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COST ANALYSIS: CONCEPTS AND METHODS OUTLINE

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INTRODUCTION

I. Subject of the Briefing

   A. Resource analysis role in cost-effectiveness analysis; the nature of resource analysis, the analytical tools it employs, and its relationship with the effectiveness side of the equation.

   B. Limitation to the aerospace industry, DOD, and NASA

      1. This industry and the government organizations it serves have been the breeding ground of cost-effectiveness analysis because of their uniquely complicated planning problems.

      2. Experience of the speaker, and probably most of the audience.

II. Varieties of Resource Analysis

   A. Emphasis of the briefing on enumerating and distinguishing among the varieties of resource analysis commonly required in cost-effectiveness analysis.

   B. Variations due to differing levels of aggregation

      1. Force structure/total plan

      2. Individual weapon system or space project

      3. Individual equipment or operation

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This paper is to be given on April 13, 1966, as part of a lecture series sponsored by the American Institute of Aeronautics and Astronautics.

C. Variations due to differing time contexts

1. Long range
2. Short term

VARIETIES OF RESOURCE ANALYSIS

I. Individual Equipment or Operation

II. Individual Weapon System Costing

A. Input variables

1. PME and AGE description
   a. design and performance data
2. Operational and organizational description
3. Manning policy
4. In commission rate data
   a. alert status
5. Maintenance concept
6. Training data
7. Ballistic missile illustration charts, more detailed presentation

B. Cost element breakout/work breakdown structure

1. Appropriate choice not a matter of maximum detail but availability of information to the decision-maker (or his cost analyst) at the point in time the decision must be made.
2. Categories should be structured to be of maximum use in the analytical problem at hand; if possible, they should be used to highlight the differences among the alternatives under consideration--more aggregation where the alternatives are alike, less where they display different features.
3. Citing a cost element explicitly rather than in an aggregate is a matter both of its relative size and variability in the analysis at hand.

C. Cost categories and their relative time impact

1. R&D
2. Investment
3. Annual operating

III. Force Structure Costing

A. Definition: determination of the resource impact of alternative future force proposals (plans): i.e., aggregations of systems (projects) as well as nonsystem-oriented activities.

1. Nonsystem-oriented activities: Air Training Command or Air Force Logistics Command; in the case of NASA, the Office of Advanced Research and Technology (OART) or the Office of Tracing and Data Acquisition (OTDA).

B. Force structure identifications

1. Missions (weapon systems), space exploration projects
2. Resource requirement breakouts
3. Time periods

C. Discussion of Air Force force-costing format

D. Interrelationships of individual systems or projects within a force structure

1. Performance of a military mission: e.g., an air defense fighter squadron and an early warning radar station
2. Resource requirements level
   a. base facilities
   b. manpower (common special skills pool: i.e., pilots)
   c. equipment development and procurement

E. Necessity of treating with force structure considerations to engage in incremental costing meaningfully.

IV. Effects of Differences in Time Context Upon Resource Projection

A. Individual equipment

1. Long range: parametric procedure
2. Short term: extension of cost quantity curves

TOOLS OF COST ESTIMATION

I. Individual Equipment or Operation CER's (Cost-Estimating Relationships)

   A. Definition: expression of cost as a function of physical characteristics, performance, and/or operational concept.

   B. Uses

      1. Projecting a major element in the evaluation of alternative, future weapon/space systems.

      2. Selection of an optimum configuration during preliminary design (equipment).

   C. Commonly used forms: linear multivariate, exponential or log-linear, curvilinear.

   D. Examples

      1. Depot maintenance cost as a function of aircraft cost and combat speed.

      2. Turbojet engine development cost as a function of maximum thrust and quantity milestones.

   E. Deriving CER's--criteria for the selection of explanatory variables.

      1. Logical or theoretical relation of the variable to cost.

      2. Statistical significance of the variable's contribution to the explanation of cost.

      3. Independence of the contribution made by the variable to the explanation of cost.

   F. Limitations of CER's

      1. Characteristically (aerospace industry) small sample sizes.

      2. Extrapolating a new equipment whose performance characteristics exceed those of most or all of the cases in the original sample.

         a. diverging prediction intervals

G. Cost-Quantity Relationships

1 Relationship of cum av and unit cost functions

2. Use of cum av and unit cost curves in projecting individual item and lot average costs.

II. Individual Weapon System Requirement: Identification Displays

A. Matrix of GSE costs by physical location and type of equipment.

B. Usefulness of such cross sectional displays in checking the completeness of a system estimate and measuring changes in the estimate with changes in system configuration.

III. Force Structure Distribution Models

A. NASA Manned Space Exploration Model

1. Compiling of physical requirements by like items demanded in a single year

2. Application of CER's, entering throughputs

3. Application of time lag factors

4. Compiling of time-phased financial requirements by individual exploration project

B. Interrelated Resource Requirements--Joint Cost Allocation Problem

1. Need for end item (mission) identification in force structure costing.

2. Multiple use resources

a. nonrecurring requirements; e.g., booster development, launch facility construction

b. recurring requirements; e.g., tracking network operations, engine procurement cost (cost-quantity effect)

3. Methods of allocation

a. proration on the basis of the proportion of the resource consumed by user projects

b. first user

c. independent project status

4. Consumption proration

a. advantages: neatness

b. disadvantages: reallocation of resources in the case of each force structure examined, difficult to distinguish joint product cost after allocation has been made, and if large may bias the case against a given project

5. First user
    a. advantages: effect on the using projects more easily understood and more clearly shown.
    b. disadvantage: heavy bias against one project
6. Independent project
    a. advantages: bias of arbitrary allocation removed, simple to identify joint product cost
    b. disadvantages: format complicated by additional element, difficulty in evaluating alternatives without some allocation of joint cost

TIME PHASING AND DISCOUNTING

I. Time Phasing
  A. Importance in resource analysis
    1. Determination of economic impact
    2. Evaluation of inherited assets
  B. Financial measurement
    1. Expenditures
      a. treasury disbursements
    2. Program requirements
      a. obligational authority possessed by Government each year

II. Discounting
  A. Definition--the application of some selected rate of interest to measure the differences in importance or preference between income at the present time with anticipated income in the future.

B. Time preference

1. To the individual or firm--preference for present income or cost savings over deferred income or cost savings.
2. Not so clear in the case of Government--which is not in the business of making resources grow for the future. Main Government interest in maximizing current or near future capability while living within fixed budgets.

C. Use in the calculation of risk or uncertainty

1. Possible application to Government decisions and resource planning. While perhaps dangerous for resource estimation where future costs tend to exceed early estimates, may be useful for general planning purposes.

D. Present value discounting method

1. Amount of money deposited at interest at the beginning of a system life and drawn on for all needs, would reduce to zero at the end of system lifetime.
2. Computations:

$$PY = \sum_{t=1}^{n} \frac{C_t}{(1+i)^t}$$

where:

PY = present value,
t = time period,
C_t = cost in time period t,
i = interest rate.

E. Interest rate controversy

0 - 25% (25% when used as an uncertainty adjustment)

it

UNCERTAINTY AND COST-ESTIMATING ERROR

I. Requirements Versus Cost-Estimating Uncertainty

   A. Requirements uncertainty refers to variations due to changes in configuration or force structure.

   B. Cost-estimating uncertainty refers to variations which occur when the configuration or system is essentially constant.

II. Requirements Uncertainty

   A. Number of empirical studies point to requirements uncertainty as the major source of uncertainty in the estimation of aerospace systems and force structures.

   B. Sources of requirements uncertainty

      1. Alteration in the original by desired performance characteristics due to changes in the overall strategic picture.

      2. Alterations in original design specifications after discovering they will not provide desired performance characteristics.

      3. Alterations in originally specified IOC dates.

      4. Discovery of errors of omission in establishing requirements for some part of the system.

   C. Requirements uncertainty basically due to the fact that cost estimates are prepared for a fixed, static configuration, while design configuration characteristically undergo frequent and substantial change during their development.

   D. RAND and Harvard Business School studies of the variation in cost estimates from preliminary design through delivery of the operational article have found variations to range as high as a factor of 4 to 1 in some cases and to average about 200 percent. One of these studies suggested a 20 to 30 percent factor as valid for cost uncertainty type errors alone. This 20 to 30 percent assumes that the estimates are not political; i.e., deliberately misstated in any way

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III. Cost-Estimating Uncertainty

A. Sources of cost-estimating uncertainty

1. Errors in cost-estimating relationships

a. normal regression theory provides <u>an estimate</u> of Y as a function of X within calculable prediction intervals--the formal statistical model accepts the existence of error.

2. Errors in data base

a. errors of measurement, errors in the observations from which the relationship had been derived

3. Extrapolation errors

a. errors in estimates of Y for values of X beyond those subtended in the data base.

4. Price level changes

a. extrapolations made by contractors for possible wage rate changes and material price changes

b. institutional changes in the industry--overhead

5. Errors due to aggregation

a. differences between estimates made at different levels of aggregation

6. Miscellaneous errors pertaining to equipment

a. subcontracting structure

b. contractor variation

c. changes in the manufacturing state of the art

d. use of exotic materials

IV. Treatment of Uncertainty in Cost Analysis

A. Limited usefulness of conventional statistical measures such as confidence limits, prediction intervals

1. Small sample sizes--difficulty of establishing independence among the explanatory variables.

2. Not applicable to key requirement uncertainty problems.

B. Magic formula approach to the downward bias of aerospace industry estimates.

1. More useful when employed for a large number of cases--may not work in preparing a particular estimate.

2. Up to present such extrapolations are prepared from limited size samples only.

V. Cost-Sensitivity Analysis

A. Individual aerospace system requirements: the examination of how cost changes as key characteristics (including both hardware design and operating concept) are varied over their relevant ranges.

B. Total force structure requirements: the examination of how cost varies with changes in the configuration characteristics of individual systems in a force, changes in force size, and force mix.

C. Cost-estimating uncertainty: how system or force costs vary due to uncertainties in cost-estimating relationships, errors in basic data, extrapolation error and the like.

D. Uses of sensitivity analysis

1. Examination of the cost implications of all interesting system and force possibilities.
2. Provides range of cost estimates for future systems rather than individual point estimate.
3. Provides relative measure of the sensitivity or insensitivity of system costs to variations in particular configuration characteristics.

E. Sensitivity analysis examples

1. Missile system cost versus payload weight versus ground environment automation.

a. insensitivity of cost to payload variation because important elements of cost--guidance, some GSE--not effected by missile size. Possibility of procuring higher payload missiles at relatively minor cost increments.

b. sensitivity of cost to ground environment automation and the diminution of system personnel requirements.

2. Missile system cost versus reliability
   a. significant sensitivity of cost to both mean time to failure and successful launch probability; justification for an extensive R&D program aimed at improving guidance reliability.
3. Recoverable versus conventional booster comparison
   a. determination of the level of demand for space transportation which justifies the development and other start-up costs of a new, more efficient vehicle.
   b. effects upon this cross-over point of improvements in the currently operational booster; i.e., either a decrease in cost or increase in payload carrying capability.

F. Limitations of sensitivity analysis
1. Presents a large volume of difficult to-display numbers to a system analyst who really wants one figure to run with.
2. Provides no formal measures of uncertainty (statistical) and, therefore, no probability statements.
3. No guarantee that any given sensitivity analysis has included all the relevant alternatives.

INDIVIDUAL WEAPON SYSTEM INPUTS

OPERATIONAL AND ORGANIZATIONAL DATA

FORCE SIZE	2000 MISSILES
ACTIVATION RATE	BUILDUP TO 25 WINGS BY END OF FY 67. FIRST SQUADRON OPERATIONAL DURING FY 63.
ORGANIZATION	25 MISSILES PER SQUADRON; 3 SQUADRONS PER WING. LCC CONTROLS ALL MISSILES IN SQUADRON, HAS SECONDARY CONTROL OF ALL MISSILES IN WING
SUPPORT BASE	ONE SUPPORT BASE PER WING TO HOUSE WING PERSONNEL, ADMINISTRATIVE, AND MAINTENANCE FACILITIES. SUPPORT BASE WILL SHARE EXISTING SAC BASES WHERE POSSIBLE.
DEPLOYMENT	1 MISSILE PER SILO; 1 LCC PER SQUADRON. 10 N MI BETWEEN SILOS. EACH SILO LOCATED WITHIN 0.5 MI OF SURFACED ROAD CAPABLE OF WITHSTANDING AXLE LOADS UP TO 20,000 LB. ALL SILOS IN REMOTE AREAS OF THE U.S.

INDIVIDUAL WEAPON SYSTEM INPUTS

MAINTENANCE CONCEPT DATA

ESTIMATED FAILURE RATE	500 MALFUNCTIONS PER WING PER MONTH; 350 ON MISSILES, 150 ON GROUND CHECKOUT EQPT.
PERIODIC INSPECTIONS	MISSILE REMOVED FROM SILO EVERY 15 MONTHS & RECIRCULATED TO MAINTENANCE FACILITY AT SUPPORT BASE. 2000 MAN-HOURS REQUIRED PER MISSILE. MISSILE ABSENT FROM SILO NO MORE THAN 10 WORKING DAYS.
MAINTENANCE IN SILO	SILO SERVICED BY FIELD CREW RESPONSIBLE FOR 5 MISSILES. CREW MOVES FROM ONE MISSILE TO ANOTHER PERFORMING CONFIDENCE CHECKS.
SUPPORT BASE	MAINTENANCE AND SERVICE FACILITY FOR COMPLETE VEHICLES AT SUPPORT BASE. THIS FACILITY REMOVES AND REPLACES FAILED BLACK BOXES. REPAIR OF BOXES TAKES PLACE IN CONTRACTOR OR SERVICE DEPOT.

INDIVIDUAL SYSTEM COST CATEGORIES (MANNED AIRCRAFT)

- RDT & E COSTS
  - DESIGN AND DEVELOPMENT
    - AIRFRAME
      - INITIAL ENGINEERING
      - DEVELOPMENT SUPPORT
      - INITIAL TOOLING
    - ENGINES
    - AVIONICS
  - SYSTEM TEST
    - FLIGHT TEST VEHICLE PRODUCTION
      - AIRFRAME
        - MANUFACTURING LABOR
        - MANUFACTURING MATERIALS
        - SUSTAINING AND RATE TOOLING
        - SUSTAINING ENGINEERING
        - OTHER
      - ENGINES
      - AVIONICS
    - FLIGHT TEST OPERATIONS
    - FLIGHT TEST SUPPORT

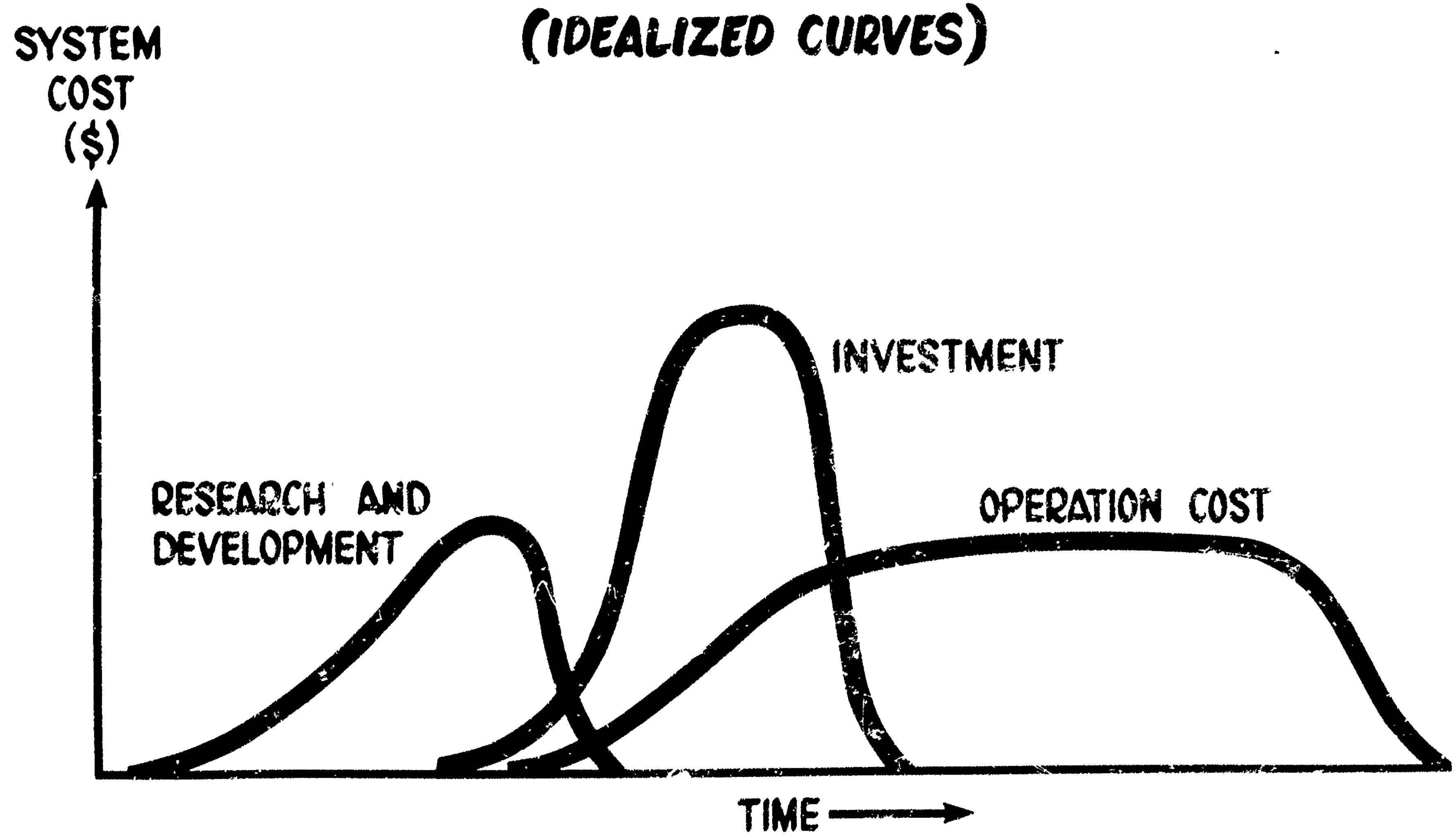
INDIVIDUAL SYSTEM COST CATEGORIES (CONT) (MANNED AIRCRAFT)

- INITIAL INVESTMENT COSTS
  - FACILITIES
  - PRIME MISSION EQUIPMENT
    - AIRFRAME
      - MANUFACTURING LABOR
      - MANUFACTURING MATERIALS
      - SUSTAINING AND RATE TOOLING
      - SUSTAINING ENGINEERING
      - OTHER
    - ENGINES
    - AVIONICS
  - UNIT SUPPORT AIRCRAFT
  - AGE
  - OTHER EQUIPMENT
  - STOCKS
  - SPARES
  - PERSONNEL TRAINING
  - INITIAL TRAVEL
  - INITIAL TRANSPORTATION

INDIVIDUAL SYSTEM COST CATEGORIES (CONT) (MANNED AIRCRAFT)

- ANNUAL OPERATION COSTS
  - FACILITIES R & M
  - PME REPLACEMENT
    - AIRFRAME
      - MANUFACTURING LABOR
      - MANUFACTURING MATERIALS
      - SUSTAINING AND RATE TOOLING
      - SUSTAINING ENGINEERING
      - OTHER
    - ENGINES
    - AVIONICS
  - PME MAINTENANCE
  - PME POL
  - UNIT SUPPORT AIRCRAFT MAINTENANCE AND POL
  - AGE REPLACEMENT AND MAINTENANCE
  - PERSONNEL PAY AND ALLOWANCES
  - PERSONNEL REPLACEMENT TRAINING
  - ANNUAL TRAVEL
  - ANNUAL TRANSPORTATION
  - ANNUAL SERVICES

SYSTEM COSTS TIME PHASING
(IDEALIZED CURVES)



ILLUSTRATIVE FORMAT FOR PRESENTING SUMMARY OF TOTAL FORCE STRUCTURE COST ESTIMATES

FORCE STRUCTURE					MANPOWER REQMTS (000's OF PEOPLE)								EXPENDITURES (OR TOA) (MILLIONS OF 1962 DOLLARS)															
MISSIONS AND SYSTEM	NO. OF SQDNS (END OF FY)				MILITARY				CIVILIAN				R & D				INVESTMENT				OPERATION				TOTAL EXPENDITURE			
	'61	'62	...	'70	'61	'62	...	'70	'61	'62	...	'70	'61	'62	...	'70	'61	'62	...	'70	'61	'62	...	'70	'61	'62	...	'70
STRATEGIC																												
B-47																												
B-52																												
B-58																												
KC-135																												
SM-68																												
SM-80																												
OTHER STRATEGIC																												
TOTAL STRATEGIC																												
DEFENSE																												
F-101, 102																												
F-104, 106																												
IM-99																												
AEW																												
BMEWS																												
OTHER DEFENSE																												
TOTAL DEFENSE																												
TACTICAL																												
F-104, 105																												
TM-76																												
TROOP CARRIER																												
OTHER TACTICAL																												
TOTAL TACTICAL																												
MISC																												
MATS																												
OTHER UNALLOCATED																												
TOTAL MISC																												
GRAND TOTAL																												

EFFECT OF TIME CONTEXT UPON RESOURCE ANALYSIS

LONG RANGE	SHORT RANGE
① WIDE RANGE OF ALTERNATIVES (BOTH FOR HARDWARE AND PROPOSED OPERATIONAL CONCEPTS)	① FEW ALTERNATIVES (HARDWARE ESSENTIALLY "GIVEN")
② GREAT UNCERTAINTY	② SMALL DEGREE OF UNCERTAINTY
③ SPECIFICATIONS AND DESCRIPTIONS OF ALTERNATIVES MAY BE SKETCHY; PAUCITY OF INFORMATION GENERALLY	③ DETAILED DESCRIPTIONS; RELATIVELY GOOD INFORMATION
④ HIGH DEGREE OF ACCURACY IN COST ESTIMATES IS NOT POSSIBLE; EMPHASIS ON TREATING THE ALTERNATIVES CONSISTENTLY	④ HIGH DEGREE OF ACCURACY REQUIRED, AND IS, IN GENERAL, POSSIBLE OF ATTAINMENT
⑤ EMPHASIS ON COMPARATIVE OR RELATIVE COSTS; LOOKING FOR MAJOR DIFFERENCES IN COST AMONG THE ALTERNATIVES TO DO THE SPECIFIED JOB	⑤ EMPHASIS ON ABSOLUTE VALUES

EFFECT OF TIME CONTEXT UPON RESOURCE ANALYSIS (CONT)

LONG RANGE	SHORT TERM
⑥ EMPHASIS ON PRESENTING RESULTS OF RESOURCE ANALYSIS IN TERMS OF INTEREST TO THE LONG-RANGE PLANNER: "END PRODUCT" OR MISSION-ORIENTED INCREMENTAL COSTS	⑥ EMPHASIS ON DEVELOPING AND PRESENTING ESTIMATES IN TERMS OF ADMINISTRATIVE AND IMPLEMENTATION ORIENTED CATEGORIES
⑦ BECAUSE OF WIDE RANGE OF ALTERNATIVES AND HIGH DEGREE OF UNCERTAINTY, EMPHASIS ON DEVELOPING A RANGE OF [illegible]TIMATES: "COST-SENSITIVITY ANA[illegible]"	⑦ EMPHASIS ON DEVELOPMENT OF "POINT ESTIMATE": LIMITED USE OF SENSITIVITY ANALYSIS
⑧ EMPHASIS ON USE OF GENERALIZED ESTIMATING RELATIONSHIPS	⑧ EMPHASIS ON COSTING OUT A DETAILED SET OF SPECIFICATIONS

FORMS OF ESTIMATING EQUATIONS

$$\text{COST} = a_0 + a_1 x_1 + a_2 x_2$$

$$\text{COST} = a_0 \, x_1^{b_1} \, x_2^{b_2}$$

$$\text{COST} = a_0 + a_1 x_1^{b_1} + a_2 x_2^{b_2}$$

WHERE X_i IS A SYSTEM PARAMETER, AND a_i AND b_i ARE NUMERICAL CONSTANTS.

EXAMPLES OF COST ESTIMATING RELATIONS

DEPOT MAINTENANCE COSTS

$$C = 14.526 + 0.050X_1 + 0.082X_2$$

C = COST IN DOLLARS PER FLYING HOUR (\$1000'S)

X_1 = AIRCRAFT COST AT THE 900TH UNIT

X_2 = COMBAT SPEED IN KNOTS

TURBOJET ENGINE DEVELOPMENT COST

$$C = 0.13937X_1^{0.74356}X_2^{0.07751}$$

C = COST IN $(\$ \times 10^6)$

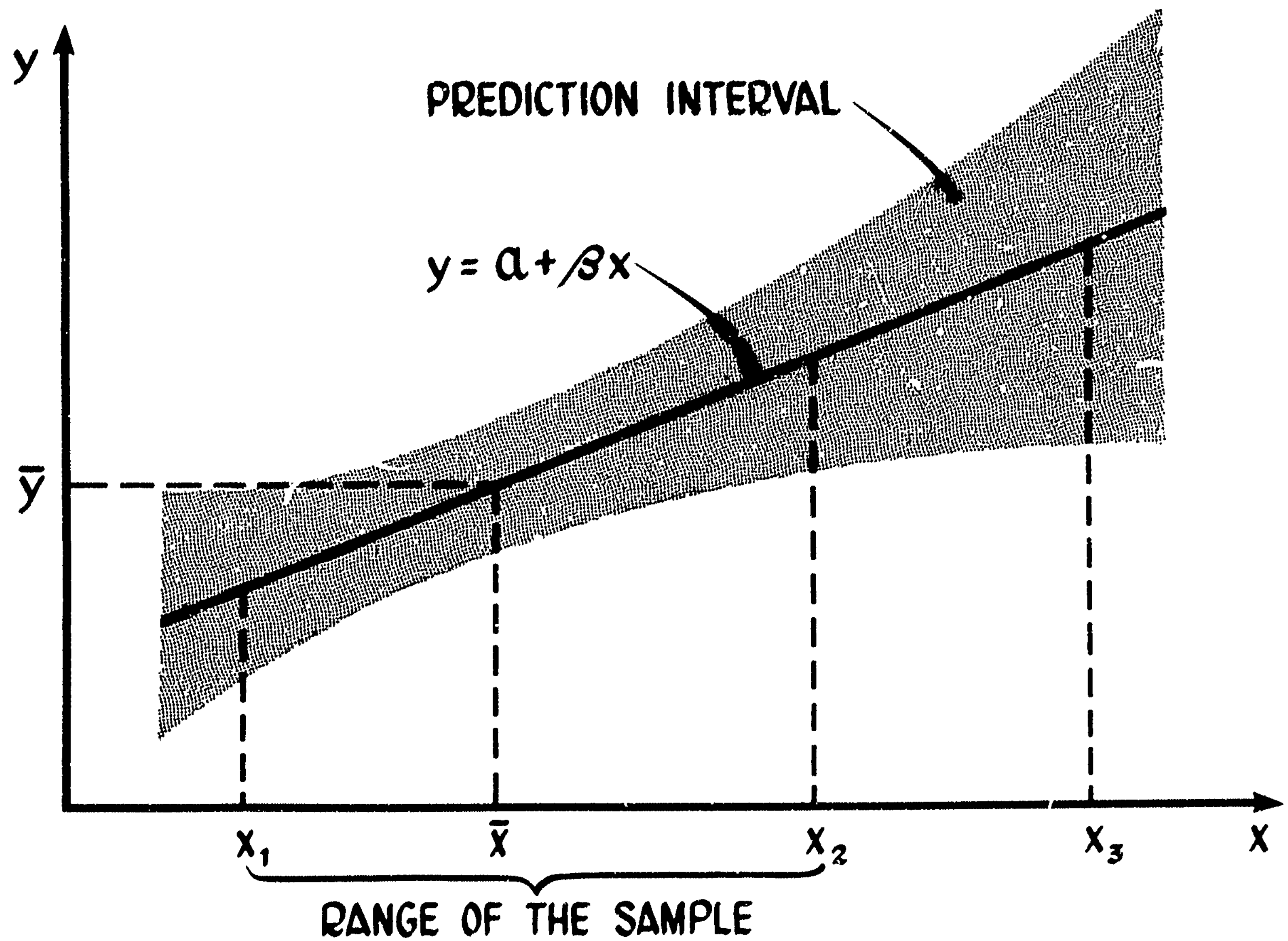
X_1 = MAXIMUM THRUST (LB)

X_2 = QUANTITY MILESTONE

DERIVING COST ESTIMATING RELATIONSHIPS
(CRITERIA FOR THE INCLUSION OF EXPLANATORY VARIABLES)

- LOGICAL OR THEORETICAL RELATION OF THE VARIABLE TO COST
- STATISTICAL SIGNIFICANCE OF THE VARIABLE'S CONTRIBUTION TO THE EXPLANATION OF COST
- INDEPENDENCE OF THE CONTRIBUTION MADE BY THE VARIABLE TO THE EXPLANATION OF COST

EXTRAPOLATING BEYOND DATA BASE LIMITS



LOG LINEAR COST QUANTITY CURVES

UNIT CURVE

$$C = aX^{-b}$$

CUMULATIVE AVERAGE CURVE

$$C = \frac{a}{N} \sum_{X=1}^{N} X^{-b}$$

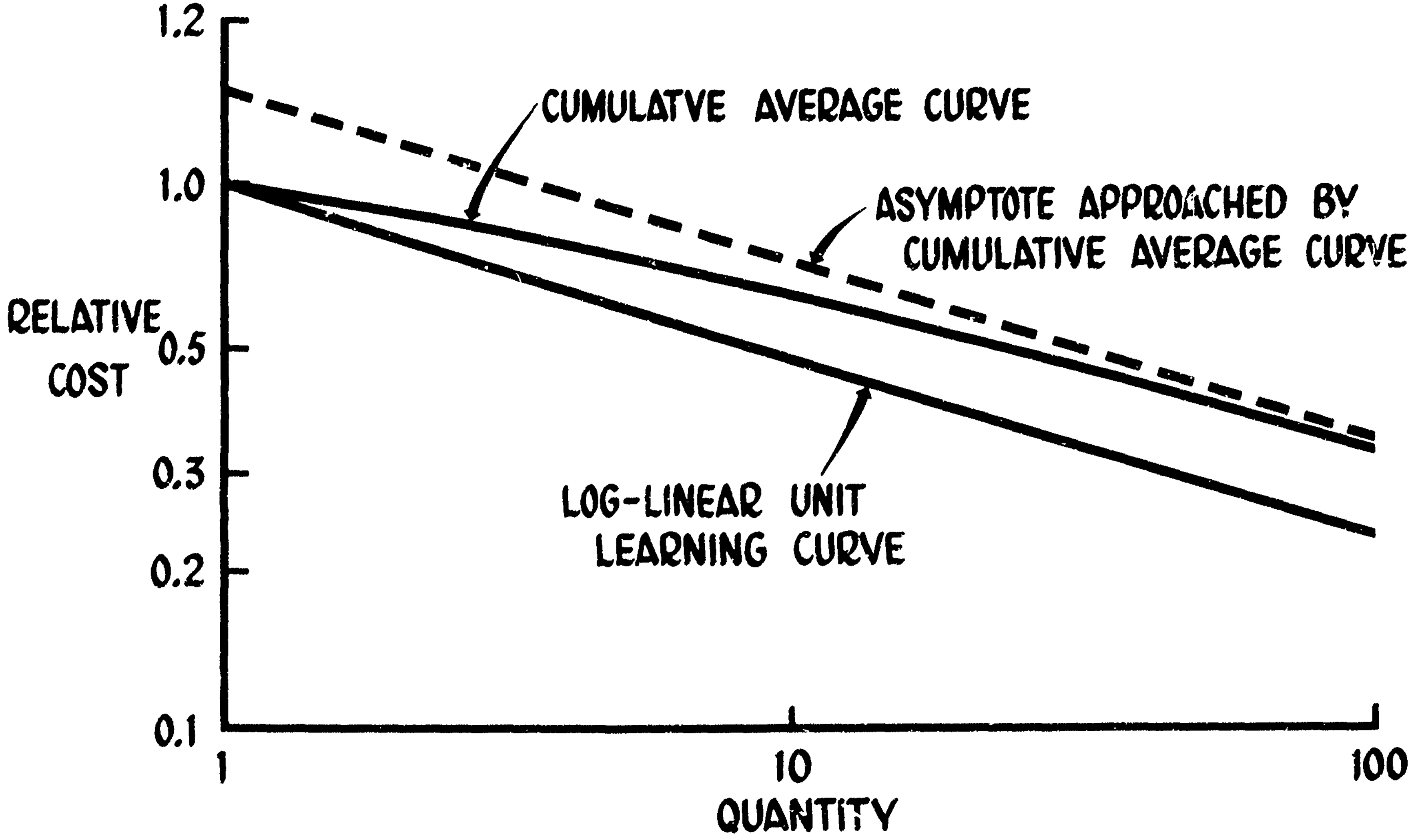
ASYMPTOTE APPROACHED BY CUMULATIVE AVERAGE CURVE

$$C = \frac{a}{1-b} X^{-b}$$

C = COST

X = PRODUCTION QUANTITY

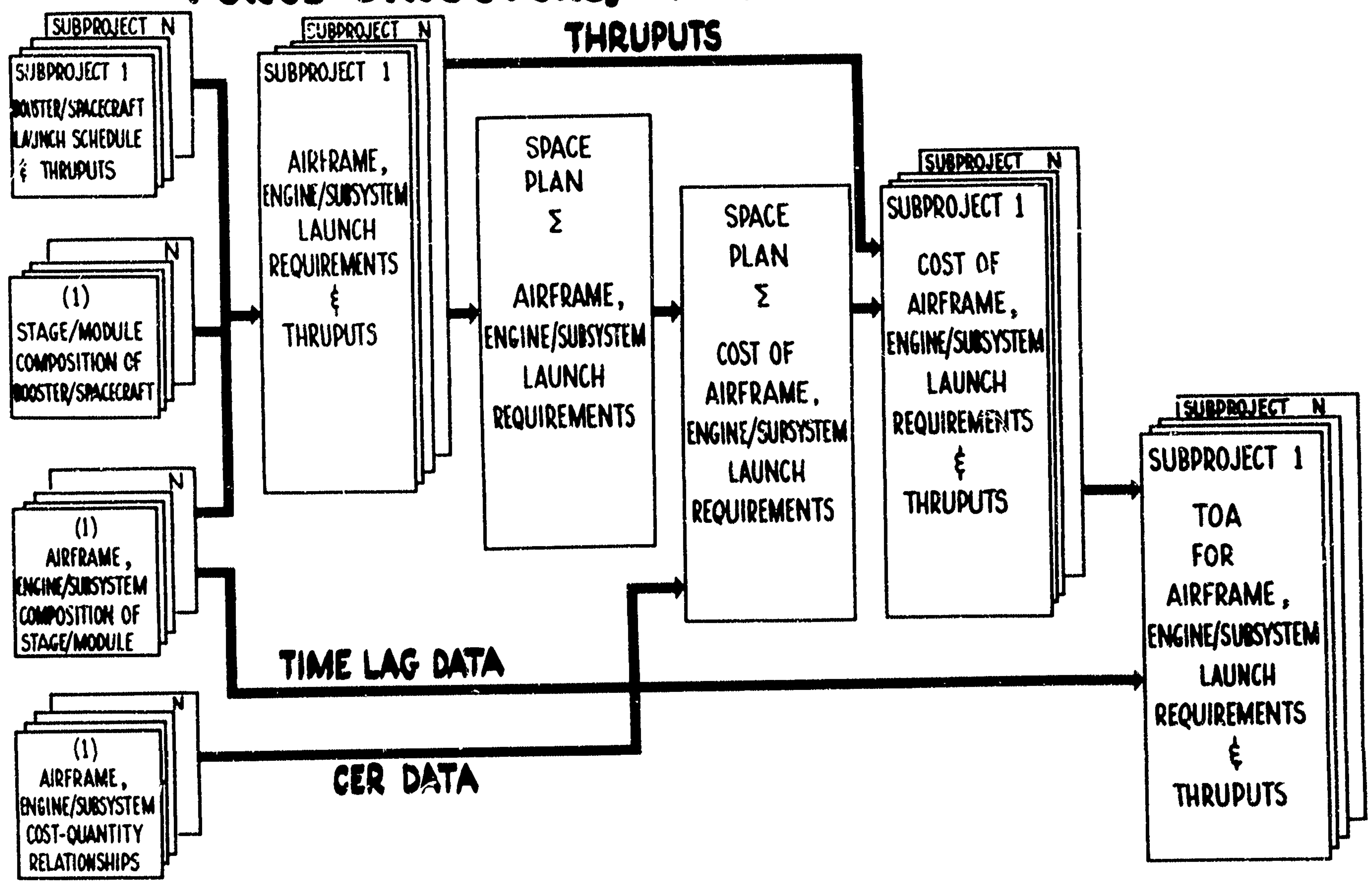
RELATIONSHIP BETWEEN UNIT AND CUMULATIVE AVERAGE LEARNING CURVES



MATRIX OF MISSILE AGE ESTIMATING RELATIONSHIPS BY TYPE OF EQUIPMENT AND LOCATION

i \ j	TYPE \ LOCATION	1 LAUNCHER	2 BLOCK-HOUSE	3 MAINT. & REAR AREA	4 MOBILE/ GENERAL	TOTAL BY TYPE
1	ELECTRICAL & ELECTRONICS	E_{11}	E_{12}	E_{13}	E_{14}	$\sum E_{1j}$
2	MECHANICAL & STRUCTURAL	E_{21}	—	XXX	XXX	XXX
3	HYDRAULIC & PNEUMATIC	E_{31}	—	XXX	XXX	XXX
4	INTERCONNECTIONS	E_{41}	—	XXX	—	XXX
	TOTAL BY LOCATION	$\sum E_{i1}$	XXX	XXX	XXX	$\sum\sum E_{ij}$

FORCE STRUCTURE/OVERALL PLAN TYPE MODEL



ALTERNATIVE METHODS OF ALLOCATING INTERRELATED SPACE PROGRAM RESOURCE REQUIREMENTS

	PROPORTIONAL ALLOCATION	FIRST USER	INDEPENDENT PROJECT STATUS
LUNAR PROGRAM AREA			
APOLLO	$ .15X	$ X	
EXTENDED LUNAR EXPLORATION	.70X		
EARTH ORBITAL PROGRAM AREA			
MOL			
LORL (24 MAN STATION)	.05X		
PLANETARY PROGRAM AREA			
MARS LANDING	.10X		
BOOSTER DEVELOPMENT			$ X
OTHER NON ALLOCABLES			
TOTAL			

PRESENT VALUE DISCOUNTING

$$PV = \sum_{t=1}^{N} \frac{C_t}{(1+i)^t}$$

PV = PRESENT VALUE

t = TIME PERIOD

C_t = COST IN TIME PERIOD t

i = INTEREST RATE

N = TOTAL NUMBER OF TIME PERIODS IN WHICH EXPENDITURES OCCUR

COST ESTIMATING UNCERTAINTY

ERRORS IN COST ESTIMATING RELATIONSHIPS

ERRORS IN DATA BASE

EXTRAPOLATION ERRORS

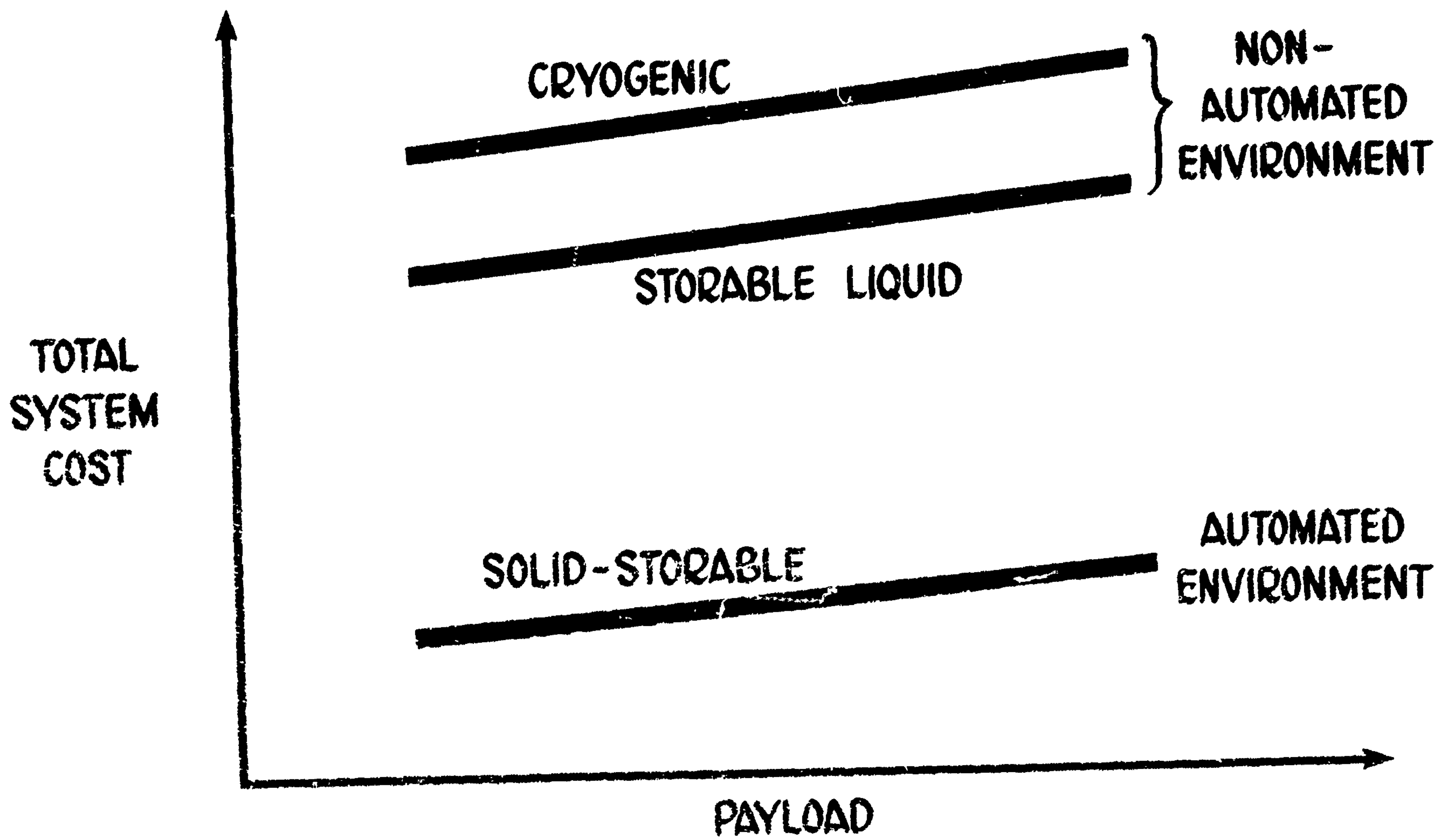
PRICE LEVEL CHANGES

ERRORS DUE TO AGGREGATION

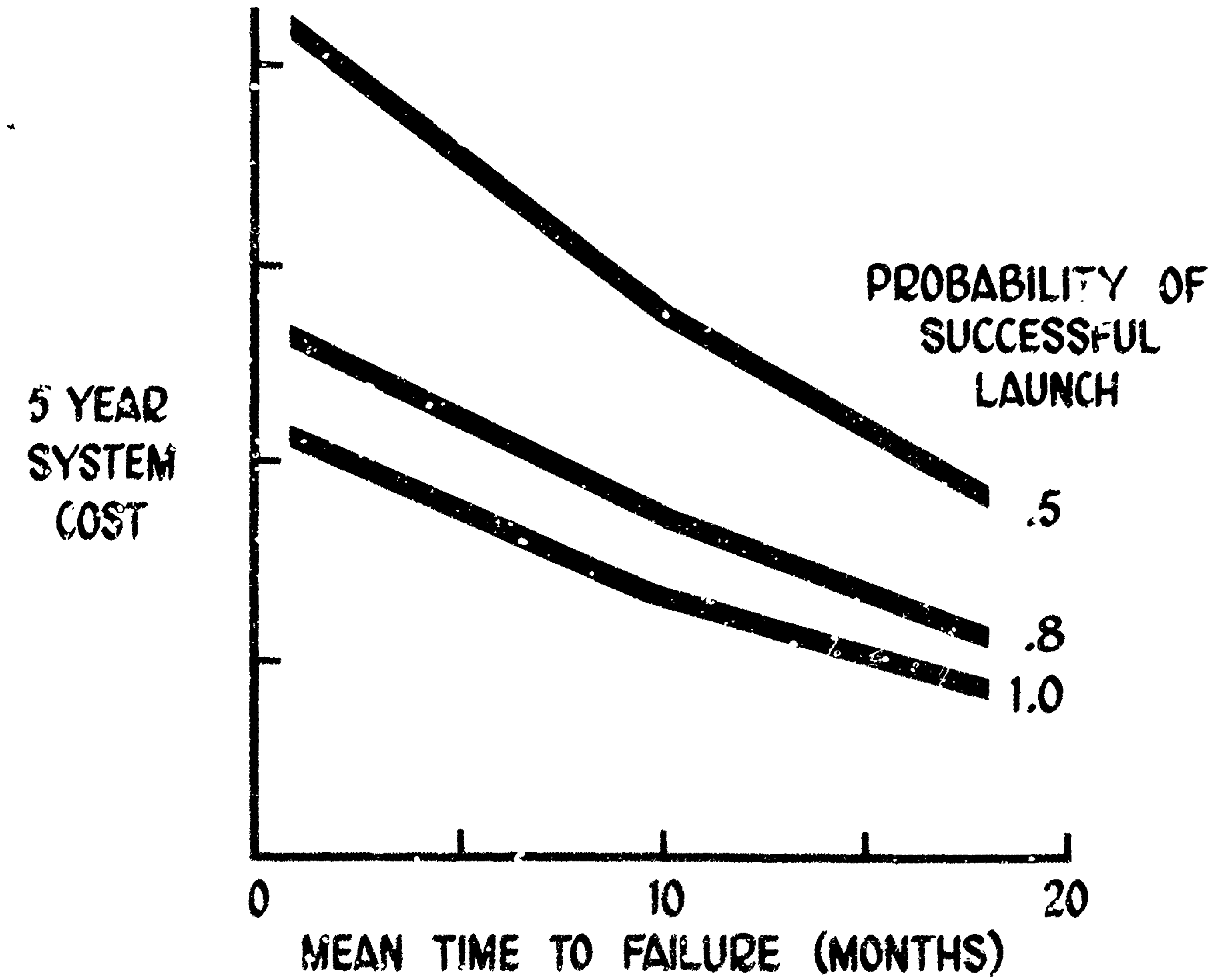
MISC. ERRORS PERTAINING TO EQUIPMENT

- SUB-CONTRACTING STRUCTURE
- CONTRACTOR VARIATION
- CHANGES IN THE MFG. STATE OF THE ART
- USE OF EXOTIC MATERIALS

MISSILE SYSTEM COST VS PAYLOAD FOR VARIOUS TYPES OF PROPELLANTS AND GROUND ENVIRONMENTS



MISSILE FORCE COSTS VS SYSTEM RELIABILITY



COST COMPARISONS OF RECOVERABLE VS NON-RECOVERABLE BOOSTERS