

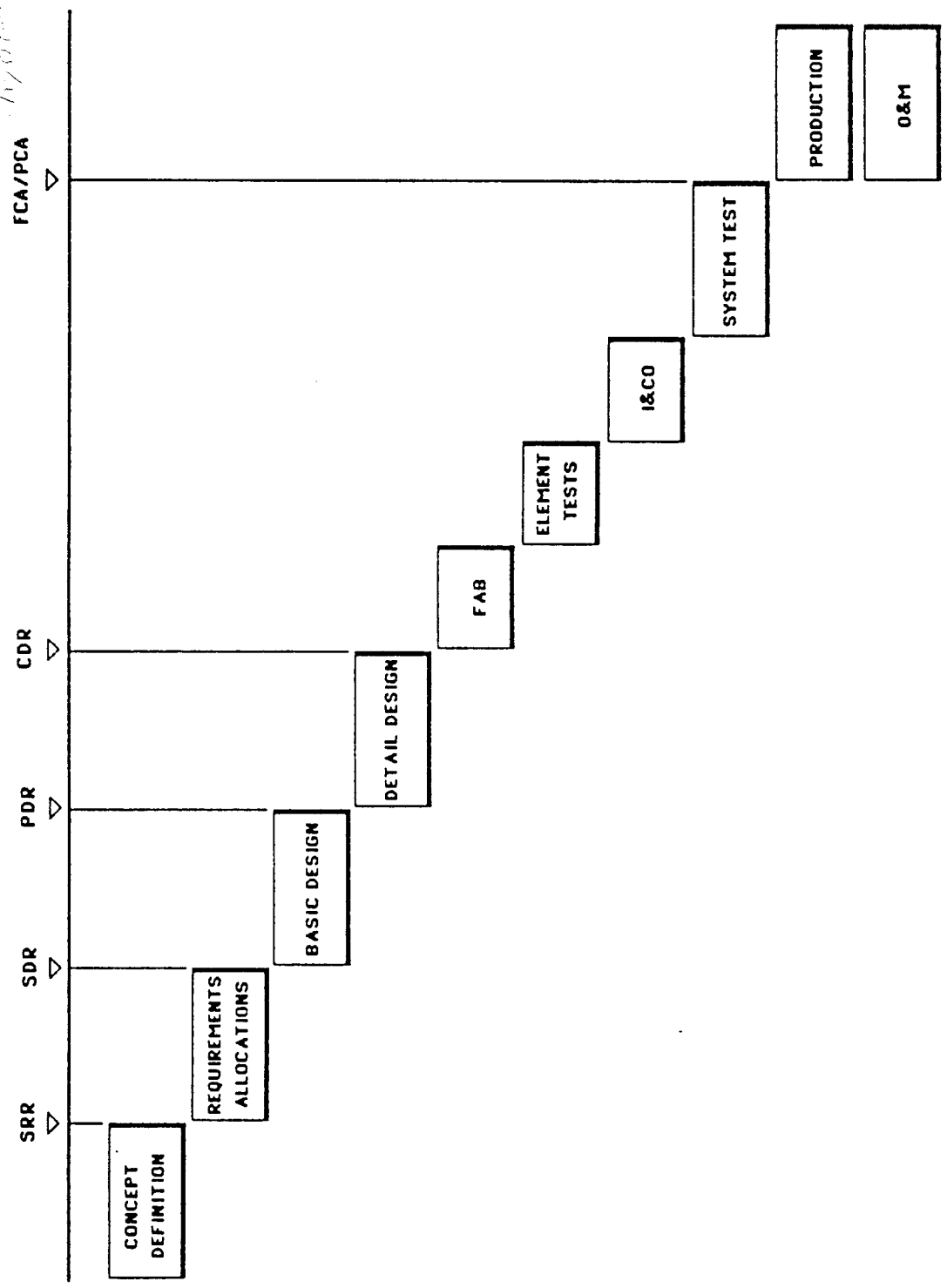
SYSTEMS ENGINEERING PROCESS

KEVIN BROWN
21 DECEMBER 1986

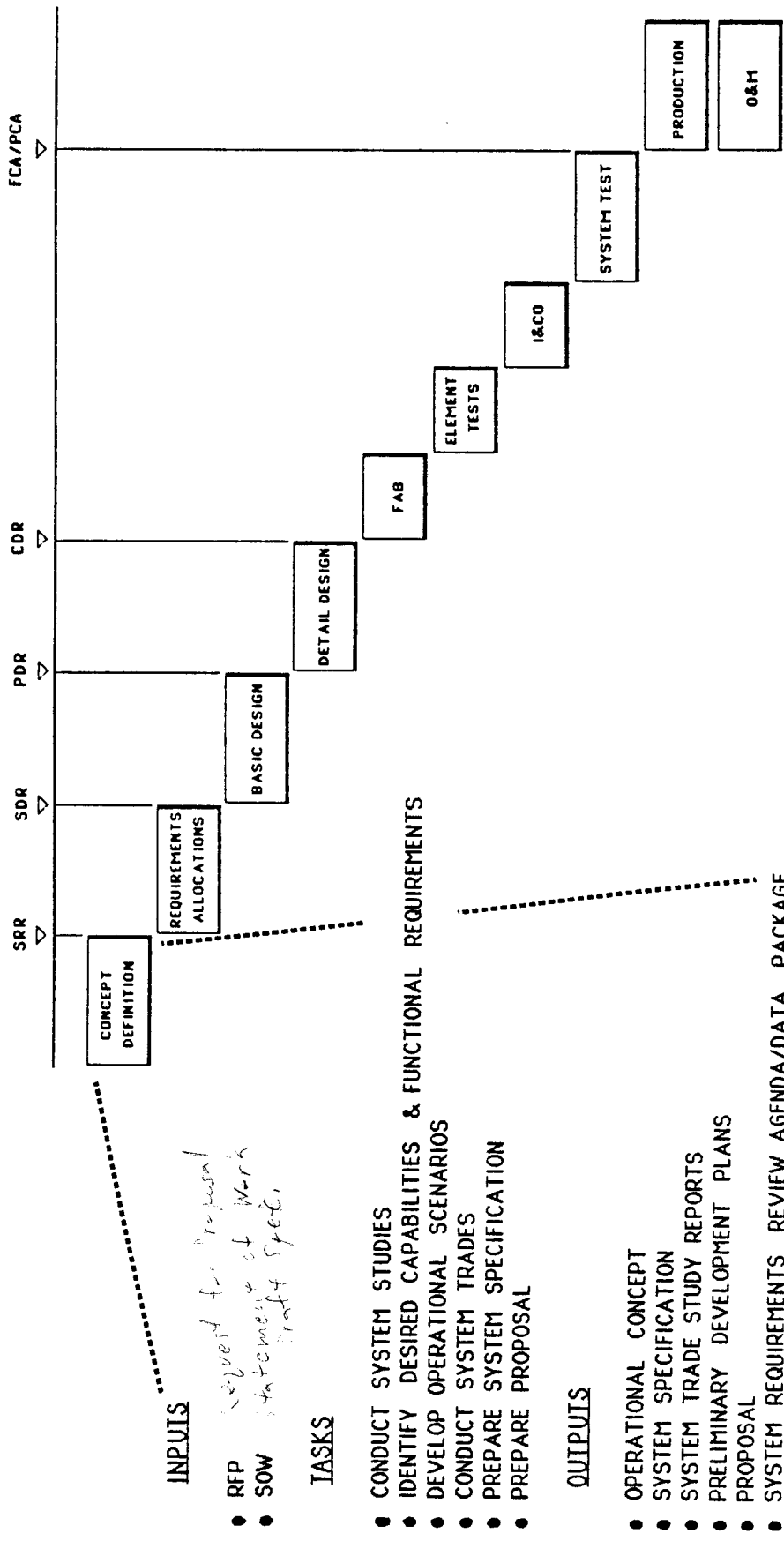
- SYSTEM DEVELOPMENT PROCESS
- BMAC APPROACH TO SYSTEM DEVELOPMENT
- SYSTEMS ENGINEERING FUNCTIONS & PRODUCTS
 - REQUIREMENTS
 - INTERFACE
 - REQUIREMENTS COMPLIANCE
 - DESIGN REVIEWS
 - SYSTEM BASELINE DEVELOPMENT
- SYSTEMS ENGINEERING MANAGEMENT TOOLS
 - TRADE STUDIES
 - TECHNICAL PERFORMANCE MEASUREMENT
 - RISK MANAGEMENT
- SYSTEMS ENGINEERING ORGANIZATION
- RESOURCES

TYPICAL SYSTEM DEVELOPMENT

Traditional System Development Cycle



CONCEPT DEFINITION



INPUTS

- RFP Request for Proposal
- SOW Statement of Work
- Draft Specs

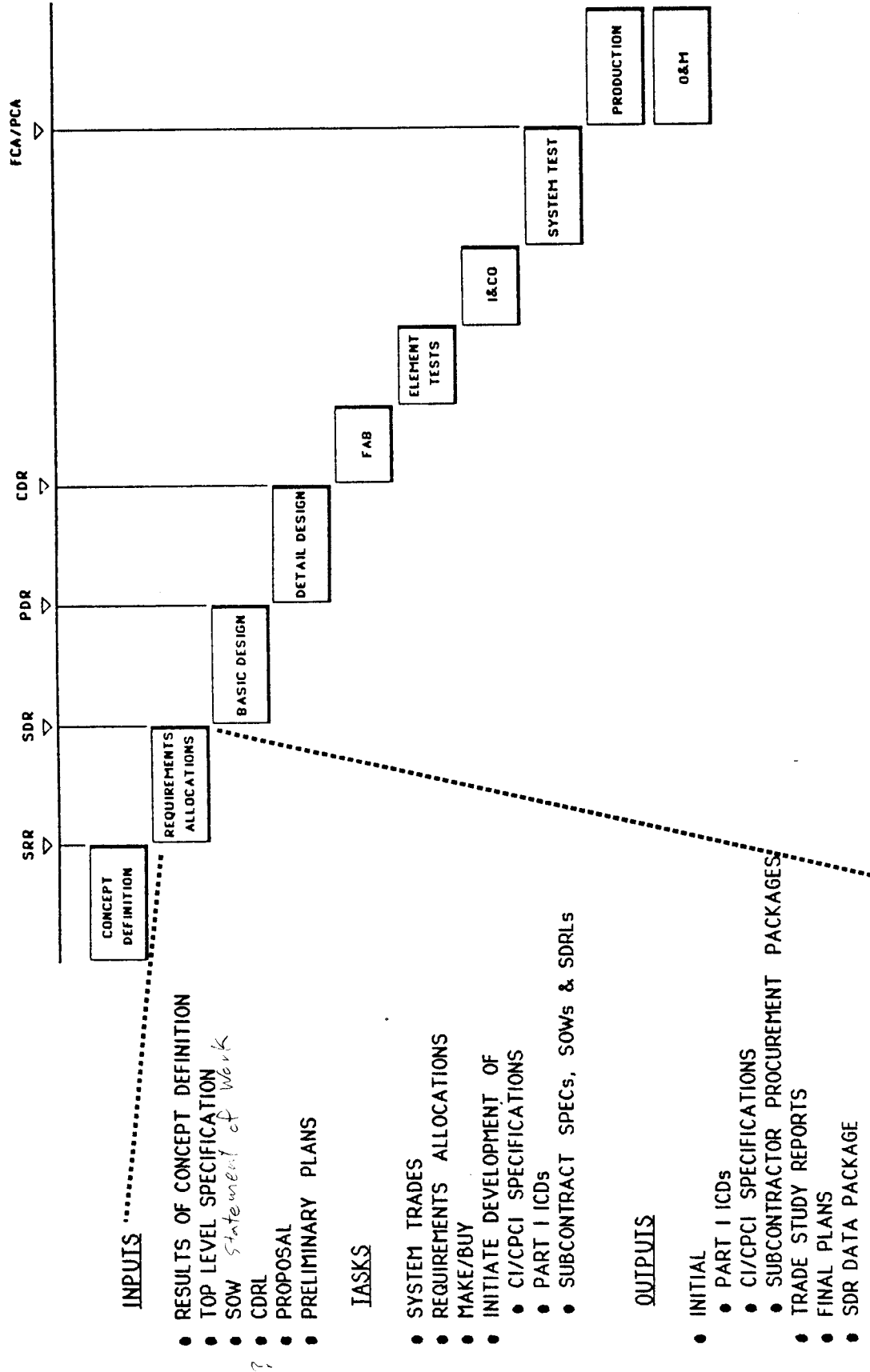
TASKS

- CONDUCT SYSTEM STUDIES
- IDENTIFY DESIRED CAPABILITIES & FUNCTIONAL REQUIREMENTS
- DEVELOP OPERATIONAL SCENARIOS
- CONDUCT SYSTEM TRADES
- PREPARE SYSTEM SPECIFICATION
- PREPARE PROPOSAL

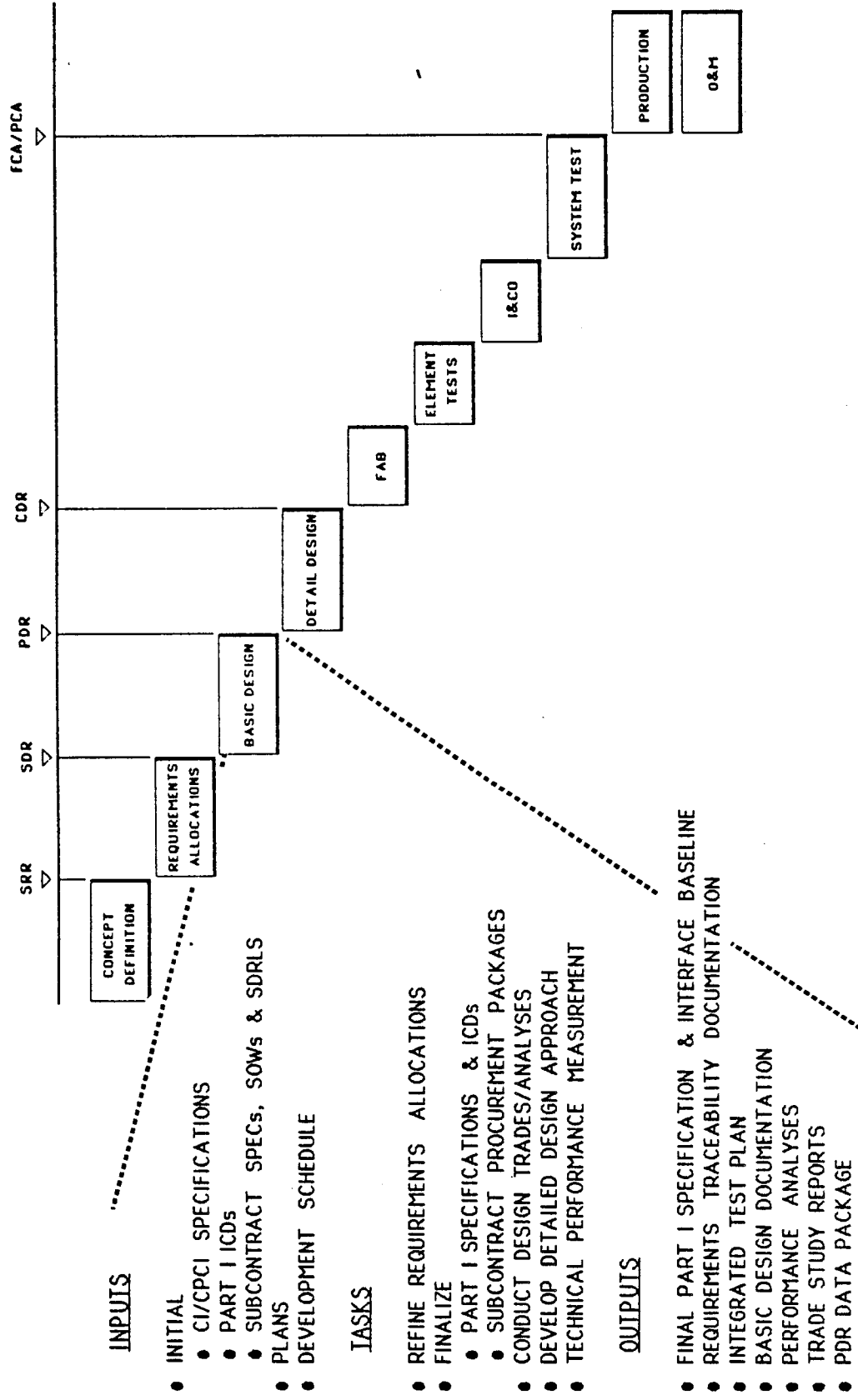
OUTPUTS

- OPERATIONAL CONCEPT
- SYSTEM SPECIFICATION
- SYSTEM TRADE STUDY REPORTS
- PRELIMINARY DEVELOPMENT PLANS
- PROPOSAL
- SYSTEM REQUIREMENTS REVIEW AGENDA/DATA PACKAGE

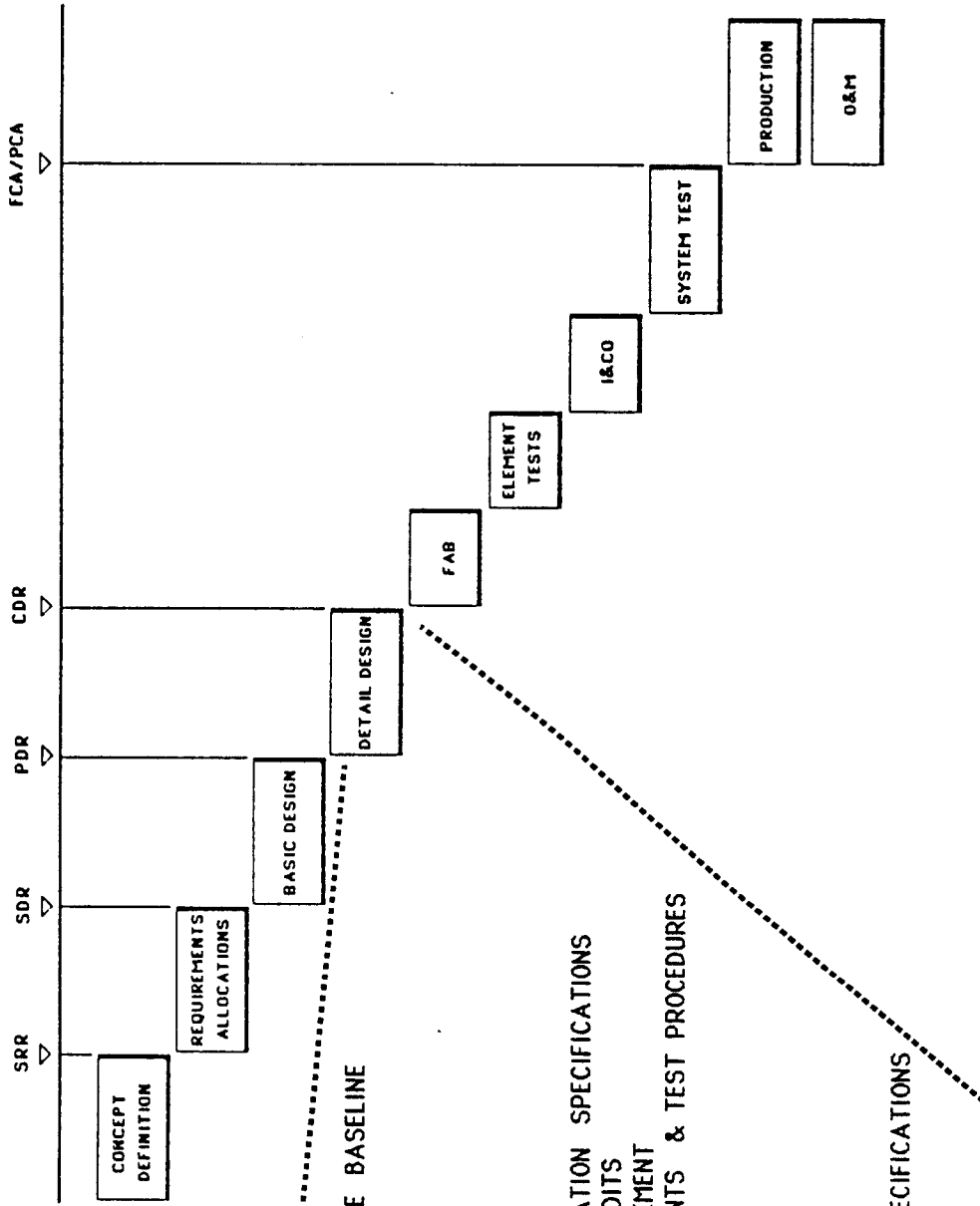
PRELIMINARY SYSTEM DESIGN & REQUIREMENTS ALLOCATION



BASIC DESIGN



DETAIL DESIGN



INPUTS

- PART I SPECIFICATION & INTERFACE BASELINE
- BASIC DESIGN APPROACH

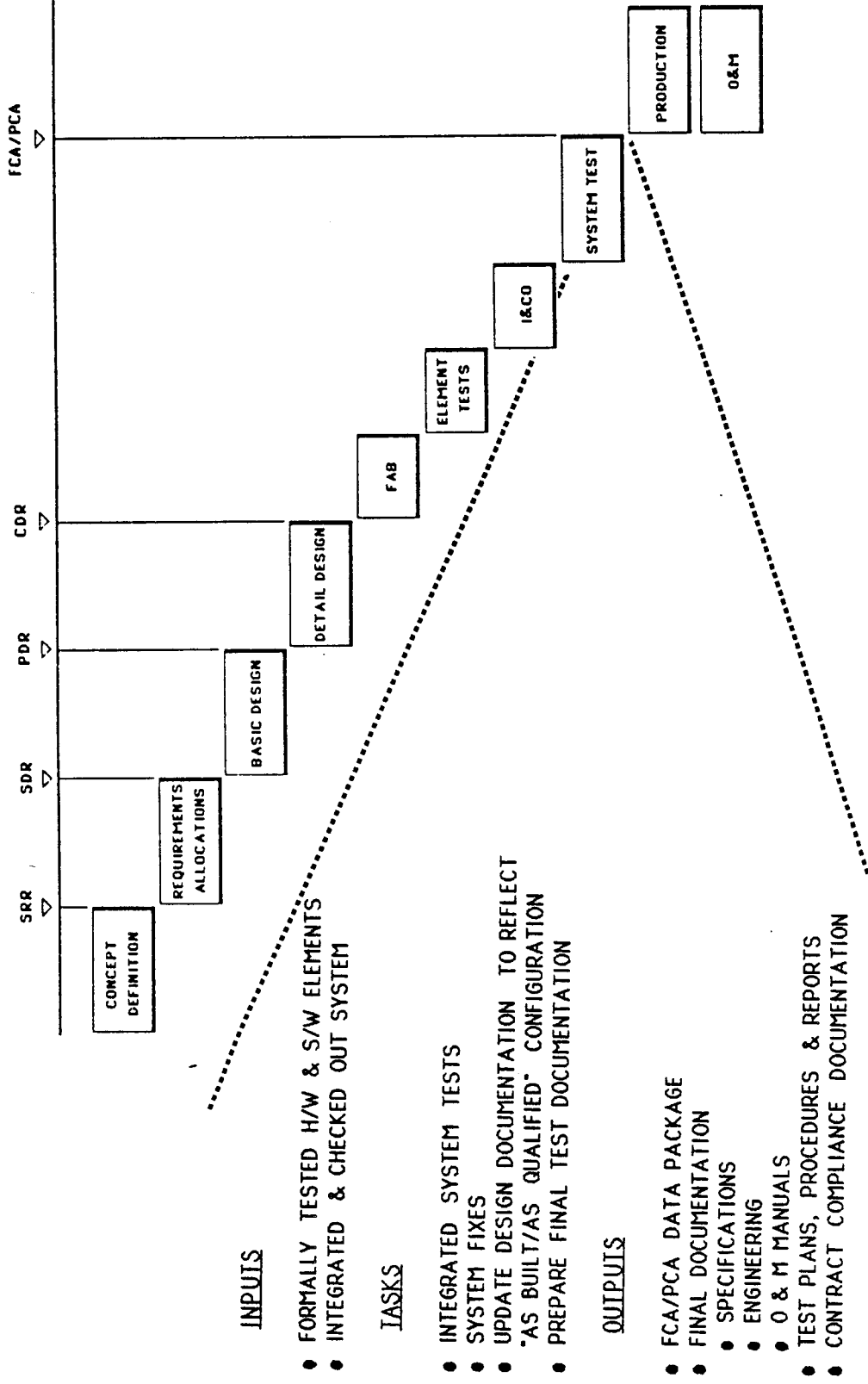
TASKS

- COMPLETE DETAIL DESIGN
- GENERATE PART II ICDS
- DEVELOP INITIAL PRODUCT FABRICATION SPECIFICATIONS
- CONDUCT INTERNAL REVIEWS & AUDITS
- TECHNICAL PERFORMANCE MEASUREMENT
- GENERATE DETAIL TEST REQUIREMENTS & TEST PROCEDURES

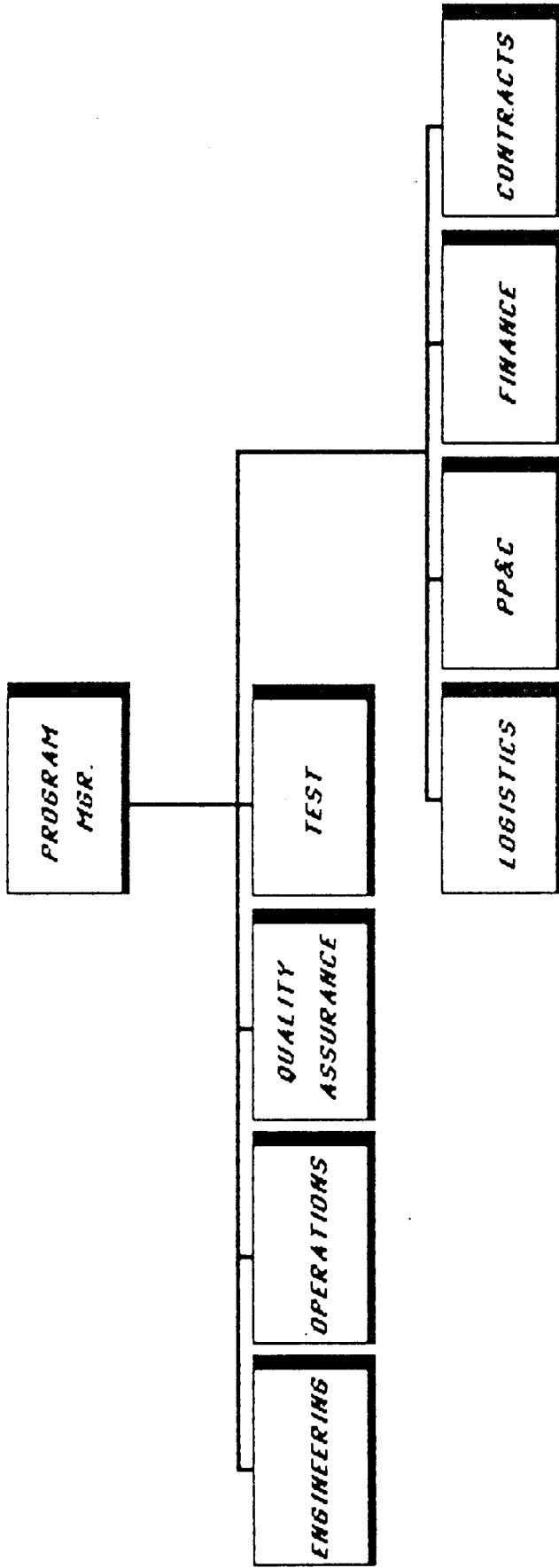
OUTPUTS

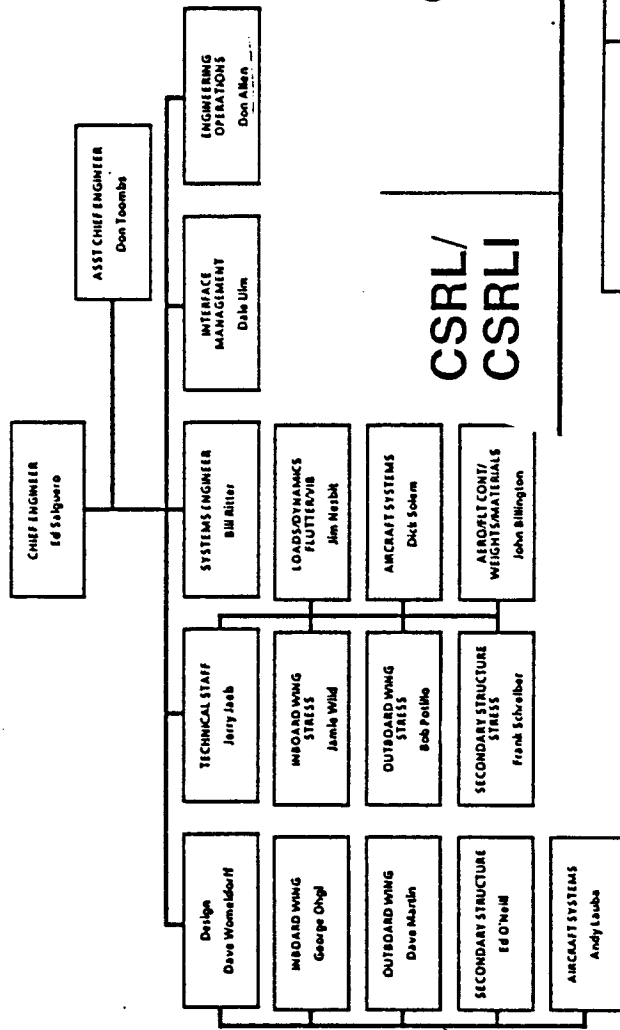
- RELEASED ENGINEERING
- FINAL PART II ICDS
- INITIAL PRODUCT FABRICATION SPECIFICATIONS
- INITIAL DTRs & TEST PROCEDURES
- CDR DATA PACKAGE

SYSTEM TEST



PROGRAM ORGANIZATION



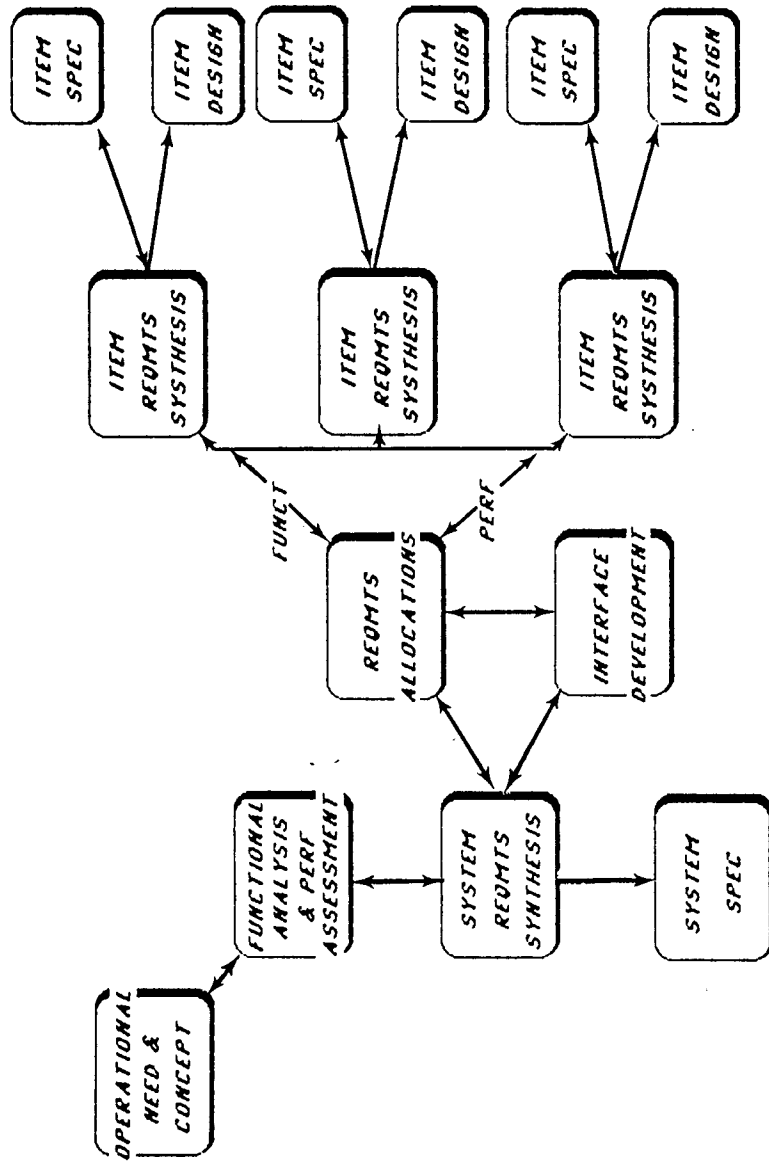


Critical
Design
Review
March 20 & 21, 1984

SYSTEMS ENGINEERING FUNCTIONS

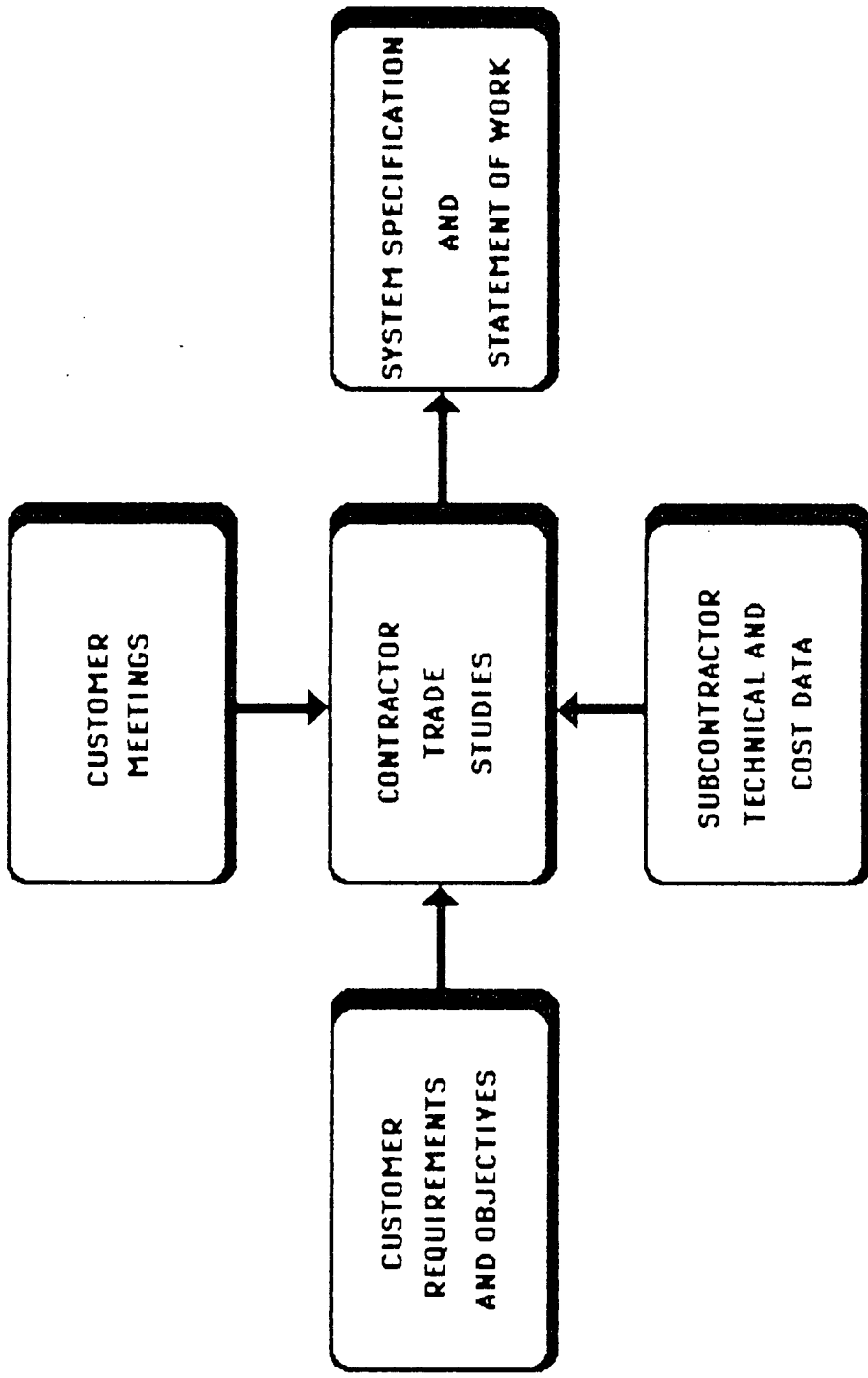
- REQUIREMENTS DEVELOPMENT, ALLOCATION & SPECIFICATION
- INTERFACE CONTROL
- SPECIFICATION COMPLIANCE
- DESIGN REVIEWS & PROGRAM BASELINE DEVELOPMENT

REQUIREMENTS DEVELOPMENT & ALLOCATION



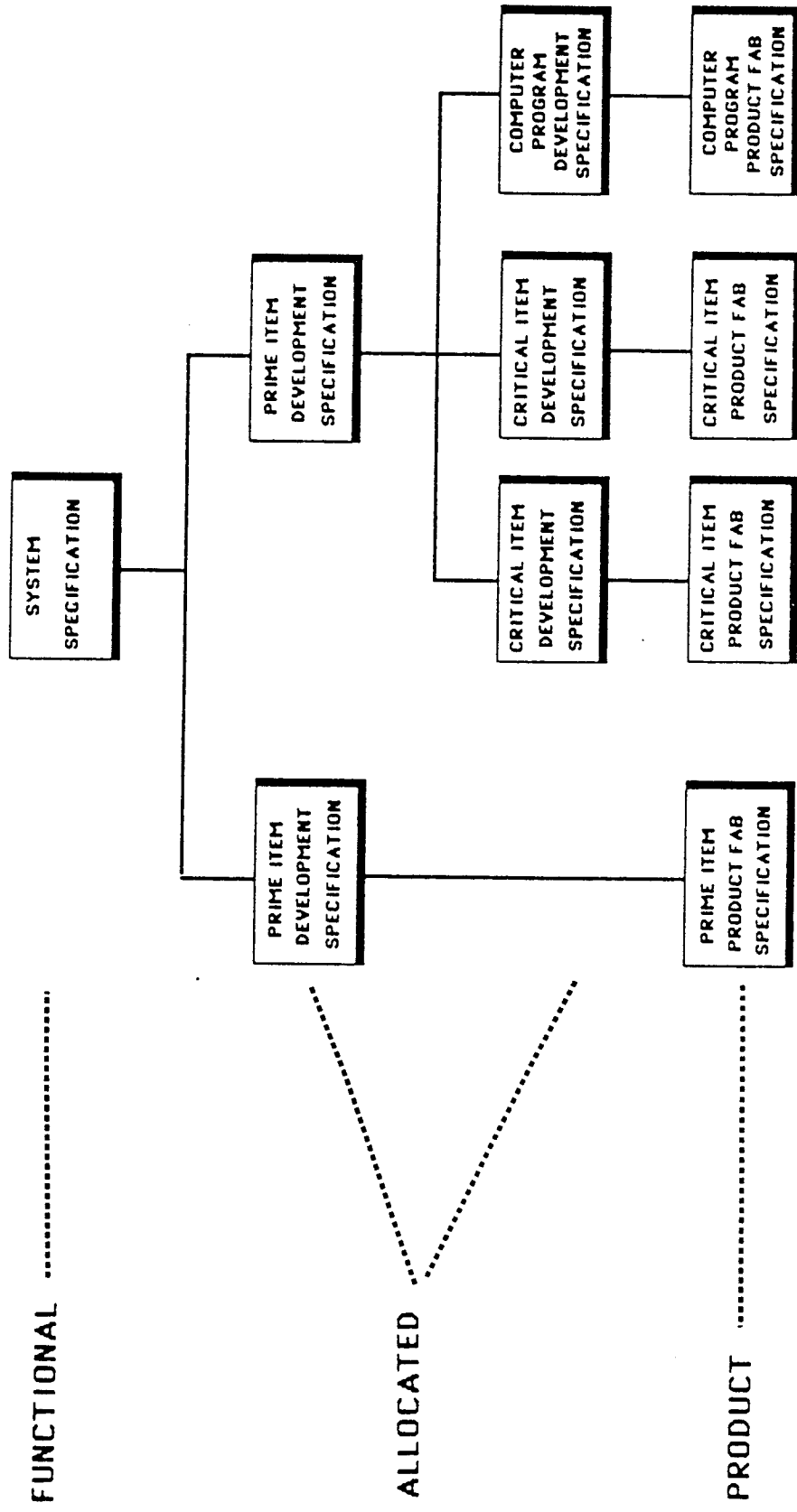
- DESIGN OPTIMIZATION
- LOGISTICS ENGINEERING
- PRODUCTION CONSIDERATIONS

SPECIFICATION DEVELOPMENT PROCESS



MIL-STD-490 SPECIFICATION PRACTICES

PROGRAM BASELINE SPECIFICATION HIERARCHY



DESIGN REQUIREMENTS EXAMPLES

PRIME ITEM DEVELOPMENT SPEC FOR B-1B AIRCRAFT

3.2.1.7 TAKEOFF, LANDING & FLOTATION

- e. THE AIRCRAFT SHALL BE CAPABLE OF A 180 DEGREE TURN ON A RUNWAY WIDTH OF 90 FEET BY USE OF THE NORMAL STEERING SYSTEM WITHOUT THE USE OF DIFFERENTIAL BRAKING.

PRIME ITEM DEVELOPMENT SPEC FOR THE COMMON STRATEGIC ROTARY LAUNCHER

3.2.2.1 WEIGHT

THE WEIGHT OF THE COMPLETE CSRL SHALL NOT EXCEED 4000 LBS.

CRITICAL ITEM DEVELOPMENT SPEC FOR THE JOINT STARS RADAR RADOME

3.2.4.1 MAINTENANCE

THE RADOME SHALL BE CAPABLE OF BEING OPENED BY ROTATING 90 DEGREES ABOUT THE LEFT HAND LONGITUDINAL HINGE AXIS WITHIN 2.0 MINUTES, AND OF BEING CLOSED IN 2.5 MINUTES.

SOURCE CONTROL DWG FOR ACTUATOR ASSY- JOINT STARS RADOME

3.4.3 BACKLASH

BACKLASH OF THE BALLNUT ON THE BALLSCREW SHALL NOT EXCEED .015 INCH UNDER A +50 LB. END LOAD.

SOFTWARE MILESTONE DOCUMENTS

DOCUMENT

MILESTONE

CONTENT

SOFTWARE SYSTEM
DESIGN CRITERIA

I

SOFTWARE SYSTEM DESIGN REQUIREMENTS

- FUNCTIONAL REQUIREMENTS
- PARTICULAR ACCURACIES, LOGIC, MATHEMATICS OR CONSTRAINTS
- INTERFACE REQUIREMENTS
- FACILITY AND EQUIPMENT REQUIREMENTS
- TEST REQUIREMENTS

IMPLEMENTATION
CONCEPT AND TEST
PLAN

II

SOFTWARE SYSTEM PRELIMINARY DESIGN

- FUNCTIONAL ALLOCATION
- SOFTWARE MODULE DESCRIPTION
- INTERFACE AND DATA BASE
- MATHEMATICS AND UNIQUE LOGIC
- TEST PLAN

SOFTWARE MILESTONE DOCUMENTS

<u>DOCUMENT</u>	<u>MILESTONE</u>	<u>CONTENT</u>
SOFTWARE SYSTEM INTERFACE SPEC <i>STR - Software Requirements Doc.</i>	III	INTERFACE REQUIREMENTS BETWEEN OPERATIONAL FUNCTIONS <ul style="list-style-type: none"> • DEFINE SOFTWARE SYSTEM ENVIRONMENT • DATA BASE AND CONTROL INTERFACE DATA • SOFTWARE SYSTEM DATA FLOW DEFINITION • OPERATIONAL FUNCTIONAL FLOW DEFINITION
SOFTWARE MODULE DESIGN SPEC	IV	SOFTWARE MODULE DETAILED DESIGN REQUIREMENTS <ul style="list-style-type: none"> • DETAILED DESIGN REQUIREMENTS FOR EACH MODULE USING APPROVED M/S2 AND M/S3 DOCUMENTATION AS A BASE • SOFTWARE MODULE ACCEPTANCE TEST PROCEDURES AND SUCCESS CRITERIA

SOFTWARE MILESTONE DOCUMENTS

<u>DOCUMENT</u>	<u>MILESTONE</u>	<u>CONTENT</u>
SOFTWARE MODULE DOCUMENTATION	V	RELEASE OF "AS BUILT" DOCUMENTATION <ul style="list-style-type: none">• UPDATED M/S4• STORAGE REQUIREMENTS• CRITICAL TIME DEPENDENCIES• TEST CARD DECKS AND LISTINGS
SYSTEM TEST AND ACCEPTANCE SPECIFICATION	VI	SOFTWARE SYSTEM LEVEL TEST PLAN (CATEGORY II) <ul style="list-style-type: none">• OVERALL TESTING CONCEPT• TEST CONDITIONS AND PURPOSE• TEST EQUIPMENT REQUIREMENTS• DETAILED ACCEPTANCE TEST CRITERIA• DETAILED & TEST PROCEDURES• TEST DATA LISTINGS AND DECKS

SOFTWARE MILESTONE DOCUMENTS

<u>DOCUMENT</u>	<u>MILESTONE</u>	<u>CONTENT</u>
OPERATING INSTRUCTIONS	VII	ALL THE INFORMATION WHICH IS NEEDED TO UTILIZE THE COMPUTER SOFTWARE SUBSYSTEM IN THE OPERATIONAL MODES
SYSTEM CONFIGURATION INDEX	VIII	SUMMARY DESCRIPTION OF THE DELIVERABLE SOFTWARE SUBSYSTEM

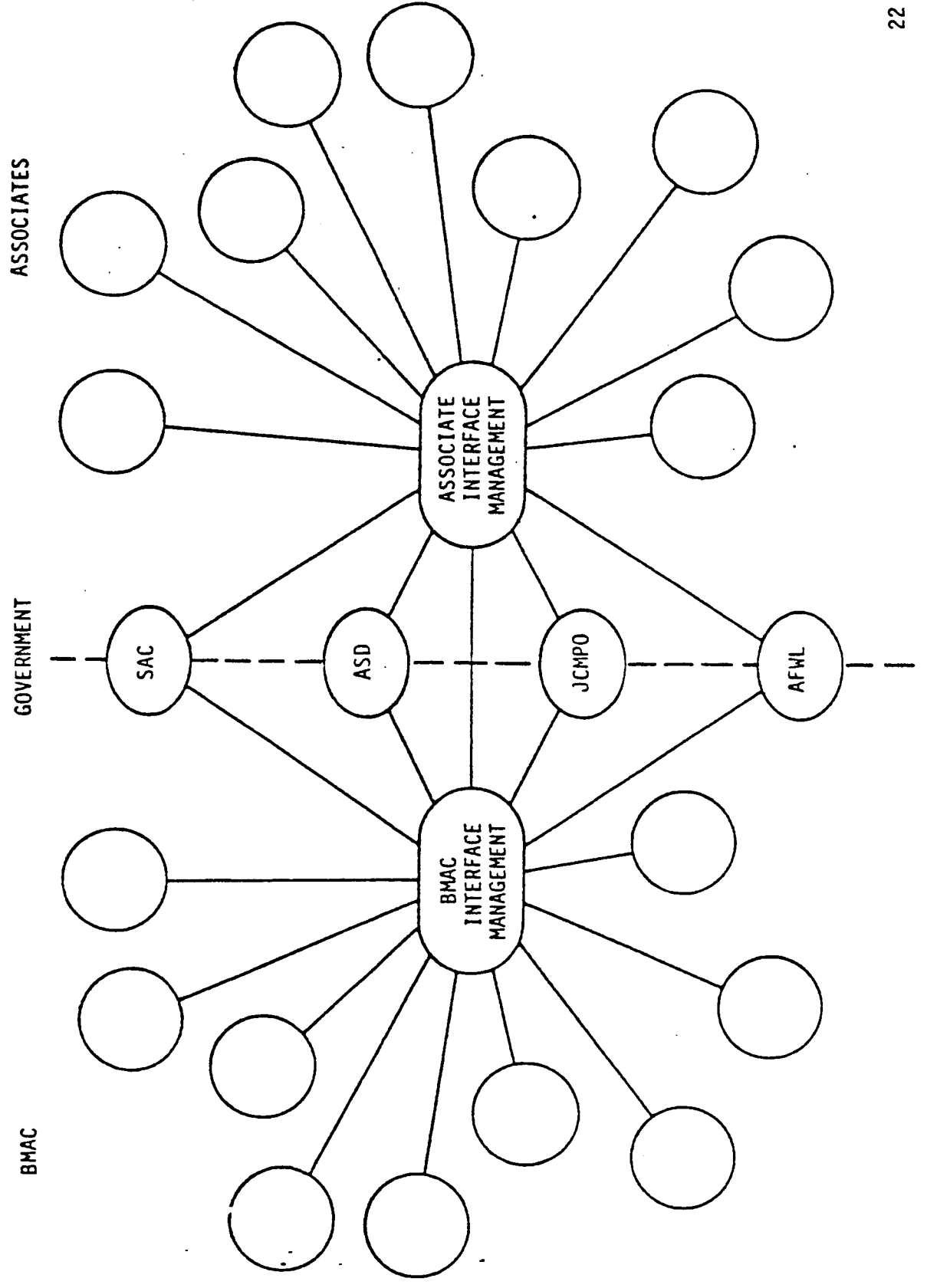
GOOD SPECIFICATIONS

- ARE COMPLETE
- CONTAIN REQUIREMENTS THAT ARE
 - CLEAR AND CONCISE
 - VERIFIABLE
 - EQUIPMENT, NOT SOW, REQUIREMENTS
- CLEARLY IDENTIFY THE METHODOLOGY FOR REQUIREMENTS COMPLIANCE VERIFICATION
- DO NOT REPEAT REQUIREMENTS
- AVOID BLANKET REFERENCE TO MILITARY STANDARDS
- CLEARLY IDENTIFY THE PRECEDENCE OF SPECIFIED REQUIREMENTS RELATIVE TO
 - SOW
 - OTHER SPECIFICATIONS
 - ICDS *Interface Control Doc*
 - REFERENCED DOCUMENTS & MILITARY STANDARDS

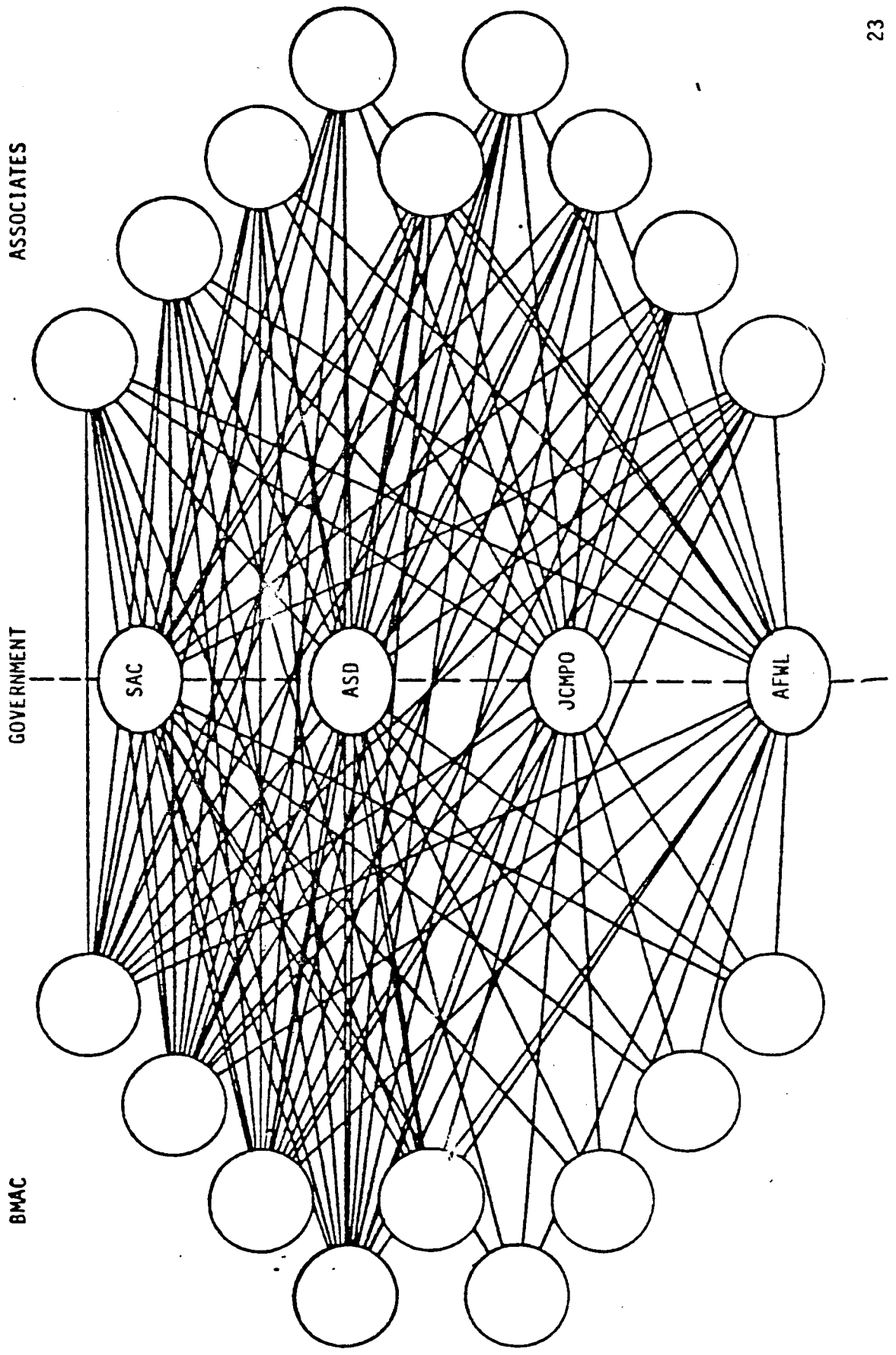
INTERFACE MANAGEMENT

- INTERFACE DEVELOPMENT PLANS & PROCEDURES
- ICD/IDD DEVELOPMENT & MAINTENANCE
- BMAC PROGRAM FOCAL
 - TECHNICAL DATA EXCHANGE (IFM)
 - TECHNICAL INTERCHANGE MEETINGS (TIMs)
- ASSOCIATES
- GOVERNMENT AGENCIES
- PRIME CONTRACTOR

LINES OF COMMUNICATION WITH INTERFACE MANAGEMENT



LINES OF COMMUNICATION WITHOUT INTERFACE MANAGEMENT



INTERFACE CONTROL

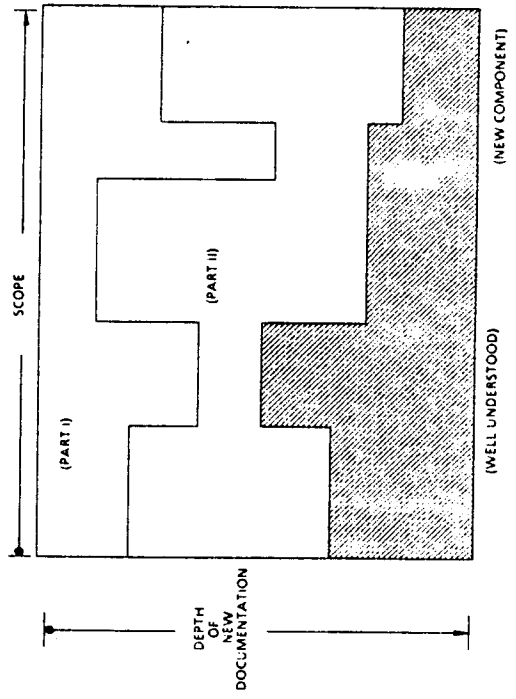
(ICD)

WHEN

- ASSOCIATE CONTRACTOR EQUIP INTERFACE
- COMPLEX/CRITICAL INTERFACE BETWEEN PRIME/SUB
- GOV'T AGENCY EQUIPMENT INTERFACE
- INTERNAL INTERFACES
 - CROSS PROGRAM
 - IDWA/ICWA
- MULTIPLE EQUIPMENT ITEM/FUNCTIONAL ORG INVOLVEMENT

Inter-Div. Work Auth. / Inter-Com. Work Auth.

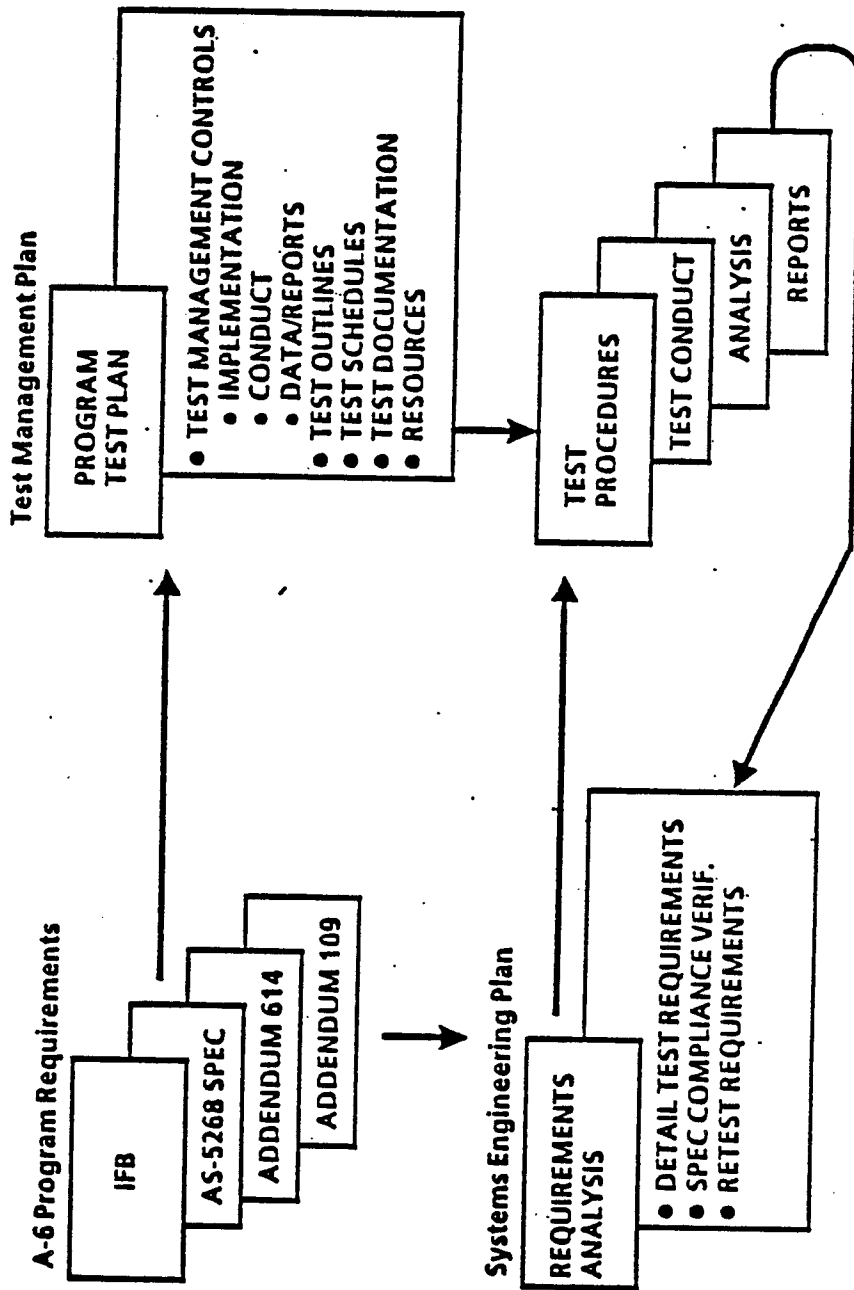
HOW MUCH



VERIFICATION METHODS

- Test**
 - Experiment of item operation
 - Use test equipment and instrumentation
 - Controlled conditions
- Demonstration**
 - Exhibition of nominal modes of operation
 - Use controls and indicators inherent in item
 - No test equipment
- Analysis**
 - Generation and examination of new data
 - Examination of existing data
- Similarity**
 - Subset of analysis of existing data
- Inspection**
 - Visual examination of item or drawing

INFORMATION FLOW



MIL-STD-1521 TECHNICAL REVIEWS

These are acronyms that have appeared earlier

● SYSTEMS REQUIREMENTS REVIEW

- ASSURE UNDERSTANDING OF SYSTEM SPECIFICATION, SOW AND PROGRAM OBJECTIVES
- TYPICALLY RESULTS IN ESTABLISHMENT OF PROGRAM FUNCTIONAL BASELINE

● SYSTEM DESIGN REVIEW

- EVALUATE CONTRACTOR DECOMPOSITION OF SYSTEM INTO PRIME/CRITICAL ITEMS
- EVALUATE OPTIMIZATION, COMPLETENESS & RISKS ASSOCIATED WITH CONTRACTOR'S ALLOCATION OF TECHNICAL REQUIREMENTS
- REVIEW CONTRACTOR'S SYSTEMS ENGINEERING PROCESS

● PRELIMINARY DESIGN REVIEW

- REVIEW FINAL REQUIREMENTS ALLOCATIONS TO PRIME/CRITICAL ITEMS
- REVIEW PRELIMINARY DESIGN SOLUTIONS
- EVALUATE COMPLETENESS, PROGRESS, CONSISTENCY & TECHNICAL ADEQUACY OF SYSTEM DESIGN & TEST APPROACHES
- TYPICALLY RESULTS IN ESTABLISHMENT OF PROGRAM ALLOCATED BASELINE & AUTHORIZATION TO PROCEED WITH DETAIL DESIGN

● CRITICAL DESIGN REVIEW

- REVIEW THE ACCEPTABILITY OF THE DETAIL DESIGN IN MEETING SPECIFIED REQUIREMENTS
- ASSESS PRODUCIBILITY & PROGRAM COST, SCHEDULE & TECHNICAL RISK PRIOR OF COMMITTING TO SYSTEM FABRICATION

MIL-STD-483 CONFIGURATION MANAGEMENT PRACTICES

AUDITS

- FUNCTIONAL CONFIGURATION AUDIT (FCA)
 - PERFORMED TO VERIFY ACHIEVEMENT OF SPECIFIED FUNCTIONAL/ PERFORMANCE REQUIREMENTS
 - SUPPORTING DOCUMENTATION
 - FUNCTIONAL/ALLOCATED CONFIGURATION IDENTIFICATION DATA
 - DEVIATIONS/WAIVERS
 - VERIFICATION DATA

- PHYSICAL CONFIGURATION AUDIT (PCA)
 - PERFORMED TO VERIFY
 - AS BUILT CONFIGURATION MATCHES PCI
 - ADEQUACY OF ACCEPTANCE VERIFICATION FOR PRODUCTION
 - SUPPORTING DOCUMENTATION
 - PCI DATA
 - DEVIATIONS/WAIVERS
 - ACCEPTANCE TEST DATA

MIL-STD-483 CONFIGURATION MANAGEMENT PRACTICES

CONFIGURATION IDENTIFICATION

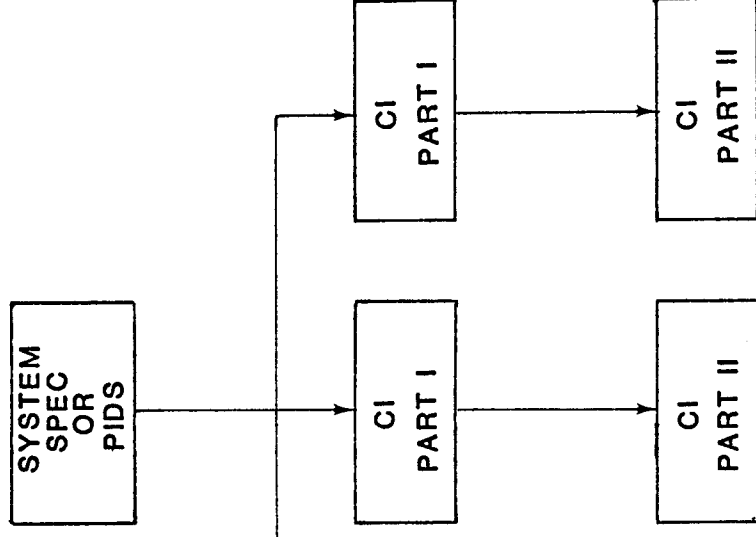
- FUNCTIONAL CONFIGURATION IDENTIFICATION (FCI)
 - ESTABLISHED WITH APPROVAL TO INITIATE ENGINEERING
 - DOCUMENTED BY MIL-STD-490
 - TYPE A (SYSTEM) SPEC
 - TYPE B1 PRIME ITEM DEVELOPMENT SPEC

- ALLOCATED CONFIGURATION IDENTIFICATION (ACI)

- CI LEVEL "DESIGN TO" REQUIREMENTS
- TYPICALLY ESTABLISHED BY PDR
- DOCUMENTED BY SUM OF MIL-STD-490
- TYPE B2 CRITICAL ITEM DEVELOPMENT SPECS

- PRODUCT CONFIGURATION IDENTIFICATION (PCI)

- CI LEVEL "BUILT TO" REQUIREMENTS
- ESTABLISHED BY PCA
- LEVEL OF DOCUMENTATION COMMENSURATE WITH ANTICIPATED REPROCUREMENT & LOGISTIC SUPPORT
 - TYPICALLY MIL-STD-490 TYPE C2
 - CRITICAL ITEM PRODUCT SPECS



TRADES

QUALITATIVE



RESIN DATA

PRELIMINARY DESIGN REVIEW

PREFERRED RESIN

BMI
350° - 400°F
GOOD

EPOXY
250° - 300°F
FAIR

REQUIRES MOISTURE BARRIER (I.E. TEDLAR FILM)

MAXIMUM SERVICE TEMPERATURE
MOISTURE RESISTANCE

FLUID RESISTANCE

JP-4

HYDRAULIC FLUID

PROCESSABILITY

BMI
SAME
SAME
EPOXY

BMI
GOOD
GOOD
GOOD

REQUIRES 400°F
FREESTANDING
POSTCURE

LOSS TANGENT

0.020

0.11

BMI

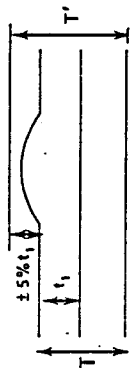


BMI IS RESIN OF CHOICE BASED ON ABOVE

QUANTITATIVE

PRELIMINARY DESIGN REVIEW

LAMINATE THICKNESS VARIATION



QUARTZ (2 PLYS)
 $t_1 = .010$



THIN GLASS (6 PLYS)
 $t_2 = .0033$



VARIATION OF RADOME SKIN THICKNESS DUE TO MATERIAL TOLERANCE WILL BE LESS WITH GLASS

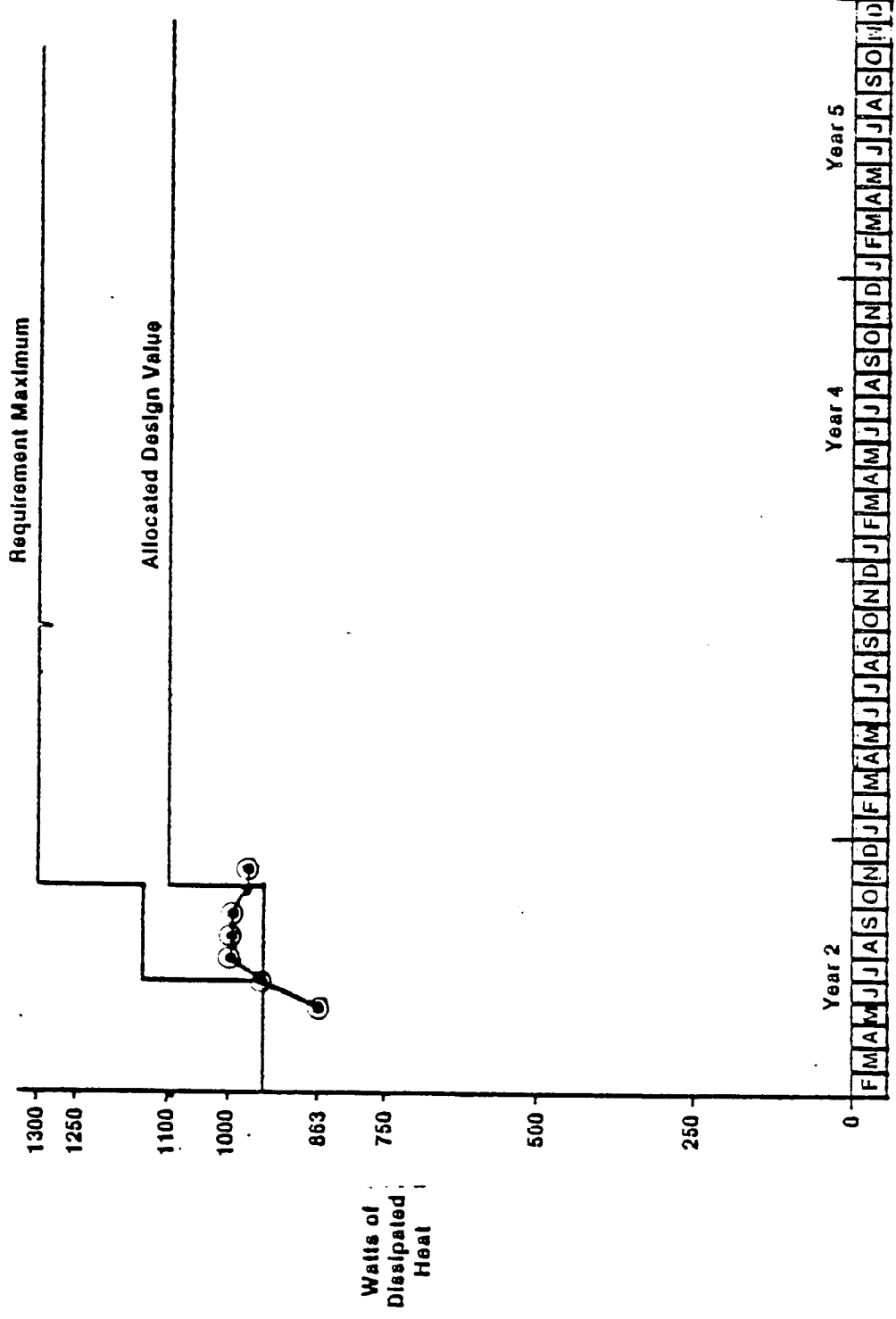
TECHNICAL PERFORMANCE MEASUREMENT

- PROVIDE MANAGEMENT VISIBILITY OF ACTUAL VERSUS PLANNED PERFORMANCE
- PROVIDE EARLY DETECTION OR PREDICTION OF PERFORMANCE THAT REQUIRES MANAGEMENT ATTENTION
- SUPPORT ASSESSMENT OF THE PROGRAM IMPACT OF PROPOSED CHANGE ALTERNATIVES

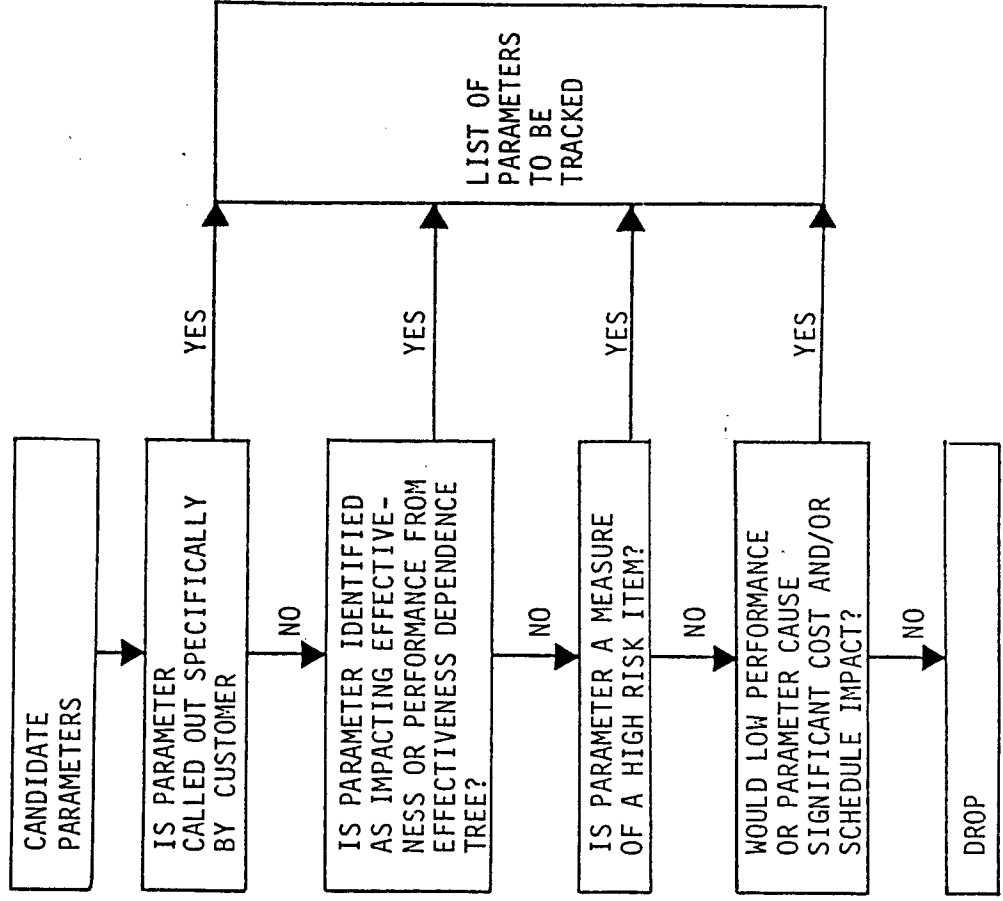
TYPICAL PERFORMANCE MEASURES

- WEIGHT/CG
- POWER CONSUMPTION
- ECS UTILIZATION
- MEMORY UTILIZATION
- THROUGHPUT
- RELIABILITY
- MAINTAINABILITY

AIR COOLING TPM



PARAMETER SELECTION LOGIC



RISK MANAGEMENT

- **RISK IDENTIFICATION**

- **RISK ASSESSMENT**

- **RISK ABATEMENT**

RISK MANAGEMENT DEFINITIONS

RISK

- POTENTIAL FAILURE TO MEET A MAJOR OBJECTIVE
- POTENTIAL OCCURENCE OF AN UNDESIREABLE EVENT

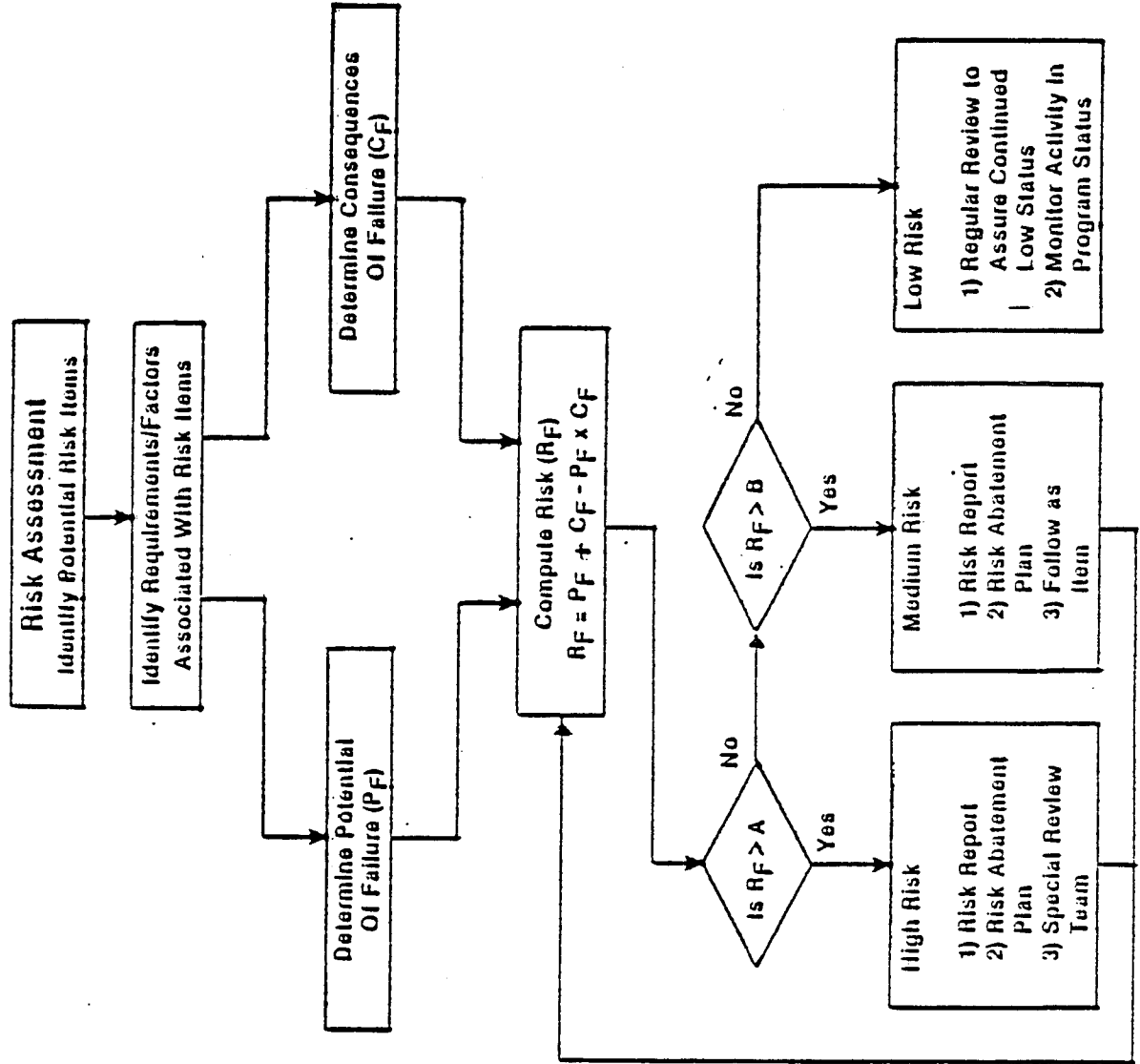
RISK IMPACT

- PERFORMANCE DEFICIENCY
- SCHEDULE SLIDE
- COST OVERRUN
- TEST FAILURE

RISK ABATEMENT

- SECOND SOURCE/BACKUP DEVELOPMENT
- INCREASED DEDICATED RESOURCE EXPENDITURES
- REDUCED REQUIREMENTS/GOALS
- OVER DESIGN
- MORE DETAILED PLANNING/MANAGEMENT TRACKING

RISK ASSESSMENT PROCESS FLOW



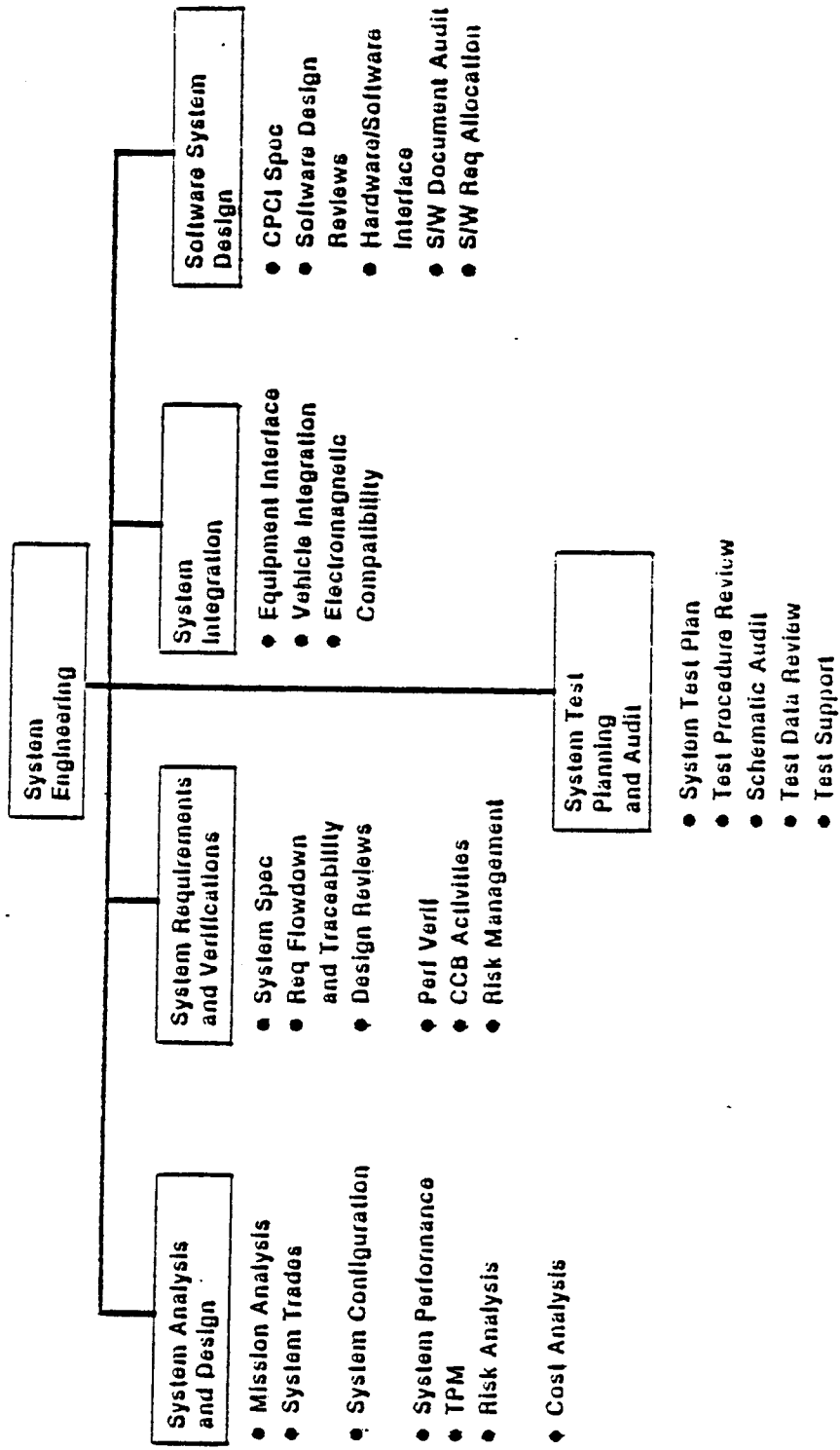
RISK CATEGORIZATION

RISK RATING	CRITERIA
HIGH	<ul style="list-style-type: none"> • REQUIREMENTS ILL-DEFINED LATE CHANGING • MAJOR STATE-OF-ART ADVANCEMENT • CAPABILITY INADEQUATE • SERIOUS PROBLEMS NO SOLUTION • EXPECT TO FAIL TO MEET REQUIREMENTS • PROGRAM MANAGEMENT ACTION MANDATORY
MODERATE	<ul style="list-style-type: none"> • REQUIREMENTS ILL-DEFINED LATE CHANGING • SOME STATE-OF-ART EXTENSION • CAPABILITY MARGINAL • SIGNIFICANT PROBLEMS - HAVE POTENTIAL SOLUTION • MAY FAIL TO MEET REQUIREMENTS • ALERT PROGRAM MANAGEMENT
LOW	<ul style="list-style-type: none"> • REQUIREMENTS WELL DEFINED • TECHNOLOGY IN HAND • CAPABILITY ADEQUATE • NO SIGNIFICANT PROBLEMS • WILL MEET REQUIREMENTS THROUGH NORMAL DEVELOPMENT • NO ACTION REQUIRED

RISK ABATEMENT

- INITIATION OF PARALLEL DEVELOPMENTS
 - FALLBACK POSITION
 - ALTERNATE SOLUTION
- EARLY INITIATION OF DEVELOPMENT ACTIVITIES
- IMPLEMENTATION OF EXTENSIVE DEVELOPMENT TESTING
- ENHANCED SIMULATIONS/ANALYSES TO PREDICT PERFORMANCE
- USE OF CONSULTANTS AND SPECIALISTS TO OVERVIEW DESIGN
- INTENSIFIED MANAGEMENT REVIEW OF THE DEVELOPMENT PROCESS

System Engineering Organization



SUMMARY

SYSTEMS ENGINEERING PROCESS

- TRANSLATION OF OPERATIONAL NEEDS INTO A TOP LEVEL SET OF SYSTEM REQUIREMENTS
 - FUNCTIONAL
 - PERFORMANCE
- DEVELOPMENT OF A SYSTEMS ARCHITECTURE/DEFINITION OF SYSTEM ELEMENTS
- ALLOCATION OF FUNCTIONAL/PERFORMANCE REQUIREMENTS TO SYSTEM ELEMENTS
- DESIGN SYNTHESIS SUPPORT/MONITORING/ADJUSTMENT
- VERIFICATION OF SYSTEM REQUIREMENTS COMPLIANCE

RESOURCES

GOVERNMENT

MIL-STD-499	SYSTEMS ENGINEERING MANAGEMENT
MIL-STD-1521	TECHNICAL REVIEWS AND AUDITS FOR SYSTEMS, EQUIPMENTS AND COMPUTER SOFTWARE
MIL-STD-490	SPECIFICATION PRACTICES
MIL-STD-480	CONFIGURATION CONTROL-ENGINEERING CHANGES, DEVIATIONS AND WAIVERS
MIL-STD-483	CONFIGURATION MANAGEMENT PRACTICES FOR SYSTEMS, EQUIPMENT, MUNITIONS AND COMPUTER PROGRAMS

ICP-208

SSSPO INTERFACE CONTROL PLAN

BOEING

8000-10	TECHNICAL INTERCHANGE MEETINGS
8000-22	RISK MANAGEMENT
8000-23	TECHNICAL PERFORMANCE MEASUREMENT
8000-29	FUNCTIONAL CONFIGURATION AUDIT
7100-54	ENGINEERING TECHNICAL REVIEWS
BSWS-1000	EMBEDDED SOFTWARE STANDARD