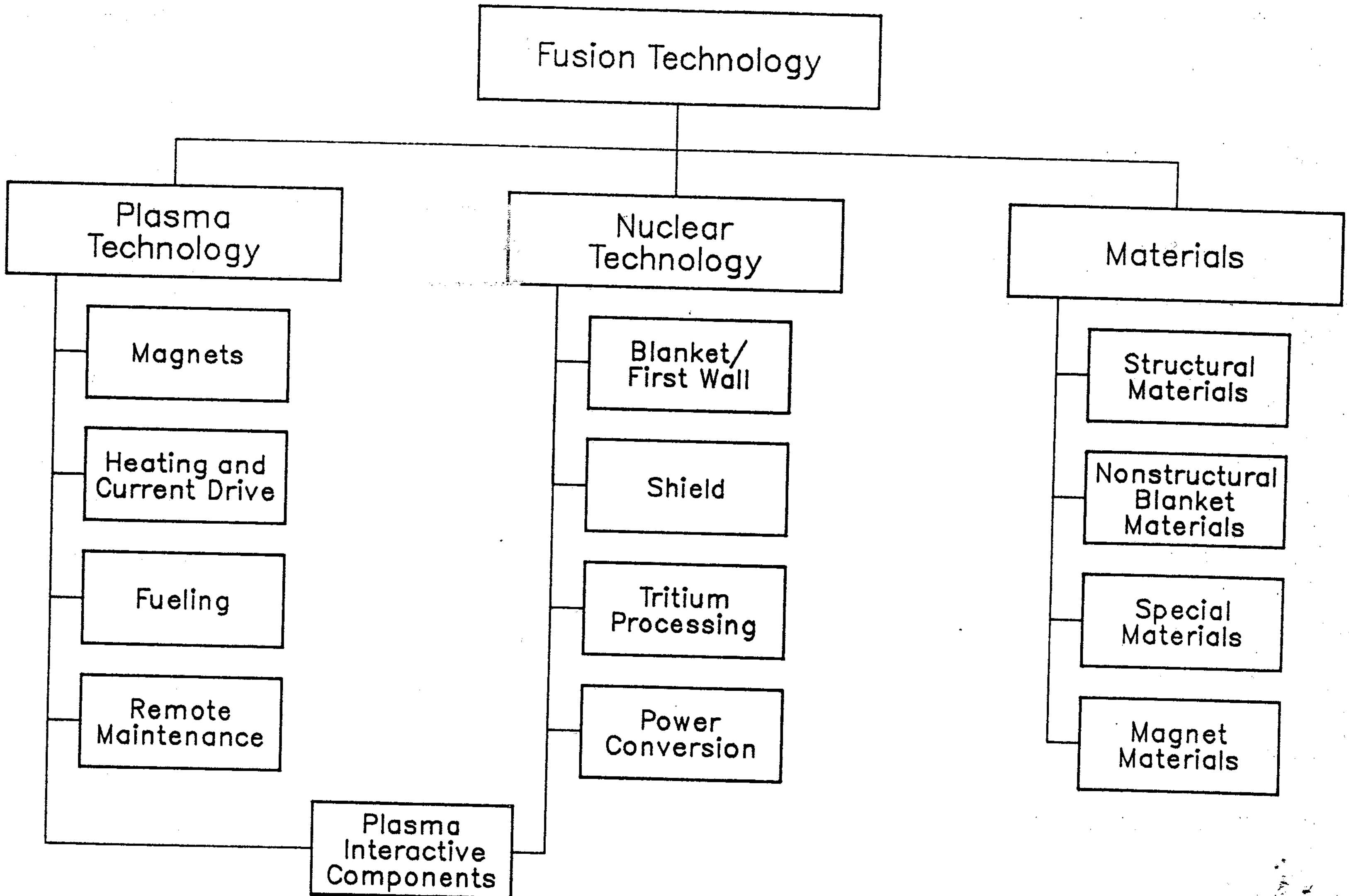

TECHNOLOGY GROUP STEERING COMMITTEE
TECHNOLOGY/PHYSICS COORDINATION
PLASMA TECHNOLOGY
NUCLEAR TECHNOLOGY
MATERIALS
(SUPPORT TECHNOLOGY FOR PLASMA BURN, CONFINEMENT ISSUE)
(MFPP ISSUE)
(MFPP ISSUE)
• MAGNETS
• HEATING/FUELING
• REMOTE MAINTENANCE
• PIC
• BLANKET/FIRST WALL/ SHIELD
• TRITIUM PROCESSING
• POWER CONVERSION
• NUCLEAR ELEMENTS OF PIC
• STRUCTURAL MATERIALS
• NON-STRUCTURAL BLANKET MATERIALS
• SPECIAL MATERIALS
• MAGNET MATERIALS


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

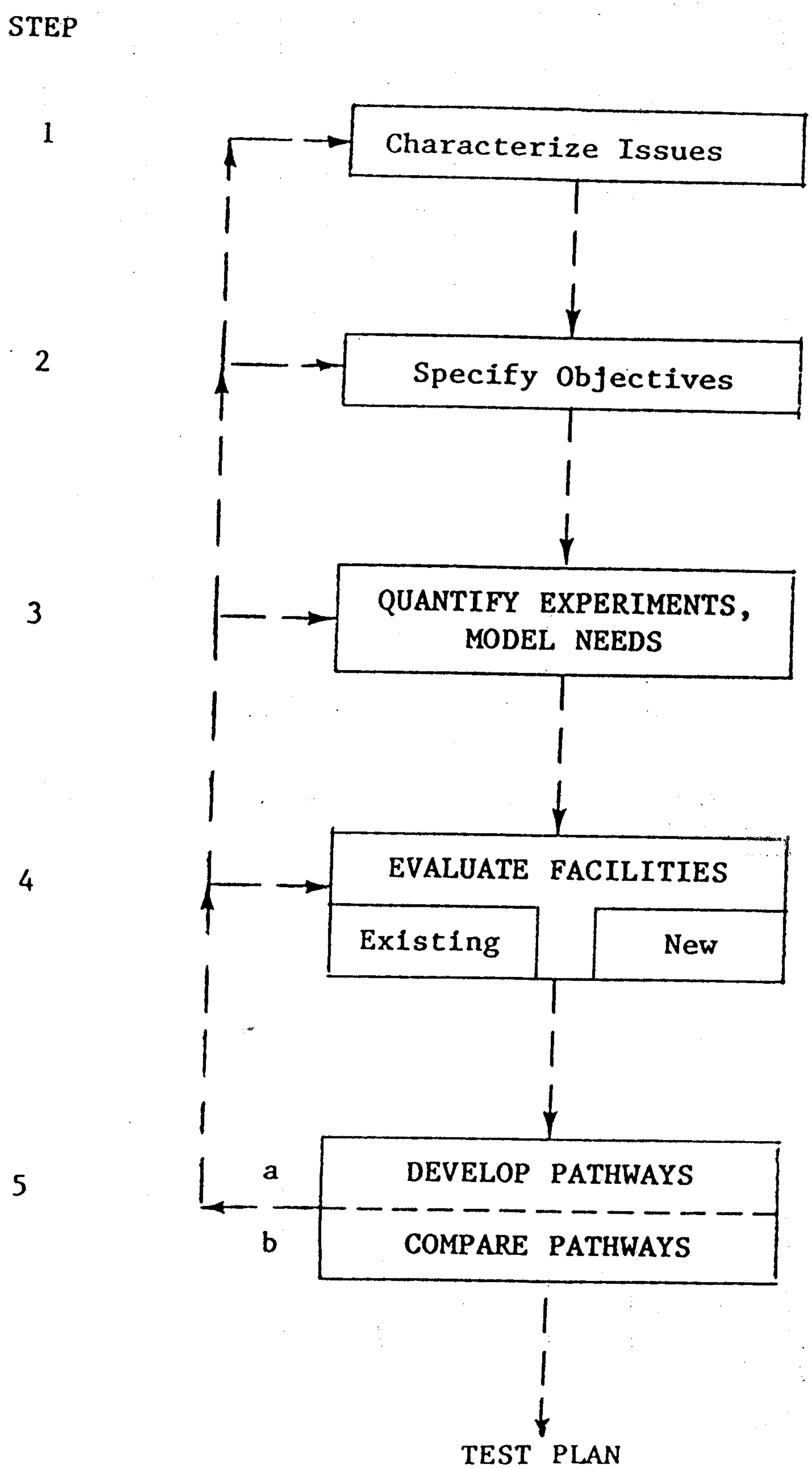
Nuclear Technology

- 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 <u>different</u> meanings:

  <u>Problem</u>

  Uncertainty with Negative Consequence

  <u>Element</u>

  Technical Area, Topic

- <u>Seldom</u> used to mean <u>positive</u>

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

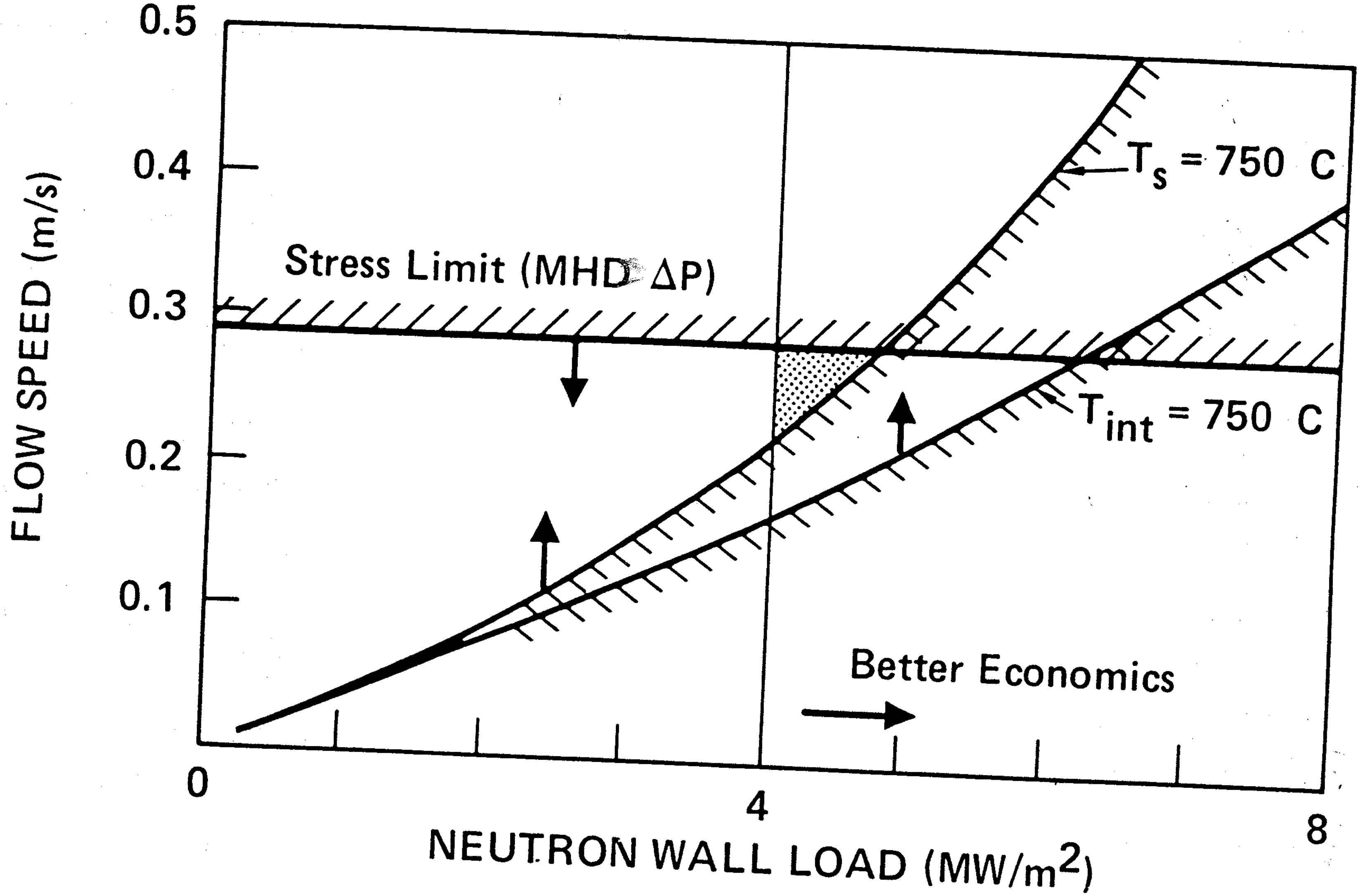
- May Close the Design Window
- May Result in Unacceptable Safety Risk
- May Result in Unacceptable Reliability, Availability or Lifetime

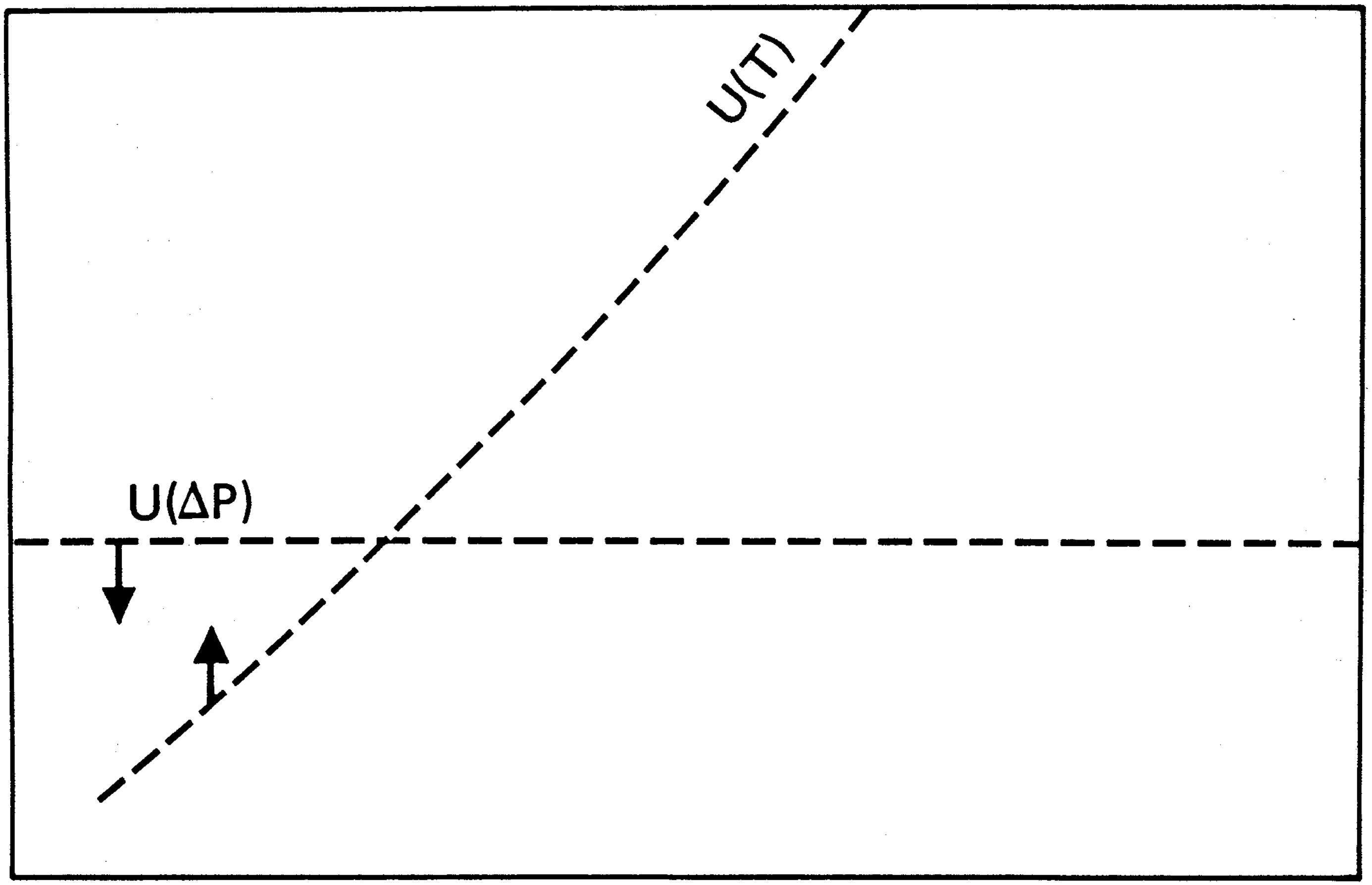
Attractiveness Issues

- 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 AND 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

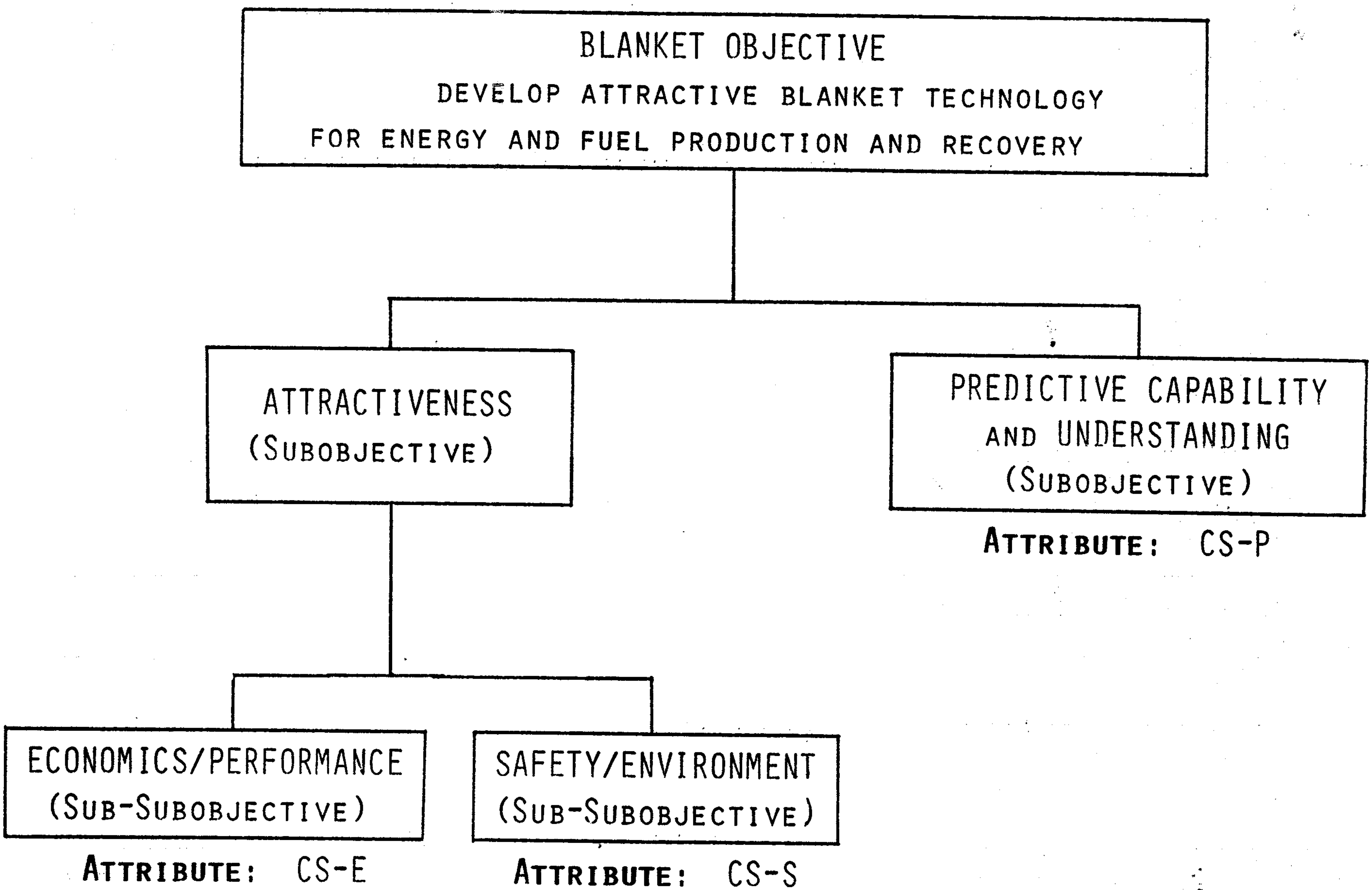
  NATURAL, PROXY, OR CONSTRUCTED

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

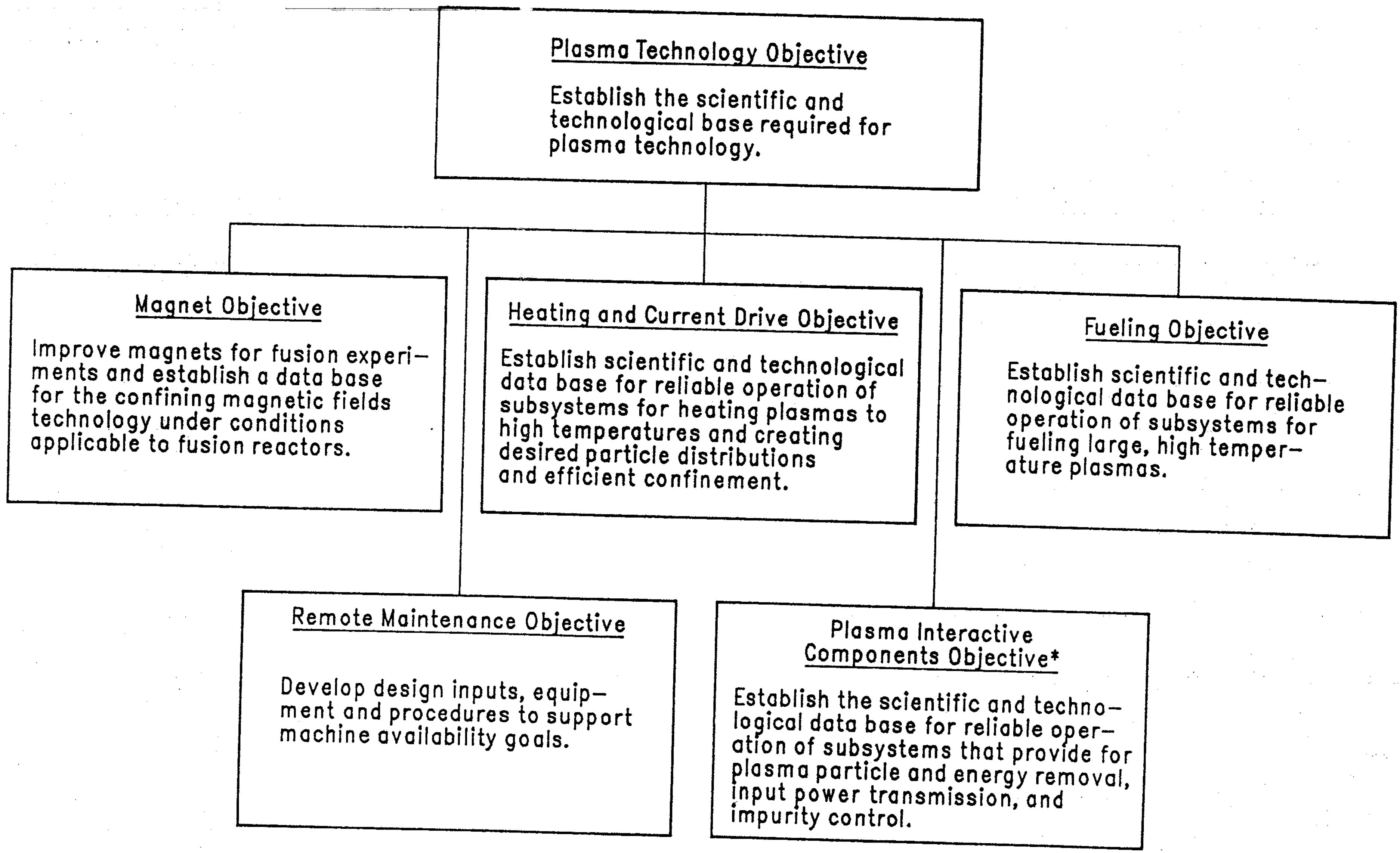
- Neutron Wall Load
- Surface Heat Flux
- Tritium Breeding
- Thermal Efficiency
- Energy Multiplication
- Blanket Thickness
- Reliability
- Lifetime
- Sector MTBF/MTTR
- Blanket/Transport Loop Cost

Safety/Environment

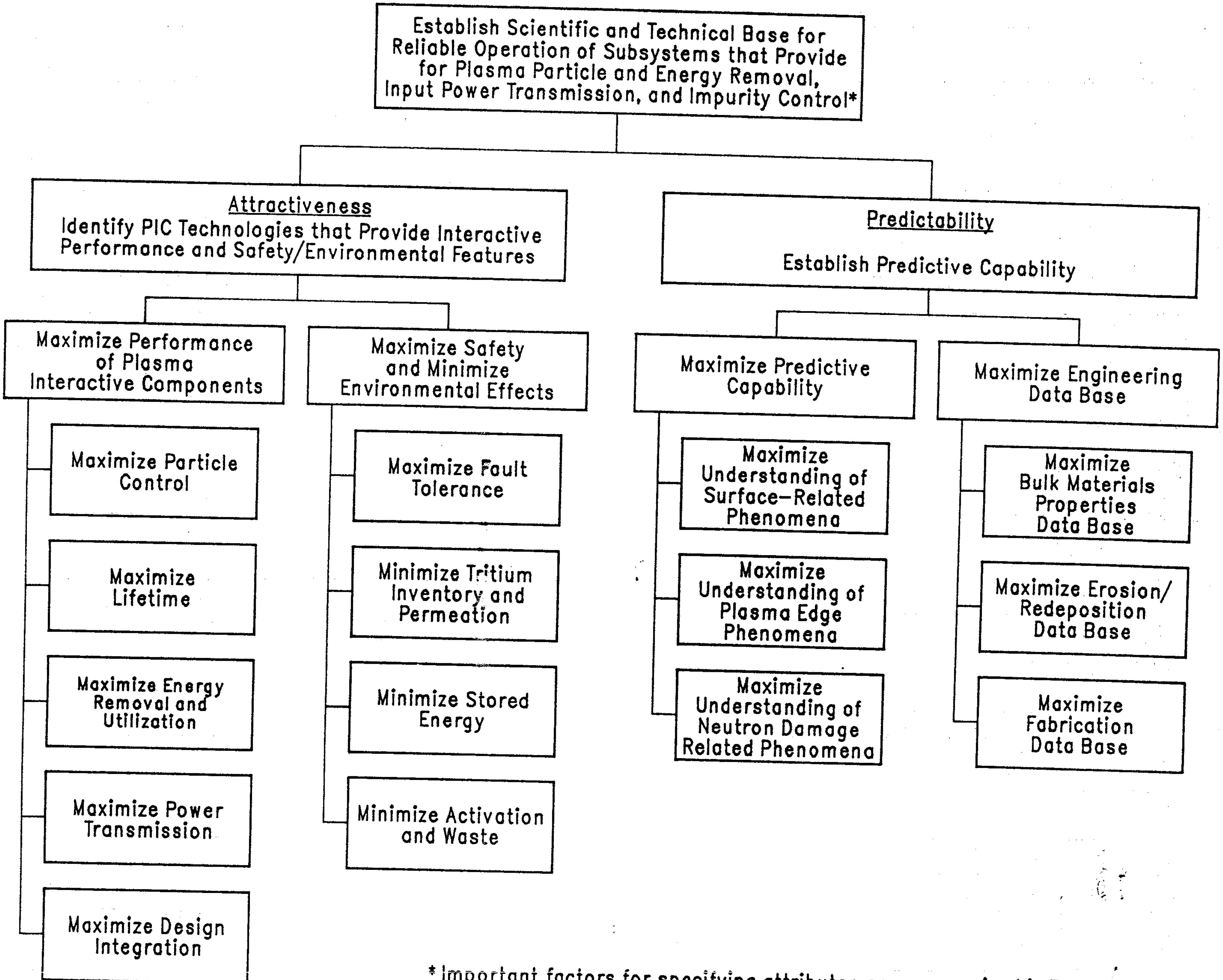
- Chemical Reactivity
- Response to Loss-of-Coolant
- Vulnerable Tritium Inventory
- Long-term Activation
- Afterheat
- Routine Radioactivity Release
- Others

Prediction/Understanding

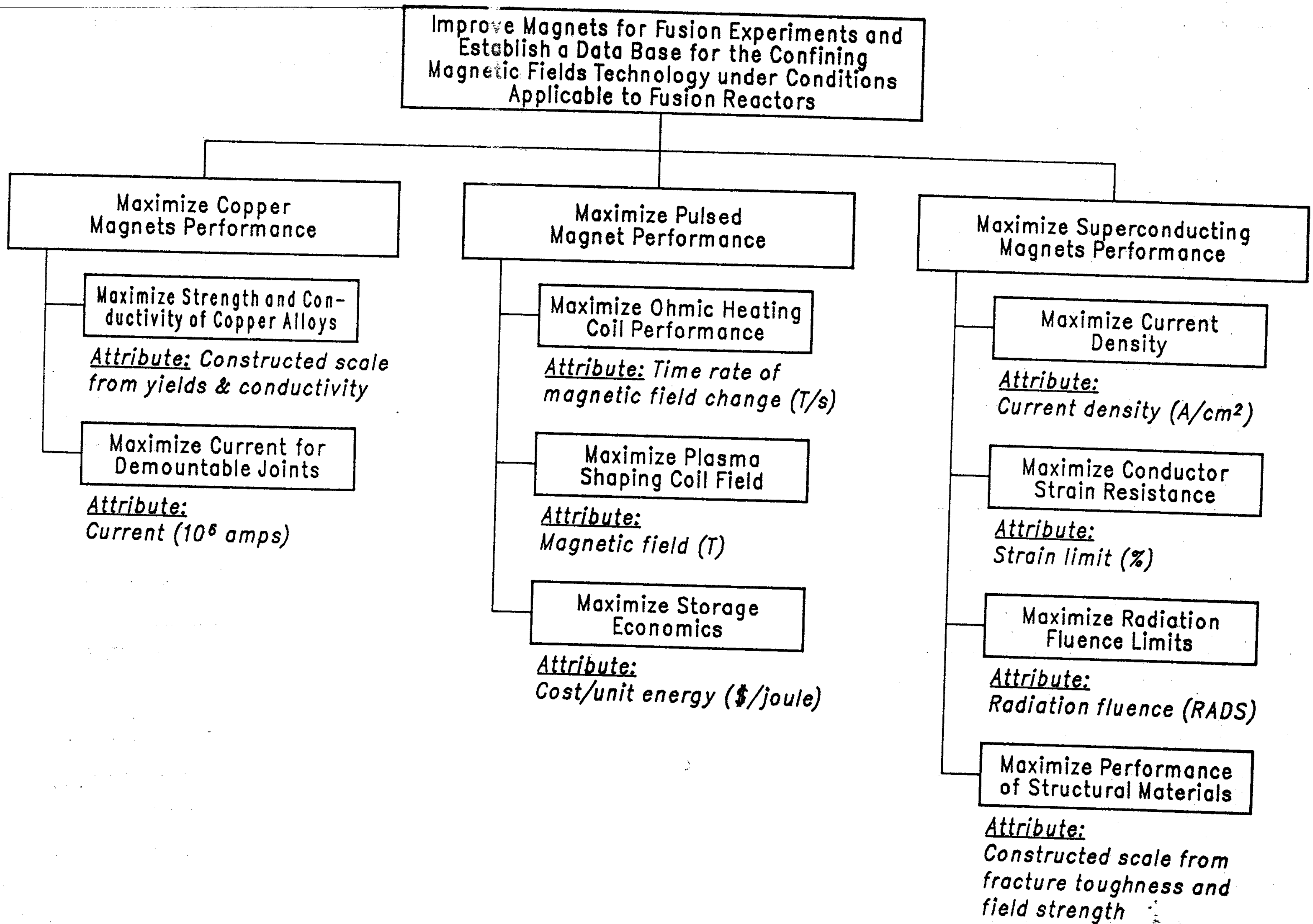
- MHD
  - fluid velocity profile
  - pressure drop
  - heat transfer
  - corrosion
- Tritium Inventory
  - solubility
  - transport
  - etc.
- Materials Interactions
  - Breeder/Structure
  - Coolant/Structure
  - Purge/Breeder



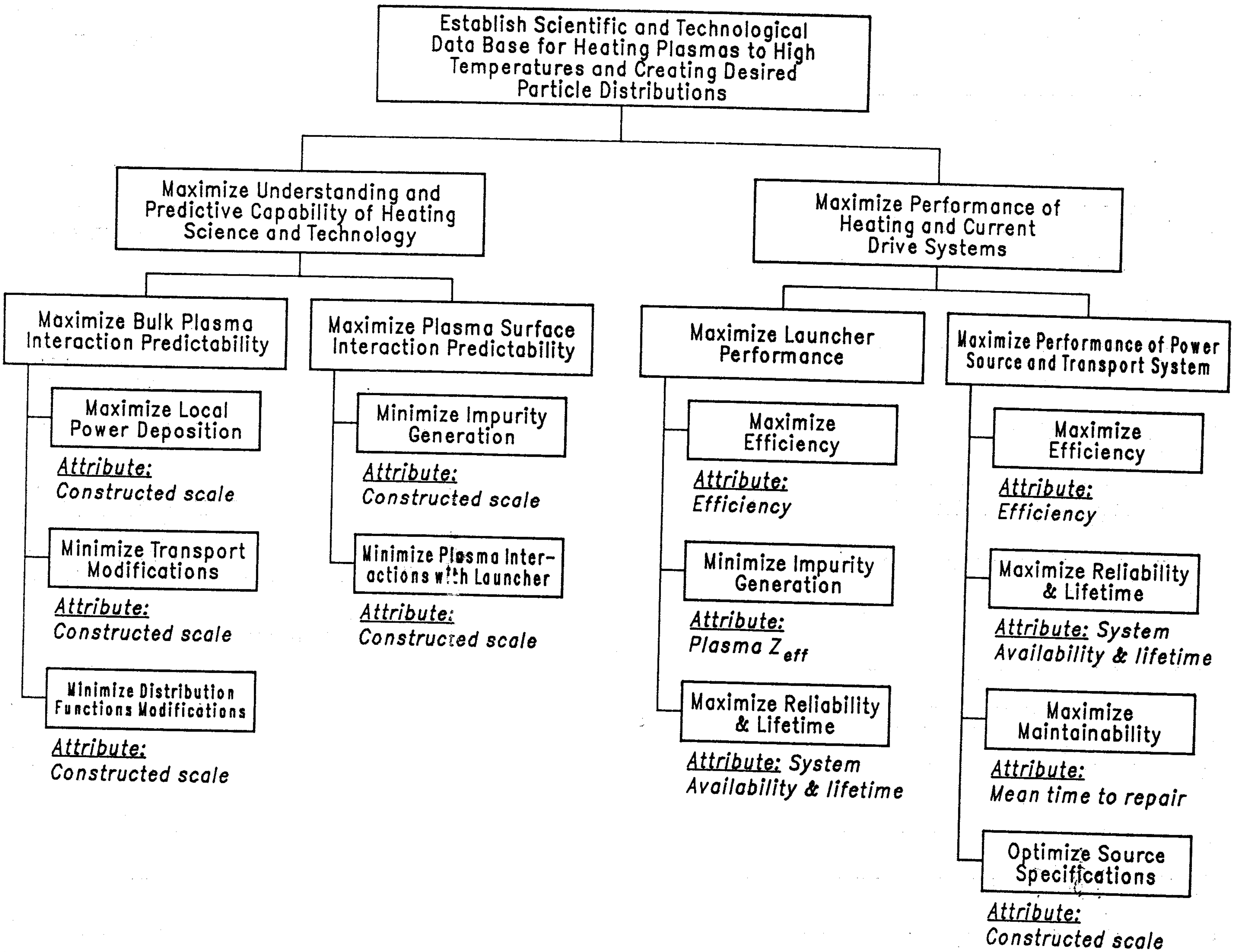
*Also shown under Nuclear Technology in Fig. 4.4-1.

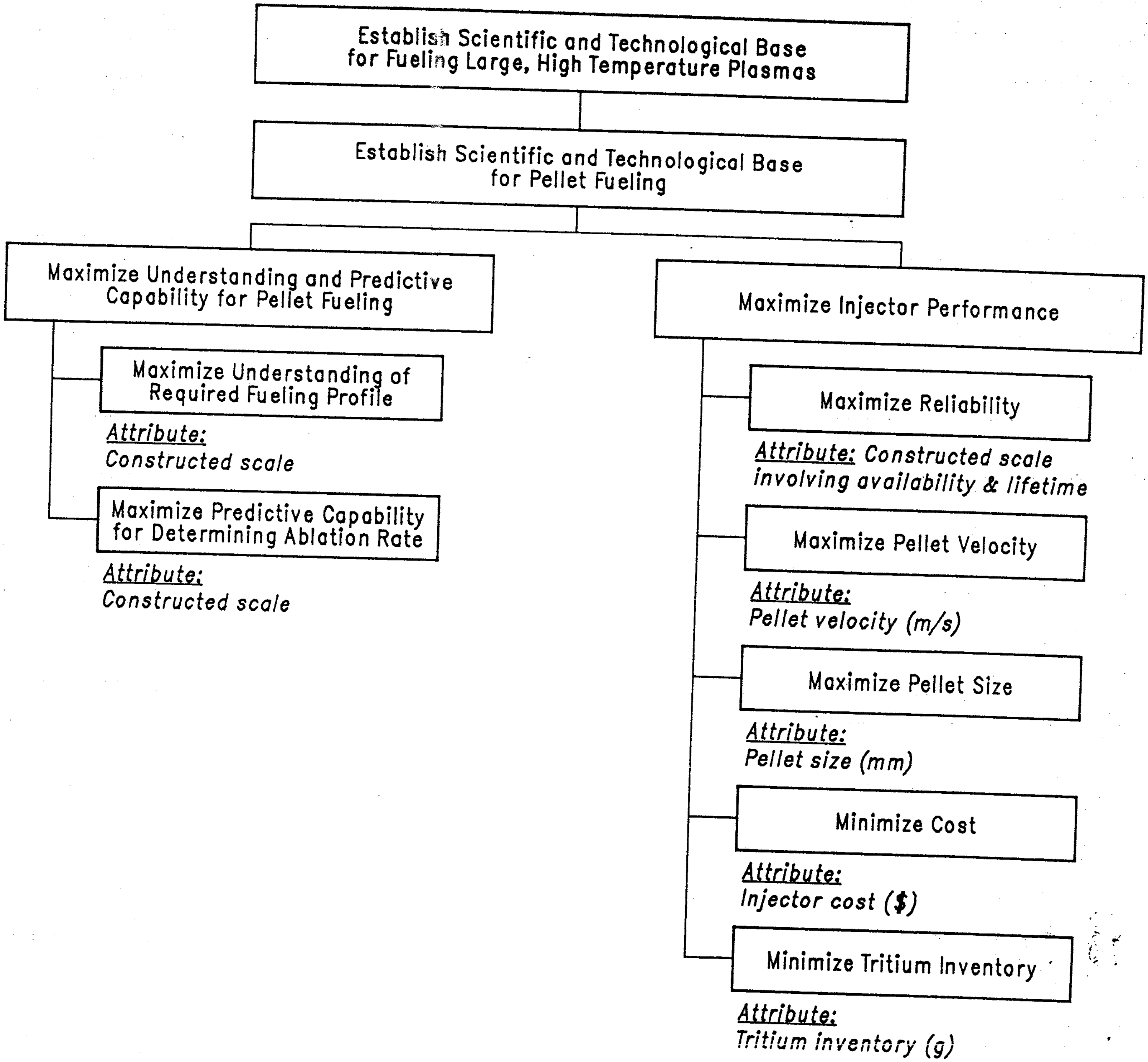


* Important factors for specifying attributes are summarized in Table 4.3-1.

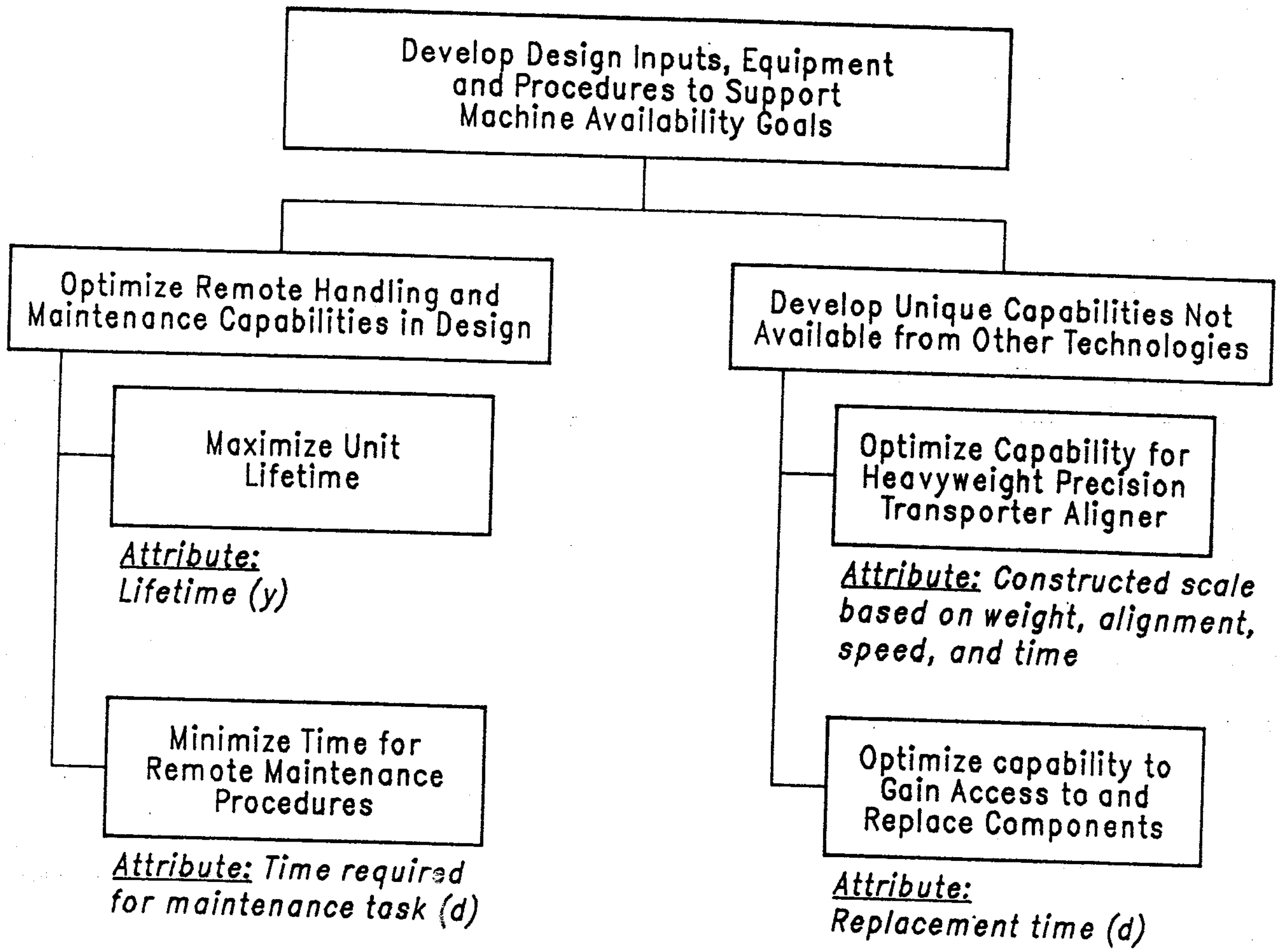


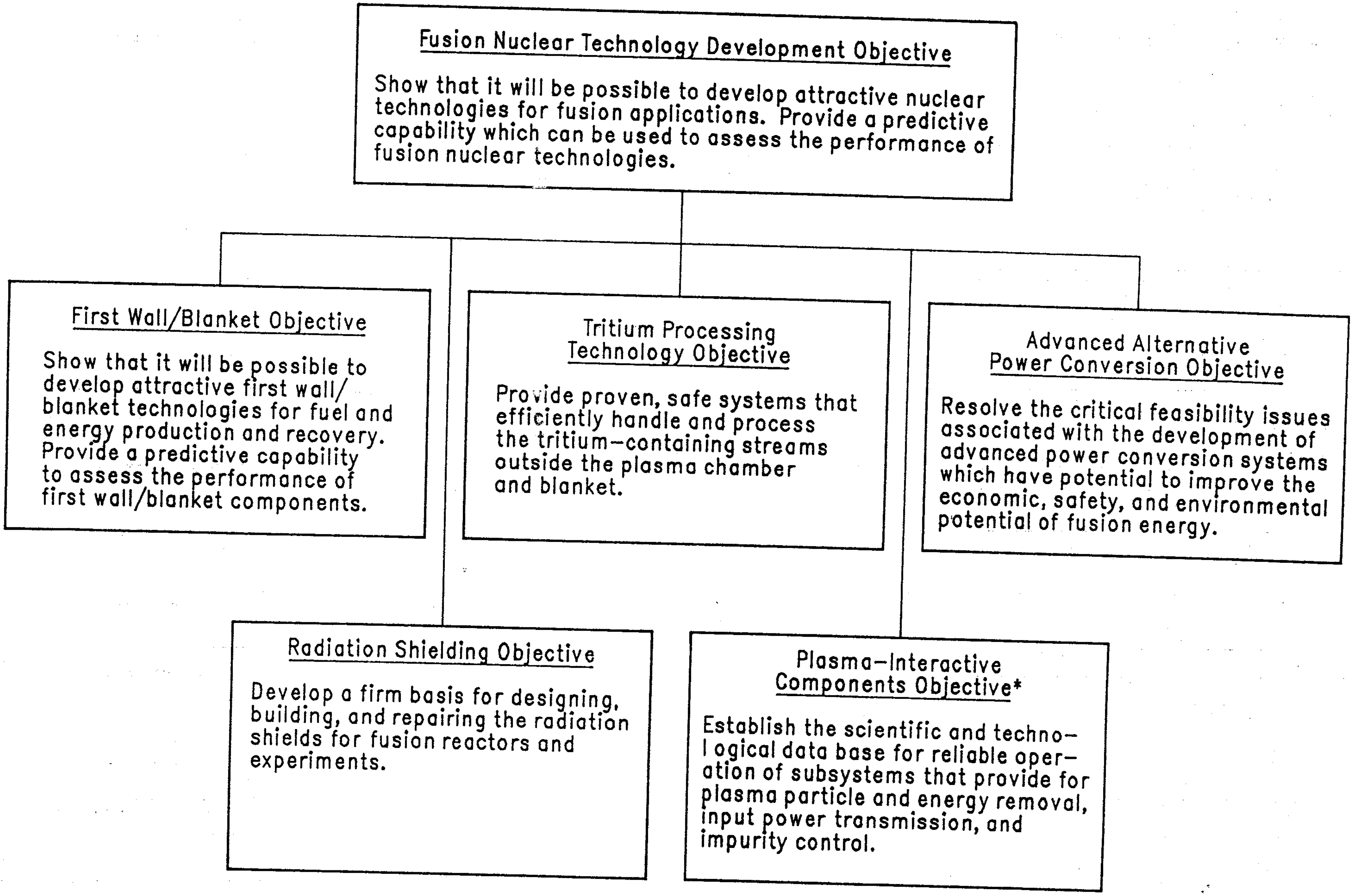
Improve Magnets for Fusion Experiments and Establish a Data Base for the Confining Magnetic Fields Technology under Conditions Applicable to Fusion Reactors
Maximize Copper Magnets Performance
Maximize Strength and Conductivity of Copper Alloys
Attribute: Constructed scale from yields & conductivity
Maximize Current for Demountable Joints
Attribute: Current (10^6 amps)
Maximize Pulsed Magnet Performance
Maximize Ohmic Heating Coil Performance
Attribute: Time rate of magnetic field change (T/s)
Maximize Plasma Shaping Coil Field
Attribute: Magnetic field (T)
Maximize Storage Economics
Attribute: Cost/unit energy ($/joule)
Maximize Superconducting Magnets Performance
Maximize Current Density
Attribute: Current density (A/cm²)
Maximize Conductor Strain Resistance
Attribute: Strain limit (%)
Maximize Radiation Fluence Limits
Attribute: Radiation fluence (RADS)
Maximize Performance of Structural Materials
Attribute: Constructed scale from fracture toughness and field strength


Establish Scientific and Technological Data Base for Heating Plasmas to High Temperatures and Creating Desired Particle Distributions
Maximize Understanding and Predictive Capability of Heating Science and Technology
Maximize Performance of Heating and Current Drive Systems
Maximize Bulk Plasma Interaction Predictability
Maximize Plasma Surface Interaction Predictability
Maximize Launcher Performance
Maximize Performance of Power Source and Transport System
Maximize Local Power Deposition
Attribute: Constructed scale
Minimize Transport Modifications
Attribute: Constructed scale
Minimize Distribution Functions Modifications
Attribute: Constructed scale
Minimize Impurity Generation
Attribute: Constructed scale
Minimize Plasma Interactions with Launcher
Attribute: Constructed scale
Maximize Efficiency
Attribute: Efficiency
Minimize Impurity Generation
Attribute: Plasma Z_{eff}
Maximize Reliability & Lifetime
Attribute: System Availability & lifetime
Maximize Efficiency
Attribute: Efficiency
Maximize Reliability & Lifetime
Attribute: System Availability & lifetime
Maximize Maintainability
Attribute: Mean time to repair
Optimize Source Specifications
Attribute: Constructed scale



Establish Scientific and Technological Base for Fueling Large, High Temperature Plasmas
Establish Scientific and Technological Base for Pellet Fueling
Maximize Understanding and Predictive Capability for Pellet Fueling
Maximize Understanding of Required Fueling Profile
Attribute: Constructed scale
Maximize Predictive Capability for Determining Ablation Rate
Attribute: Constructed scale
Maximize Injector Performance
Maximize Reliability
Attribute: Constructed scale involving availability & lifetime
Maximize Pellet Velocity
Attribute: Pellet velocity (m/s)
Maximize Pellet Size
Attribute: Pellet size (mm)
Minimize Cost
Attribute: Injector cost ($)
Minimize Tritium Inventory
Attribute: Tritium inventory (g)


Develop Design Inputs, Equipment and Procedures to Support Machine Availability Goals
Optimize Remote Handling and Maintenance Capabilities in Design
Maximize Unit Lifetime
Attribute: Lifetime (y)
Minimize Time for Remote Maintenance Procedures
Attribute: Time required for maintenance task (d)
Develop Unique Capabilities Not Available from Other Technologies
Optimize Capability for Heavyweight Precision Transporter Aligner
Attribute: Constructed scale based on weight, alignment, speed, and time
Optimize capability to Gain Access to and Replace Components
Attribute: Replacement time (d)



*Also shown under Plasma Technology in Fig 4.3–2.

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:

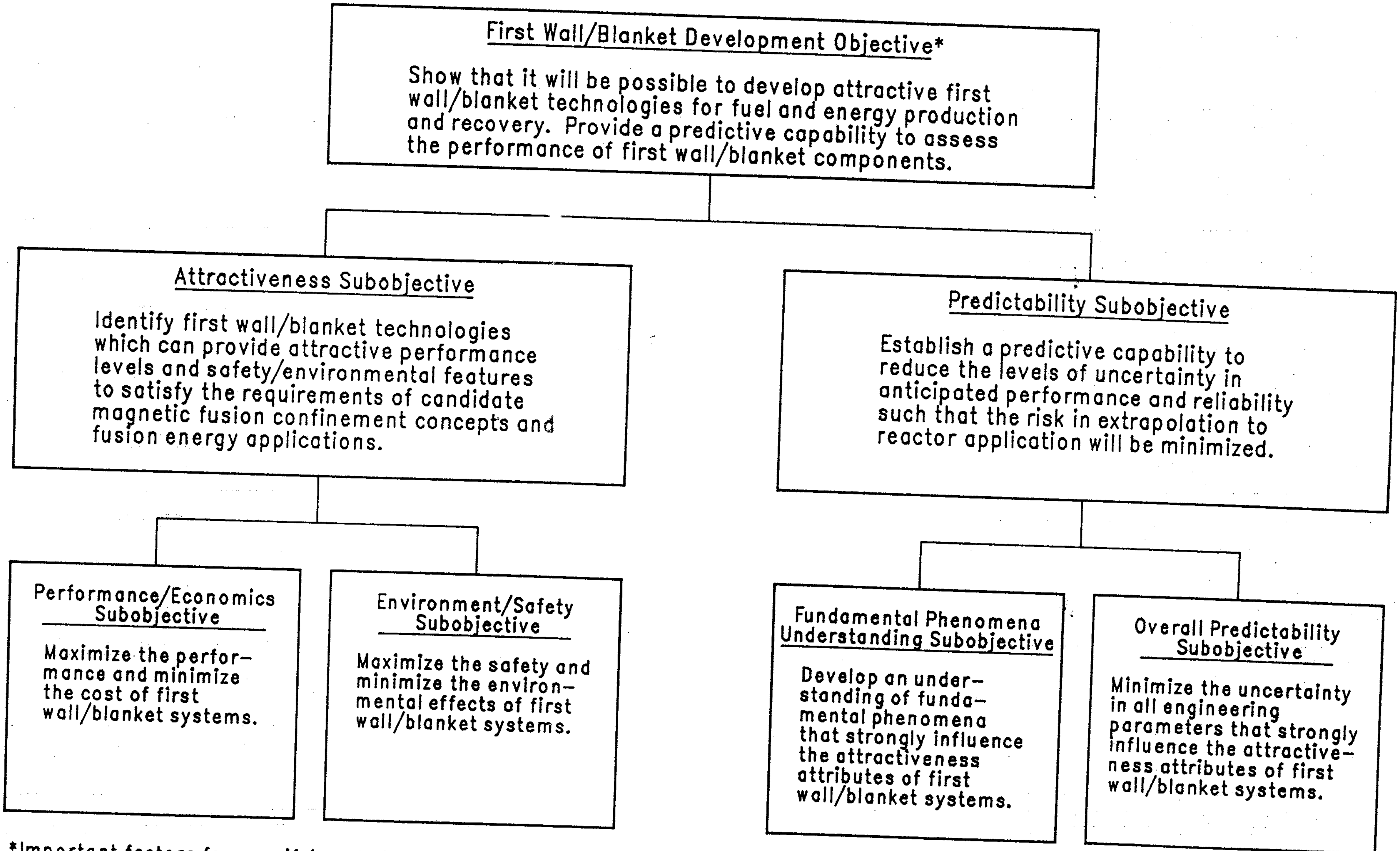
1) SUPPORT PLASMA-EXPERIMENTS
2) ADDRESS SELECTED KEY LONG-TERM ISSUES WHERE RESOLUTION IS CRITICAL FOR ECONOMIC AND ENVIRONMENTAL ASSESSMENT

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)



*Important factors for specifying attributes are summarized in Table 4.4-2.

Radiation Shielding Development Objective*

Develop a firm basis for designing, building, operating, and repairing the radiation shields for fusion reactors and experiments.

Shielding Requirements Subobjective

Establish limits for allowable radiation heating dose and dose rates for key components including superconducting magnets and diagnostics.

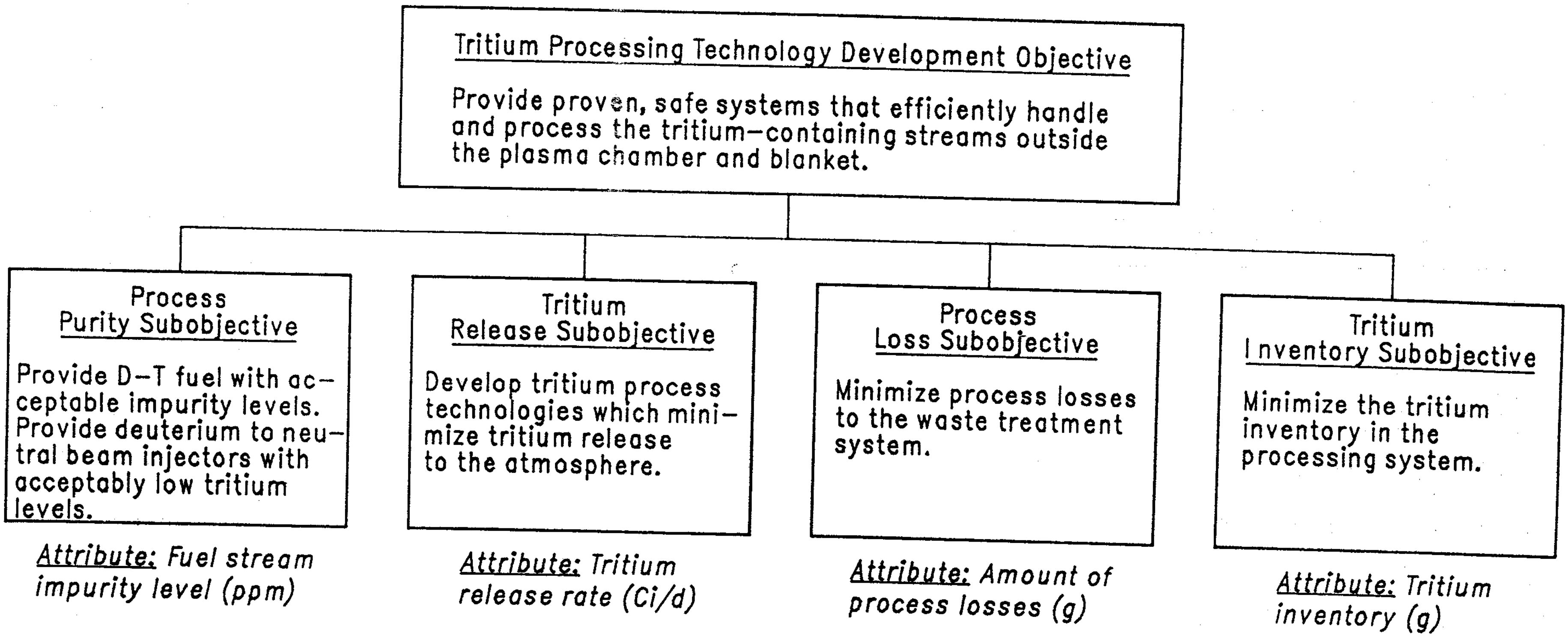
Effectiveness Verification Subobjective

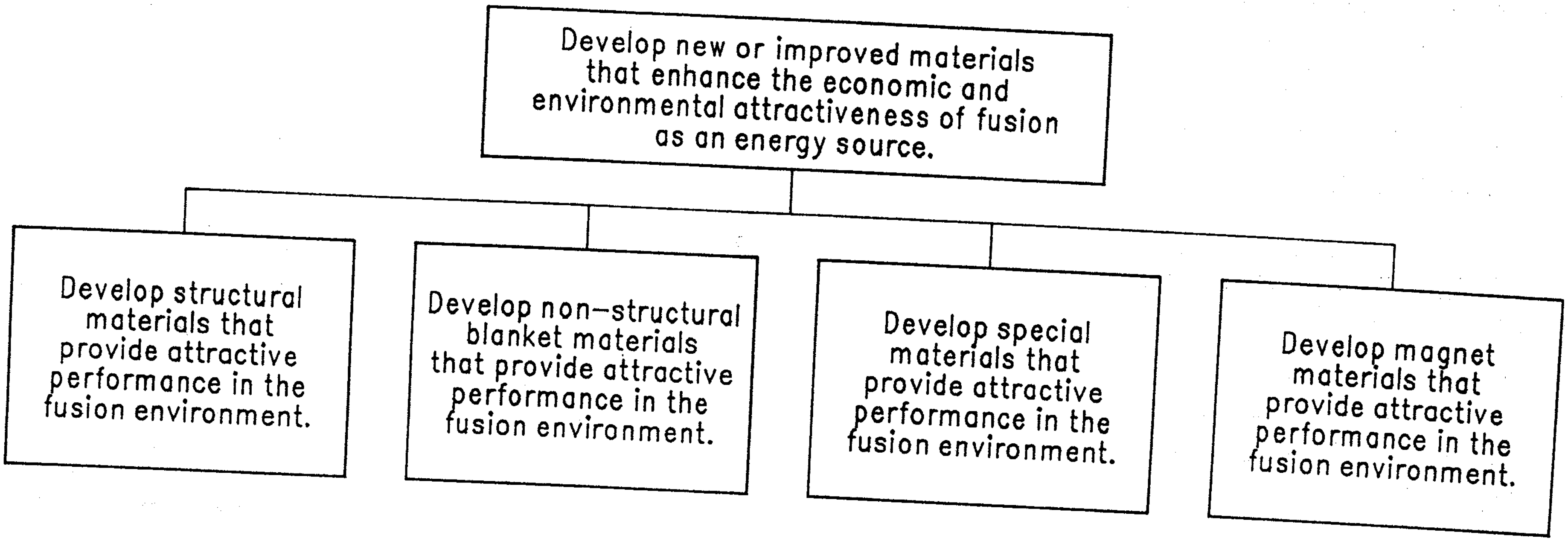
Validate radiation shield analysis codes and data for shielding calculations to verify the adequacy of shield designs.

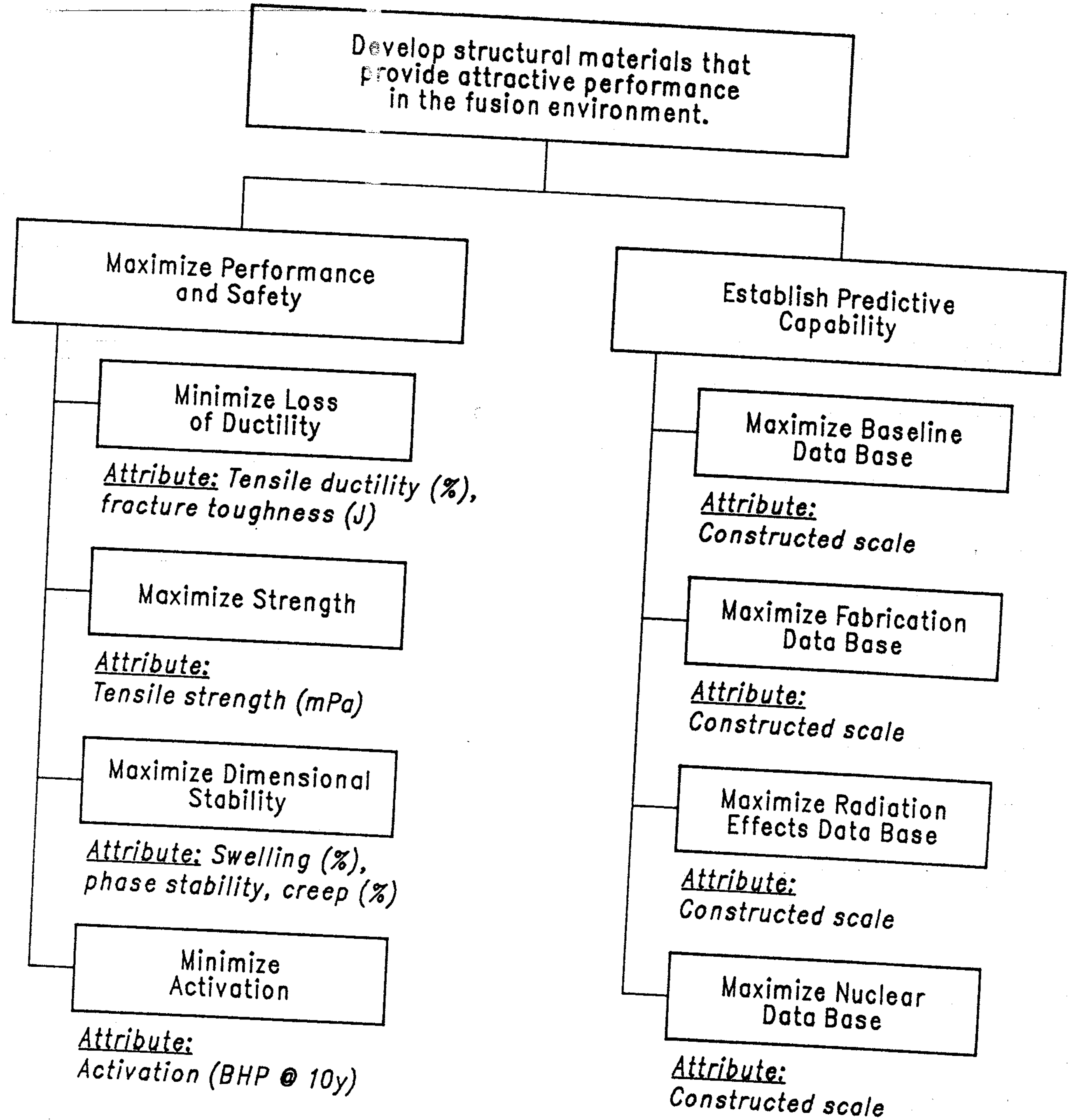
Design Optimization Subobjective

Develop optimized shield designs for maximum effectiveness and minimum cost.

*Attributes for radiation shielding are constructed scales.


Tritium Processing Technology Development Objective
Provide proven, safe systems that efficiently handle and process the tritium–containing streams outside the plasma chamber and blanket.
Process Purity Subobjective
Provide D–T fuel with acceptable impurity levels. Provide deuterium to neutral beam injectors with acceptably low tritium levels.
Attribute: Fuel stream impurity level (ppm)
Tritium Release Subobjective
Develop tritium process technologies which minimize tritium release to the atmosphere.
Attribute: Tritium release rate (Ci/d)
Process Loss Subobjective
Minimize process losses to the waste treatment system.
Attribute: Amount of process losses (g)
Tritium Inventory Subobjective
Minimize the tritium inventory in the processing system.
Attribute: Tritium inventory (g)


Develop new or improved materials that enhance the economic and environmental attractiveness of fusion as an energy source.
Develop structural materials that provide attractive performance in the fusion environment.
Develop non-structural blanket materials that provide attractive performance in the fusion environment.
Develop special materials that provide attractive performance in the fusion environment.
Develop magnet materials that provide attractive performance in the fusion environment.


Develop structural materials that provide attractive performance in the fusion environment.
Maximize Performance and Safety
Minimize Loss of Ductility
Attribute: Tensile ductility (%), fracture toughness (J)
Maximize Strength
Attribute: Tensile strength (mPa)
Maximize Dimensional Stability
Attribute: Swelling (%), phase stability, creep (%)
Minimize Activation
Attribute: Activation (BHP @ 10y)
Establish Predictive Capability
Maximize Baseline Data Base
Attribute: Constructed scale
Maximize Fabrication Data Base
Attribute: Constructed scale
Maximize Radiation Effects Data Base
Attribute: Constructed scale
Maximize Nuclear Data Base
Attribute: Constructed scale