San Fernando Valley State College

FEASIBILITY PARAMETERS IN THE
MODERN VALUE ENGINEERING FUNCTION

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Science in Business Administration

by

Gex B. Coons

January, 1970
The thesis of Gex B. Coons is approved:

Committee Chairman
San Fernando Valley State College
January, 1970
TABLE OF CONTENTS

LIST OF FIGURES ....................................................... v

ABSTRACT .............................................................. vi

Chapter

I. INTRODUCTION ...................................................... 1

   Value Engineering Defined ........................................ 2
   Purpose of the Thesis ............................................... 3
   Scope of the Thesis ............................................... 3
   Sources and Methods of Collecting Data .......................... 4
   Historical Background ............................................. 5
   Value Engineering in the Department of Defense ............... 9
   Value Engineering Job Plan ........................................ 16
   Value Engineering--Cost Reduction and Cost Prevention ....... 20
   Report Preview .................................................... 22

II. VALUE ENGINEERING PARAMETERS .................................. 24

   Cost Analysis .................................................... 25
   Cost Measurement ................................................ 35
   Dollar Value ..................................................... 36

III. VALUE ENGINEERING UTILIZATION ................................. 37

   Concept Formulation Phase ....................................... 40
   Definition Phase ................................................ 48
   Development Phase ............................................... 50
   Production Phase ................................................ 50

IV. DEVELOPING AND TESTING THE VALUE MODEL ..................... 51

   Developing a Value Model ......................................... 53
   Testing the Value Model ......................................... 56

V. SUMMARY ............................................................ 66
BIBLIOGRAPHY ........................................... 72
APPENDICES .............................................. 76
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Guide to Value Engineering Contract Clauses</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>ASPR Value Engineering Clauses-Pertinent Provisions</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>Application of ASPR Value Engineering Clauses</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>ASPR Contract Definitions</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>DOD Cost Reduction Program</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>Value Engineering Contribution to DOD Cost Reduction</td>
<td>17</td>
</tr>
<tr>
<td>7</td>
<td>Value Engineering Job Plan</td>
<td>19</td>
</tr>
<tr>
<td>8</td>
<td>Product Life Cycle</td>
<td>25</td>
</tr>
<tr>
<td>9</td>
<td>Economic Considerations Pertinent to the Acceptability of Changes</td>
<td>28</td>
</tr>
<tr>
<td>10</td>
<td>Eighty Per Cent Learning Curve</td>
<td>34</td>
</tr>
<tr>
<td>11</td>
<td>System Life Cycle-Value Engineering Highlights</td>
<td>39</td>
</tr>
<tr>
<td>12</td>
<td>Concept Formulation Flow Diagram</td>
<td>41</td>
</tr>
<tr>
<td>13</td>
<td>Components of Effectiveness</td>
<td>43</td>
</tr>
<tr>
<td>14</td>
<td>Concept Formulation Task Plan</td>
<td>44</td>
</tr>
<tr>
<td>15</td>
<td>Comparison of the Value Engineering Job Plan with the Concept Formulation Flow Diagram</td>
<td>45</td>
</tr>
<tr>
<td>16</td>
<td>Significant Value Model Factors</td>
<td>55</td>
</tr>
</tbody>
</table>
ABSTRACT

FEASIBILITY PARAMETERS IN THE MODERN VALUE ENGINEERING FUNCTION

by

Gex B. Coons

Master of Science in Business Administration

January, 1970

Value engineering techniques were developed to reduce the excessive costs incurred in almost every segment of industrial and governmental activities. The question of the economic feasibility of applying value engineering techniques to production programs is confused by the relative infancy of the discipline and by the lack of Department of Defense (DOD) guidance concerning the use of value engineering. This thesis reviews the various value engineering parameters and presents a value model from which feasibility can be determined. The value model is concerned with only the Production and the Operational phases of the product life cycle because they represent the most tangible areas for measuring the results of value engineering efforts.

Data for the analysis of value engineering parameters were obtained from the reports of field authorities and from DOD handbooks and specifications. Information for the preparation and
test of the value model was solicited from the Aerospace Industry. The value model described in this thesis was developed by the author utilizing value engineering examples obtained from the Lockheed-California Company, a Division of the Lockheed Aircraft Corporation.

Literature research disclosed industry's lack of direction concerning the feasibility of employing value engineering techniques. Results of the value model test indicate that feasibility can be determined and that production and operational costs can be reduced using value engineering techniques. Because of the small sample size, however, further tests should be conducted to assure a more universal application of the value model.
CHAPTER I

INTRODUCTION

There is a growing crusade in the United States today aimed at reducing costs in almost all areas of industrial and governmental activities. One of the most important tools of this endeavor is a technique called "value engineering." This movement has received the backing of many organizations, including the Executive Branch of the Federal Government through the Department of Defense (DOD).

Value engineering, relatively new as a recognized discipline, has long been applied to the design process wherever cost has been of importance. Prior to advances by Lawrence D. Miles in the 1940's, however, value engineering was practiced without an organized job plan and, therefore, without benefit of a check list of value-in-design.

Value engineering, also known as value analysis, takes several forms. Practitioners of the technology have defined it in a number of ways, yet all of the many definitions have a common denominator: they all emphasize the analysis of functions and the relationship of function to cost. It is interesting to examine value engineering's various meanings and applications.
Value Engineering Defined

In 1947, Lawrence D. Miles, while a member of the Procurement Department of the General Electric Company, was assigned the task of cost reduction during the production phase of the product life cycle. His efforts resulted in the development of the first value engineering techniques which Miles called "value analysis," and he has since been called the father of "value analysis" and "value engineering" by his associates. Miles defines value analysis as:

A philosophy implemented by the use of a specific set of techniques, a body of knowledge, and a group of learned skills. It is an organized, creative approach which has for its purpose the efficient identification of unnecessary cost, i.e., cost which provides neither quality, nor use, nor life, nor appearance, nor customer features.¹

The Lockheed-California Company, one of the country's leading aerospace firms, defines value engineering as:

An objective evaluation of all elements of a system for the purpose of achieving the required function, reliability, producibility, maintainability, and quality at a minimum overall cost.²

The Society of American Value Engineers (SAVE) was founded in March, 1960, and is now composed of a large industry-wide membership. SAVE's definition of value engineering encompasses all of the essential points of the first two definitions and is best suited to the purposes of this thesis. This organization defines value engineering as:


An arrangement of techniques which make clear the functions the user wants from a product, service, or organization; establishes the appropriate cost for each function; then causes the required knowledge and creativity to be used to provide each function for that cost. Value analysis is considered to be synonymous.3

Purpose of the Thesis

The purpose of this thesis is to (1) explore the parameters of value engineering, (2) examine the feasibility of value engineering application to the development phases of product design, and (3) develop a means for determining the feasibility of applying value engineering during the product acquisition phase for cost reduction purposes.

Scope of the Thesis

Research data for the preparation and test of the value model were solicited from five major aerospace firms in the Los Angeles area. Analysis of submitted data, however, narrowed the field of applicable input to one source, the Lockheed-California Company.

The value model developed in this thesis is concerned with cost reduction in hardware design which has been released to production and with customer-approved equipment specifications. The model does not cover areas of cost prevention, i.e., design or specification changes processed before the design is released to production. Designs or specifications which have not been released to production cannot be considered finalized and, therefore, it would be inaccurate to claim credit for preventing their

high cost through value engineering changes.

There are many phases of activity during the life cycle of a product, e.g., the Concept, the Development, the Design, the Production, and the Operational phases. This survey has been restricted to the Production and the Operational phases of the product life cycle in developing a value model and in testing the feasibility of its application. This restriction is appropriate because these two phases represent the most tangible areas for appraising the outcome of value engineering efforts.

Sources and Methods of Collecting Data

Data for the analysis of value engineering parameters were obtained through research of books and periodicals published by authorities in the field and from handbooks and specifications issued by the Department of Defense (DOD). Library research was conducted at the San Fernando Valley State College Library, the University of California Library at Los Angeles, the Los Angeles public libraries, and the Engineering Library at the Lockheed-California Company, Burbank, California. A major source of data was the published proceedings of the SAVE National conventions.

Data for development and test of the value model were obtained from the Lockheed-California Company located in Burbank, California. Two aircraft development and production programs afforded sufficient meaningful data to exercise the value model for comparison with actual program saving results. Another aircraft program provided input data; however, due to the lack of actual hardware production, actual program savings data were unavailable.
for comparison.

**Historical Background**

A discussion of the evolution of value engineering as a recognized discipline is essential in order to develop an understanding of, and appreciation for, value engineering techniques presently used in industry. In addition, to justify the cost of value engineering programs, and the costs associated with changes nurtured by such programs, it is important to review some examples of the results of value engineering efforts. This is not intended to be an exhaustive presentation of value engineering techniques as they have progressed during the past twenty-five years, but rather a brief description of the value engineering efforts of a few selected companies.

**General Electric Company.** As previously stated, value engineering had its origin in the late 1940's when the General Electric Company assigned Lawrence D. Miles the task of finding a new method to reduce product costs. Miles' approach was to analyze the functions of a product or part, to eliminate unnecessary functions, and to find low-cost methods of accomplishing the desired functions. Miles called this technique "value analysis." By matching and comparing the functions of a part with its costs, Miles found he could locate what he called areas of "poor value." For example, the General Electric Company was using an aluminum strap to fasten an oil-wick assembly at a cost of $7.70 per

---

4"Poor value" in Miles' analysis represented either a function provided at an excessive cost, or a function provided but not needed.
thousand. Miles' investigations revealed that an ordinary staple could fasten the oil-wick assembly just as well, and at the reduced cost of only 3.09 per thousand.  

United States Navy. Heralding the growing DOD interest in value engineering, the Navy's Bureau of Ships (BuShips) adopted General Electric's problem-solving approach in 1954. In contrast, however, the Navy attacked costs by using seminar teams composed of representatives from engineering, purchasing, and manufacturing. BuShips called their technology value engineering, whereas Miles had called his value analysis.

The Navy's value engineering seminar participants learned that by consistently utilizing the capabilities of specialty vendors—rather than accepting unspecialized, in-house, designer concepts—many end-item costs could often be reduced from 70 per cent to 90 per cent without compromising quality. The job of locating these specialty vendors was commonly given to the purchasing agent. This step in the evolution of value engineering resulted in the establishment of value engineering activities in both the purchasing and the engineering departments of many firms.

New Holland Machine Company. In 1954 the New Holland Machine Company founded its value analysis program, and two years later established a value engineering group within its Purchasing Department. One illustration of the effects of this company's


6Ibid.
value engineering efforts is demonstrated by their discovery of an overdesigned gear box. The gear box was discovered to have high cost dowel pins and fasteners in removable panels, expensive material in a spring, unneeded grease line and fittings, and poor design of a formed part. Value engineering of this gear box reduced its cost by over $6,700 per year of production.\(^7\)

Radio Corporation of America. The Radio Corporation of America (RCA) initiated a "Value Improvement Program" in 1957 which coordinates value analysis in Purchasing, value engineering in Engineering, and methods improvement in Production. Each of these departments work together in cost reduction and in cost prevention. Cost prevention normally takes place in Engineering by determining the essential function and the simplest method of accomplishment, and by reviewing designs regularly for performance, reliability, maintainability, and cost.

RCA uses both permanent value analysis and value engineering personnel, as well as special value engineering teams. Considering all the costs of change, including the costs of value engineering studies, investigation has shown that value engineering has yielded about fifteen times its cost on items designed before cost prevention. On equipment designed under full cost-prevention techniques, returns from cost-reduction programs, understandably, are much lower.

RCA has also found that value engineering can aid in product reliability by locating overdesigned or underdesigned elements,

\(^7\)Ibid., p. 1-43.
highly stressed components, heat sources, nonessential refinements, duplicated functions, or drafting inconsistencies. For example, RCA was involved in the design of a large radar. It was initially determined that high flexibility could be attained by using separate interbank cable connections. However, value engineering investigations revealed that the radar would be housed in a standard building where integral cabling, rather than interbank cabling, could be used. Reliability was increased considerably by eliminating two soldering connections and two mating connections per wire (ninety-six connector pairs per system). Initial costs of $2,037 for materials and $3,600 for labor were cut to $242 for material and $36 for labor, resulting in a saving of $5,359 per year of production.\(^8\)

**Boeing Aero-Space Company.** Value engineering was undertaken at the Boeing Aero-Space Company in 1960. The program is patterned after the General Electric value analysis system but differs in that it is directly under management, rather than under Purchasing. The present value engineering group is therefore not engineer-oriented, a fact which Boeing personnel feel reduces the roadblocks normally encountered in the anticipation of engineering and design problems.

A few striking examples of Boeing's value engineering efforts are: (1) redesign of a dado strip for the Model 707 that cut material, handling, and fabrication costs by 84 per cent; (2) replacement of a special thermal-relief valve by an off-the-shelf

unit, saving 75 per cent; (3) redesign of a missile battery so that only the cells and rubber components are discarded each six months, decreasing annual costs by $700,000; (4) reduction of the excess grip-length on pieces to be stretchformed, saving $56,000 per year; and (5) replacement of a pull-up-type fastener by a stub-type titanium fastener on one section of the B-52, saving $100,000 per year.\(^9\)

Value Engineering in the Department of Defense

Original cost and cost reduction in military and governmental procurement has long been of concern. The history of warfare, and the world as well, has been shaped by the cost of hardware. It is pertinent, therefore, to examine the effects which Department of Defense efforts have had upon the development and utilization of value engineering techniques.

Charles J. Hitch, commenting upon remarks from Joseph Alsop's book on the Greek Bronze Age, states:

Cost alone could explain why all Bronze Age armies, not only the Pylians, were generally small and based on an elite corps. Here we see how a technically inferior weapon (the iron sword), simply because it is cheaper (than the bronze sword) and therefore can be acquired in larger numbers, can beat the superior weapon which is dear and can only be acquired in small numbers.\(^{10}\)

\(^{9}\)Ibid., pp. 1-42.

Robert McNamara, Secretary of Defense from 1961 to 1968, was one of that Department's strongest proponents of cost effectiveness, systems analysis, systems engineering, and value engineering. During his tenure of office, special emphasis was given to cost prevention and cost reduction in the procurement of items for the military establishment. Most of the programs and procedures which were established during his term of office will undoubtedly be continued and augmented by future Secretaries.

In 1963, several documents were issued by the DOD which defined value engineering and its uses. The first of these documents was Handbook H-111 on Value Engineering Methodology. Handbook H-111 was issued by the DOD to "aid Government activities and contractors in expanding and accelerating their value engineering programs to achieve meaningful cost reductions."

Another important document issued by the DOD in 1963 was Mil-V-38352, Value Engineering Program Specification. This Specification presents an outline of logical steps and documentation requirements for the implementation of a complete value engineering program. It has been imposed upon contractors by the DOD, and upon subcontractors and suppliers by prime contractors, for some recent high-value contracts.

The last and most important of the 1963 DOD documents issued on value engineering was Revision 3 of Section 1, Part 17 of the

---


Armed Services Procurement Regulation (ASPR). This document was revised by Defense Procurement Circular (DPC) Nos. 11, 13, and 19. The DOD has recognized that industry, operating for the most part, if not exclusively, on the profit motive must benefit by, "increased profit on future and existing business through financial incentive provided for successful value engineering efforts." Incentive clauses, therefore, are now included in most new military procurement contracts. The formal and legal approaches to these financial incentives are contained in the revision to the ASPR and in issues of Defense Procurement Circular (DPC) Nos. 11, 13, and 19.

In October, 1964, the most noteworthy of the Defense Procurement Circulars, No. 11, was issued. This Circular outlined (1) Value Engineering Incentives and Programs, (2) Value Engineering Sharing Methods, (3) Special Contract Provisions, (4) Cost Allowability, (5) Evaluation and Acceptance, (6) Value Engineering Incentive Clauses, and (7) Value Engineering Program Requirement Clauses. This Circular has become the primary guide for all DOD contractors in their value engineering contract negotiations with the DOD.

One DOD contractor, the Lockheed Missiles and Space Company, has summarized DPC 11 into a value engineering contract clause simulator. This simulator is shown in Figures 1 through 4. Figures 1 through 3 indicate that value engineering contracts are to have two basic types of incentive clauses: "Incentive Clauses"

<table>
<thead>
<tr>
<th>Incentive Clauses</th>
<th>Contractor Share of Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Contract</strong></td>
<td><strong>ASPR Reference</strong></td>
</tr>
<tr>
<td>FFP</td>
<td>1-1707.2</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>FPE</td>
<td>1-1707.2</td>
</tr>
<tr>
<td>FPPR</td>
<td>1-1707.5</td>
</tr>
<tr>
<td>FPI (Firm Targets)</td>
<td>1-1707.3</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>FPI (Successive Targets)</td>
<td>1-1707.4</td>
</tr>
<tr>
<td>CPIF</td>
<td>1-1707.6</td>
</tr>
<tr>
<td><strong>Program Clauses</strong></td>
<td></td>
</tr>
<tr>
<td>CPFF</td>
<td>1-1708.1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>CPIF</td>
<td>1-1708.2</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>FPI (Firm Targets)</td>
<td>1-1708.3</td>
</tr>
<tr>
<td>FPI (Successive Targets)</td>
<td>1-1708.4</td>
</tr>
<tr>
<td>FP (Other)</td>
<td>1-1708.5</td>
</tr>
</tbody>
</table>

Fig. 1—Guide to Value Engineering Contract Clauses

*In the absence of adequate price competition, less than 50% may be appropriate.

**If it is determined that reasonable certainty exists that costs and savings can be accurately estimated.

***If it is determined that reasonable certainty does not exist that costs and savings can be accurately estimated.

Source: Lockheed Missiles and Space Company.
<table>
<thead>
<tr>
<th>REQUIRED VE EFFORT</th>
<th>INCENTIVE CLAUSES ASPR 1-1707</th>
<th>PROGRAM CLAUSES ASPR 1-1707</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE REQUIRED.</td>
<td>LEVEL OF EFFORT AS SPECIFIED IN THE SCHEDULE.</td>
<td>BOTH CLAUSES CONSIDER NORMAL VE EFFORT. THE PROGRAM CLAUSE ADDS REQUIREMENT OF SPECIFIC LINE ITEM EFFORT.</td>
<td></td>
</tr>
<tr>
<td>SHARING OF SAVINGS</td>
<td>IT IS STATED DOD POLICY TO BE GENEROUS IN INCENTIVE ARRANGEMENTS IN VOLTAGE COST REDUCTIONS, INCLUDING TWO ELEMENTS OF ASSURANCE TO CONTRACTOR—(1) FARE PROPORTION OF SAVINGS, AND (2) PROPORTION APPLIED TO SUBSTANTIAL CASE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INSTANT CONTRACT</td>
<td>UNDER INCENTIVE CONTRACTS, PERCENTAGE (25% MAX) RELATED TO CERTAINTY OF ACCURATELY ESTIMATING COSTS AND SAVINGS; UNDER CPEF CONTRACTS, LOWER MAXIMUM PERCENTAGE SET (10% MAX).</td>
<td>CONSENSUS EFFORT SHOULD BE MADE TO NEGOTIATE SHARING AT RATE SIGNIFICANTLY GREATER THAN THE OVER-ALL COST INCENTIVE PATTERN.</td>
<td></td>
</tr>
<tr>
<td>FUTURE ACQUISITION</td>
<td>UNDER INCENTIVE CONTRACTS, PERCENTAGE (20% MAX) TO BE SIGNIFICANTLY LESS THAN INSTANT CONTRACT SHARING; UNDER CPEF CONTRACTS, LOWER NORMAL PERCENTAGE STATED (8%).</td>
<td>ALL CONTRACTS CONTAINING VE CLAUSES SHOULD INCLUDE PROVISION COVERING FUTURE ACQUISITIONS WITH SHARING NEGOTIATED AT HIGHEST RATE CONSISTENT WITH PERIOD INVOLVED.</td>
<td></td>
</tr>
<tr>
<td>COLLATERAL</td>
<td>SAME AS UNDER INCENTIVE CLAUSES.</td>
<td>ALL CONTRACTS CONTAINING VE CLAUSES SHOULD INCLUDE PROVISIONS COVERING COLLATERAL SAVINGS.</td>
<td></td>
</tr>
<tr>
<td>COST ALLOWABILITY</td>
<td>COSTS OF PROGRAMMED EFFORT ARE ALLOWABLE AS DIRECT COSTS.</td>
<td>PROGRAMMED COSTS COULD COVER ONLY DIRECT ENGINEERING HOURS. NORMAL VE COSTS OF DESIGN AND HARDWARE REVIEWS, TRAINING PROGRAMS, PROGRAMMING, SUBCONTRACT LIAISON, REPORTS AND DOCUMENTATION, ETC. HOWEVER, ALL OF THESE ELEMENTS MIGHT BE INCLUDED IN A PROGRAM PACKAGE.</td>
<td></td>
</tr>
<tr>
<td>PRICING/FUNDING</td>
<td>COSTS OF PROGRAMMED EFFORT WILL BE TREATED AS ANY OTHER LINE ITEM. COSTS OF NORMAL PROGRAM SAME AS UNDER INCENTIVE CLAUSE.</td>
<td>FUNDING DOES NOT PRECLUDE SHARING. MAJOR PROBLEM IN THIS AREA IS FUNDING OF EXTENSIVE DEVELOPMENT, PROTOTYPE AND TESTING COSTS.</td>
<td></td>
</tr>
<tr>
<td>SUBCONTRACTS</td>
<td>SAME AS UNDER INCENTIVE CLAUSE.</td>
<td>CONTRACTOR'S COSTS TO INCLUDE SUBCONTRACTOR'S IMPLEMENTATION COSTS AND INCENTIVE PAYMENTS OR SHARED, NO.</td>
<td></td>
</tr>
<tr>
<td>DATA</td>
<td>SAME AS UNDER INCENTIVE CLAUSE.</td>
<td>BY USE OF RESTRICTIVE LEGEND, AND IN ABSENCE OF ACCEPTANCE, GOVERNMENT ACQUIRES NO RIGHTS IN VECP DATA SUBMITTED UNDER EITHER TYPE OF CLAUSE.</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 2—ASPR Value Engineering Clauses—Pertinent Provisions**

**Source:** Lockheed Missiles and Space Company.
<table>
<thead>
<tr>
<th>Required in</th>
<th>Incentive Clause ASPR 1-1702.3(a)</th>
<th>Program Clause ASPR 1-1702.3(b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFP</td>
<td>Contracts over $100,000.</td>
<td>CPFF - Contracts over $1,000,000.</td>
</tr>
<tr>
<td>FPI</td>
<td></td>
<td>- Unless:</td>
</tr>
<tr>
<td>CIF</td>
<td>- Unless:</td>
<td>1. Head of Procuring Activity determines no potential for VE reductions</td>
</tr>
<tr>
<td></td>
<td>1. Contract includes Program clause</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Item is a commercial product</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Head of Procuring Activity determines no potential for VE reductions</td>
<td></td>
</tr>
<tr>
<td>May be used in</td>
<td>FFP</td>
<td>CIF</td>
</tr>
<tr>
<td></td>
<td>Contracts for A &amp; E, Research or Exploratory Development upon determination by Contracting Officer of potential for VE reductions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Contracts less than $100,000 at discretion of Contracting Officer</td>
<td></td>
</tr>
<tr>
<td>Normally not used in</td>
<td>Contracts for A &amp; E, Research or Exploratory Development</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Procurements less than $100,000</td>
<td></td>
</tr>
<tr>
<td>Shall not be used in</td>
<td>CPFF contracts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contracts which are formally advertised</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3--Application of ASPR Value Engineering Clauses

Source: Lockheed Missiles and Space Company.
<table>
<thead>
<tr>
<th>Type of Contract</th>
<th>ASPR Reference</th>
<th>Contract Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFP</td>
<td>1-1707.2</td>
<td>Firm Fixed Price contract.</td>
</tr>
<tr>
<td>FPE</td>
<td>1-1707.2</td>
<td>Fixed Price contract with Provisions for Escalation.</td>
</tr>
<tr>
<td>FPI (Successive Targets)</td>
<td>1-1707.3, 1-1708.3</td>
<td>Fixed Price Incentive contract with successive targets.</td>
</tr>
<tr>
<td>FPI (Firm Targets)</td>
<td>1-1707.4, 1-1708.4</td>
<td>Fixed Price Incentive contract with firm targets.</td>
</tr>
<tr>
<td>FPPR</td>
<td>1-1707.5</td>
<td>Fixed Price contract with Provisions for Prospective Price Redetermination.</td>
</tr>
<tr>
<td>CPIF</td>
<td>1-1707.6, 1-1708.2</td>
<td>Cost Plus Incentive Fee contract.</td>
</tr>
<tr>
<td>CPFF</td>
<td>1-1708.1</td>
<td>Cost Plus Fixed Fee contract.</td>
</tr>
<tr>
<td>FP</td>
<td>1-1708.5</td>
<td>Fixed Price contract other than incentive contract.</td>
</tr>
</tbody>
</table>

Fig. 4--ASPR Contract Definitions

Source: Lockheed Missiles and Space Company.
and "Program Clauses." The Incentive Clause Contract contemplates normal value engineering effort but does not set forth that activity as a requirement. Sharing of savings is allowed at a high value (75 per cent maximum), thereby encouraging a high degree of participation. The Program Clauses set forth the required value engineering effort on specific line items. Sharing under Program Clauses is reduced (25 per cent maximum) in the absence of voluntary initiative. Sharing under either clause is a function of the degree of price competition and/or the degree to which costs and savings can be accurately estimated.

The issuance of DPC 11 demonstrates the DOD's sincere concern with cost reduction and their confidence in the contribution they feel value engineering can make to that effort. The DOD's emphasis on cost reduction through value engineering has produced some interesting results since 1961 as illustrated by the tabulation below, and Figures 5 and 6.

In 1965:

Twenty-three of the top one-hundred DOD contractors processed less than ten Value Engineering Change Proposals (VECP's).

Fifty-four of the top one-hundred DOD contractors had no VECP's processed.¹⁴

Value Engineering Job Plan

Organization of effort produces definition of purpose and economy of activity for almost any task. Industry and the Depart-

Fig. 5--DOD Cost Reduction Program*

Fig. 6--Value Engineering Contribution to DOD Cost Reduction**


ment of Defense recognized the need for an organized approach to value engineering studies during the early stages of their development. The instrument for the organization of value engineering effort which evolved is called a "job plan." The Lockheed-California Company describes a value engineering job plan as follows:

The key to any value engineering study or value analysis lies in using an organized approach. This approach is called the job plan. It consists of a step-by-step method of proceeding with a cost study, from its inception through to its execution and realization of its potential savings.15

In his work at the General Electric Company, Lawrence D. Miles developed a seven-phase job plan which he considered essential to the conduct and success of his investigations. Industry and the Department of Defense have used his plan as a starting point for the formulation of their own value engineering job plans, but variations have necessarily been developed. Miles' job plan is as follows:

- **Phase 1:** Orientation. What is to be accomplished?
- **Phase 2:** Information. Get all the information.
- **Phase 3:** Speculation. Obtain alternatives.
- **Phase 4:** Analysis. Select most promising ideas.
- **Phase 5:** Program Planning. Plan the investigation of the ideas.
- **Phase 6:** Program Execution. Develop the most desirable alternative.
- **Phase 7:** Status Summary and Conclusion. Sell the selected alternative to the decision maker.16

The DOD has also established a seven-phase job plan. Their

15 Key Techniques to Value Engineering. A report prepared in 1963 by the Lockheed-California Company, Burbank, California.

process, however, is slightly different:

- Phase 1: Product Selection.
- Phase 2: Determination of Function.
- Phase 3: Information Gathering.
- Phase 4: Development of Alternatives.
- Phase 5: Cost Analysis of Alternatives.
- Phase 6: Testing and Verification.
- Phase 7: Proposal Submission and Follow-up.17

The Lockheed-California Company job plan consists of only four phases which guide its value engineering efforts. These phases, however, encompass all of the processes used by General Electric and the DOD. Lockheed's job plan is:

- Phase 1: Information Phase.
- Phase 2: Speculative Phase.
- Phase 3: Analytical Phase.
- Phase 4: Planning and Execution Phase.18

Figure 7 outlines a value engineering job plan which encompasses all of the essentials of the various plans and expresses them in terms akin to those used in systems engineering and program management.

---


18 Key Techniques to Value Engineering. A report prepared in 1963 by the Lockheed-California Company, Burbank, California.
During the Problem Definition and Function Analysis Phase, a thorough search is made of all the available information. "Brain storming" sessions are then held to identify product functions. These functions are reduced to their simplest form utilizing one-verb and one-noun descriptions. For example, General Electric's oil-wick staple would be identified as "hold material." Function analysis frequently results in the discovery of unnecessary functions which can be eliminated. Methods of accomplishing functions are also examined during this first phase.

Phase two consists of the selection and development of alternative methods of function accomplishment. This is sometimes called the Speculative Phase. Efforts are made to uncover many possible methods for accomplishing a given task with an eye toward cost reduction. The costs of each alternative are determined and ideas are refined during the Analytical Phase. Selections of alternatives are then made by further analysis and trade-off during the Evaluation Phase.

The entire value engineering process is concluded only after the successful implementation of proposed methods, processes, or designs. This is accomplished in the Planning and Implementation Phase and involves a clear documentation of conclusions in a sales campaign, and incorporation of the proposal into the product, service, or organization.

Value Engineering--Cost Reduction and Cost Prevention

The rapid growth of the discipline and processes of value

\[19\text{Ibid.}, \ p. \ 3.\]
engineering, as evidenced by the foregoing, has been nurtured by two basic factors: (1) the successes achieved in cost reduction by companies and governmental agencies applying the techniques, and (2) the promotional efforts of the Department of Defense. These promotional efforts have been interpreted by both industry and governmental agencies as an indication that value engineering should be applied to all programs and that its primary function is cost reduction.

Evidence that value engineering is not just a cost reduction technique, but also a cost prevention technique, is presented by Richard J. Zanetti and Theodore A. Tasis in a paper addressed to the 1968 SAVE National Convention. To quote from that paper:

In many cases, the tendency is to look upon value engineering as a way of reducing costs, or to put it more bluntly, as a way to make it cheaper. A reduction in cost is only one facet of value engineering. Other equally important facets are performance improvements, manufacturability improvements, reliability improvements, and maintainability improvements, at no or minimal cost increase in comparison to the degree of improvement. However, because of the deeply ingrained notion that any improvement can only be gained from large expenditures, this area is largely ignored in favor of making it cheaper, which has the connotation of a sacrifice in quality. As such, value engineering is relegated to the broader aspects of cost reduction, dominated by Industrial Engineering whose main concern is tooling and assembly procedures. When the time comes for high level management to examine the P and L (profit and loss) statement, the efforts of value engineering are buried under the overall category of cost reduction savings. Thus, not only does value engineering lose its identity, but its effectiveness is reduced because less is expected of it than it is capable of.  

---

Another voice supporting the contention that value engineering is more than merely cost reduction is that of E. M. Menke in an address to the 1966 SAVE National Convention. Quoting from his paper:

Cost engineering, the science of determining and relating cost to system and hardware design, is urgently needed in support of cost effectiveness and value engineering analysis required during system evolution.

This paper will show that (1) this emphasis on cost is a natural result of the technological explosion and that it is considered very important to the DOD, (2) the major decisions requiring cost support occur during the Operation Analysis and System Engineering phase of evolution because fixed price incentive contracts are signed at the completion of these phases, (3) the nature of cost support requires the development of cost engineering as a permanent addition to the growing list of technologies, (4) basic cost research is in order, and (5) several specific tasks for cost engineering are described and are shown to be essential for cost effectiveness or value engineering results. 21

---

the product life cycle.

The feasibility of value engineering application during the Production and Operational phases can be determined by the use of a value model. Chapter IV presents a series of formulas comprising such a model. The value model is then tested for validity and accuracy using three cost reduction program proposals from the Lockheed-California Company. The thesis concludes with a summary of the major findings of this study, followed by the author's conclusions and recommendations.
CHAPTER II

VALUE ENGINEERING PARAMETERS

In order to determine the feasibility of applying value engineering to the various phases of the product life cycle, it is first desirable to explore the parameters of the value engineering process. The process involves the comparison of two or more alternative concepts for the purpose of providing the desired functions for the least cost. It is therefore most important that the costs of all relevant parameters be compared and that the scale of measurement be uniform for each parameter.

Value engineering, then, to be completely effective, must consider all elements of future cost which might be incurred during the product life cycle. Future costs can be defined as those costs which would be incurred by the in-force (baseline) concept and by the proposed (candidate) concepts from the point of the completion of the analysis to the end of the remaining life cycle of the product.

The total product life cycle, shown graphically by Figure 8, includes the following periods: (1) Research, Development, Test, and Evaluation (RDT&E), (2) Design, (3) Production, and (4) Operation and Support. Proposals to consider alternative concepts can occur at any point along the life cycle, even as the first ideas
Fig. 8--Product Life Cycle
for the product are conceived. They may also occur much later, even during the operation and support periods. Figure 8 illustrates two possible points of value engineering proposal implementation.

Costs which have been incurred against the baseline or original concept prior to change can be considered "sunk costs," unless they are retrievable. It is sometimes possible, for example, to dispose of obsolete product and/or tooling materials through salvage sales. Such retrieved costs would favor change and in comparative evaluations would be added to the benefit side of change.

**Cost Analysis**

To insure credibility in the value engineering process, it is necessary to use accurate and all-inclusive costs in comparing alternative methods of accomplishment. The Lockheed-California Company's value engineering training manual emphasizes this point as follows:

In order to achieve cost savings when "evaluating the worth of a thing" it is necessary to have accurate cost figures. Valid design comparisons and accurate decisions cannot be made without them.

These cost figures include two basic items. First, the cost numbers themselves must be accurate; and second, all costs which bear on the subject must be included. All factors which influence the total cost of the product must be considered and included.¹

¹Key Techniques to Value Engineering, p. 27. A report prepared in 1963 by the Lockheed-California Company, Burbank, California.
For the purpose of comparative analysis, costs fall into several classifications. Some costs are incurred once during the development of a product and are not repeated during the life cycle of that product. These are classified as "nonrecurring" or "one-time" costs. Some examples are:

- Engineering
- Planning and tooling
- Production development
- Supplier's development
- Instruction handbooks
- Training and training devices
- Support equipment and facilities

Costs which do repeat during the product life cycle are called "recurring" costs, and include:

- Production (material and labor)
- Maintenance
- Spare parts

These cost classifications are not always inflexible. There are times, for example, when new tooling may be required at various intervals during the product life cycle, making those costs recurring. On the other hand, it may be possible and/or advisable to include the procurement cost of all spares within the original purchase price, thereby classifying their cost as nonrecurring.

One list of comparative costs which has served as an industry guide in the analysis of product support of alternative concepts is BuWeps Instruction No. 13052.2A, Figure 9, issued by the Navy in 1962. These instructions establish the policies and procedures for processing Class I engineering changes, changes resulting from value engineering programs, and Class I and Class II changes resulting from second source procurement of selected Contractor
1. Each engineering change submitted shall be evaluated on the basis of a comparative analysis of the relative cost of supporting the original configuration versus the new configuration. Comparative analysis and estimates related to following factors are required:
   a. Revised or new publications costs
   b. Personnel training and training devices costs
   c. Support equipment, tools, and facilities requirements and costs
   d. Effect on GFAE and related costs
   e. Man-hour requirements for maintenance, inspection, servicing, and rework
   f. Service life and reliability
   g. Existing government assets of equivalent items
   h. Introduction, stocking, and administrative and support costs including but not limited to the following:
      (1) Establishment of new items of supply
      (2) Determination of the number of stockpoints based on repairability and/or replacement
      (3) Supporting spare and repair parts - quantity and cost

NOTE: Increased costs, man-hours, etc., alone shall not be considered as reason for disapproving a change. Trade-offs between items which still result in total over-all program cost saving is, however, mandatory for approval. For trade-off purposes, in determining total program cost, the hourly rates of contractor personnel shall be used for item e. above.

2. To aid in implementing this Instruction, the following cost estimates are supplied:
   a. With regard to paragraph 1.h.(1) above, the cost of establishing a new item of supply is $45.45 per item. This estimate includes all administrative charges including procurement actions related thereto.
   b. With regard to paragraph 1.h.(2) above, once the determination of the number of stockpoints has been made, based on repairability and/or replacement, the cost of holding a quantity of an item in supply is $3.25 per item per stockpoint. Cost of preservation, prior to stocking, is excluded from the above and is estimated at $2.00 per stock item. Suitable adjustment upward of these estimates for large, expensive, or delicate items should be considered where special handling is involved.

3. The determination of the number of stockpoints and cost of supporting spare and repair parts must of necessity be established upon specifics by negotiation between the contractor, ASO, and the cognizant BUWEPSREP or Inspector (MIS).

Fig. 9--Economic Considerations Pertinent to the Acceptability of Changes

Source: Bureau of Naval Weapons.
An analysis of the various cost classifications (recurring, nonrecurring, and those outlined in BuWeps Instruction 13052.2A) will give an insight into their detail and the extent of their application to the product life cycle. Reliable comparative analysis requires that all the applicable costs be considered in selecting alternative methods of accomplishment.

**Engineering Costs.** Engineering costs include all expenditures which can be allocated to the work package. These costs vary and are dependent upon company policy and upon the classification of costs as direct or indirect. Engineering costs include at least the following elements, with overhead added as a factor:

- Design and design support man-hours
- Model building
- Testing
- Qualification

**Planning and Tooling Costs.** As in the case of engineering costs, planning and tooling costs are variable with regard to the allocation of costs. In general, however, these costs include:

- Preparation of the manufacturing plan
- Design of tooling
- Tooling material
- Fabrication and qualification of tooling

---

2 Class I and Class II changes are defined by ANA Bulletin No. 445 issued July 12, 1963. Briefly stated, Class I changes (those requiring customer approval before the change is made) affect specific performance factors and contract price. These are the changes which are covered by value engineering incentive contract clauses.

Class II changes consist of all other changes. The customer does not share in Class II cost reductions unless he initiates contract renegotiations in order to maintain a reasonable profit margin.
Production Development Costs. Production development costs may be required because of the complexity of the alternative or the infancy of the processes. These costs include:

- Training of production personnel
- Special production facilities and machines

Supplier's Development Costs. When the concepts being analyzed require the purchase of the product or components of the product from a subcontractor or supplier, the subcontractor may be required to spend development money to update his capability. This expense should be included in the cost analysis. Supplier's development costs will be nonrecurring costs unless the supplier chooses to amortize the expense into his product or material sales price.

Instruction Handbooks. Handbooks which are issued by the manufacturer to present operation and repair information for a given product or component may be affected by a proposed change. When such is the case, variations in cost should be determined for the following nonrecurring parameters:

- Instruction preparation and planning
- Page layout and illustration
- Printing, binding, and distribution

Training and Training Devices. Training in the operation, maintenance, and repair of some products is required. Sometimes the effort is minimal, utilizing only the Instruction Handbooks. Some products, however, require special training techniques, working models of the product, training manuals, facilities, training instructors, etc. Cost variations for these expenditures should not be overlooked.
Support Equipment and Facilities. Operation, maintenance, and repair of a product may require support equipment and/or facilities. Checkout of navigation equipment, for example, may require a special shop power-supply and a test set. Some parameters which might vary with product design are the cost of:

- Test equipment
- Maintenance and repair tools
- Maintenance training and training devices
- Maintenance facilities

Man-hour Requirements for Maintenance, Inspection, Servicing, and Rework. A product may be simple in construction, compact, and attractive, but may be very difficult to maintain, service, or rework. Variations in man-hours for this activity are important considerations.

Effect upon Interfacing Equipment. Variations in the design of a product may have an effect upon an interfacing component or piece of equipment (Government Furnished Airborne Equipment, GFAE, for example). The costs required to maintain compatibility should be included in the comparative analysis of concepts.

Service Life and Reliability. Concepts of differing design may have significantly different service lives. Reliability analysis and field service data for similar concepts provide a basis for predicting variations in this parameter. These variations are used to determine replacement periods, maintenance points, and other associated costs.

Existing Assets of Equivalent Items. Changes in product design may leave the user with a stock of obsolete parts. Determination of the utility of these parts and their ultimate disposition
is necessary. Parts which can be used as substitutes will produce a minimum cost effect, while obsolete parts will probably have only scrap or salvage value. Any recovery value can be added to the cost analysis as a favorable change.

**Items of Supply.** Products which have more repairable component parts necessarily require more part storage space in warehouses and more record keeping. BuWeps Instruction 13052.2A allows $45.45 per item for the establishment of storage space and records. This can become a significant parameter in comparative analysis.

**Spare Parts.** The determination of spares requirements is usually a subject of negotiation between the customer and the contractor. Predictions can be made to indicate the ratio of spare parts to original parts which must be maintained. The ratio will vary as a function of the product design. Procurement of spares may be on a one-time basis or, as is more often the case, may be spread out on a periodic, recurring basis. The ratio can be a significant parameter in comparing design concept costs.

**Production Costs.** Production costs are most significant in the comparative analysis of concepts. These are repetitive or recurring costs; therefore, relatively small differences in alternative costs can grow into decisive amount when multiplied by production and spares quantities. The design engineer establishes features in the original design which have a profound influence upon minimum production costs. As stated in the Lockheed Missiles and Space Company value engineering training manual:
The importance of the design engineer in controlling cost is too often underrated; in fact, too often unknown or unappreciated by the design engineer himself.

The degree of factory efficiency, tooling ingenuity, and purchasing resourcefulness utilized will determine how closely the factory approaches the minimum cost of manufacturing and producibility. The fact remains that the most efficient factory methods, ingenious tooling, and resourceful purchasing cannot reduce the cost of the product below the minimum established by the design engineer. Quite obviously, the effectiveness of any cost control program will depend to a large degree on the engineer's awareness of the role he must play, and upon the extent of his active participation in such a program.

On the other hand, the responsibility for cost control is not alone that of the engineer. A multitude of non-engineering functions influence the course of product development to a greater or lesser degree. Thus, effective cost control in fact becomes everybody's business. It follows that unnecessary costs will result in each stage of the product cycle where this fact is ignored.3

Production costs are calculated from two basic parameters: material and labor. Material costs include costs from such sources as (1) raw material, (2) standard parts, and (3) purchased special components. Labor costs are the costs required to convert raw material into the finished product and package it for delivery.

Labor man-hours vary with the production quantity and the time span. As a program progresses and units are completed, labor costs decrease. Mr. Charles T. Horngren discusses this point in his textbook on cost accounting as follows:

Many companies use the so-called "learning curve" to solve the problem of predicting changes in labor costs (and standards) as workers gradually become familiar with their tasks. Case studies have shown that labor time needed per unit of product should become progressively smaller at some constant percentage rate as the operator becomes

better acquainted with his specific task. The applicable percentage rate varies from 60 per cent to 85 per cent, but 80 per cent seems to be most common. Thus, as cumulative quantities double, average time per unit should fall 20 per cent. 4

An illustration of the 80 per cent learning curve is shown in Figure 10.

![Figure 10](image)

**Fig. 10--Eighty Per Cent Learning Curve**

Comparative production costs begin at the points of implementation on the product life cycle. It is important, therefore, to accurately predict the point of implementation. Change boards composed of representatives from all plant branches usually determine the change serialization and the point of schedule implementation. In early phases, where design detail is sketchy, production costing is sometimes based on the proposed product's similarity to an established item already in production, on the dollars per pound of product, or on some other "educated guess-

---

tion" technique.

Cost Measurement

It is not always possible or practical to assign a dollar evaluation to all the parameters for the purpose of concept comparisons. It is very difficult, for example, to place a dollar value upon product appearance. In recognition of this problem, Paul F. Wellborn, Jr., in a paper presented to the 1966 SAVE National Convention, discussed the mathematical evaluation of value problems. The following is an excerpt from his excellent paper:

Frequently the Value Engineer is confronted with multiple potential solutions to a value problem. After generating these potential solutions, how can he evaluate the relative merits of the solutions when the criteria to be used in evaluation occupy different dimensions? Also, the evaluation criteria may vary in their effect upon the acceptance/rejection decision. Due to these variations in effect and dimensions, one must consider, during evaluation, a type of "weighted guidelines" approach, rather than a static, or nonreflective, approach. One approach which fulfills this requirement is dimensional analysis.

It should be noted that some criteria have definite dimensions for measurement, such as pounds, dollars, and hours. Other criteria require the development of a ranking system to indicate their desirability. One system of this nature is the Numerical Designation Index (NDI). This system assigns a numerical value, relative to the desirability of the criteria being considered, in accordance with the following: Very Good = 10, Good = 8, Fair = 6, Poor = 4, Very Poor = 2. This system is used when the criterion being considered does not lend itself to any definite dimensions, or when measurement of the dimension is not practical at the point in time at which the design is being considered.5

When dollar valuations are not applied, the resulting analysis is subjective as a whole. Usually, however, evaluations are "sold" on the basis of comparative dollar savings in conjunction with subjective evaluations, such as the NDI evaluation, quoted for their added influence upon the decision maker.

Dollar Value

The value of money varies with time. It is important, therefore, to use the same time factor and its dollar value whenever evaluating value engineering alternative concepts. The Lockheed Missiles and Space Company Value Engineering Handbook defines the time value of money as:

The immediate value of capital which must be paid at some future time. If, for example, a one-year loan of $100 at a 6 per cent interest rate were made today, the borrower may receive $100 but would be required to pay the lender $106 by the end of the year. This time value of money must also be considered a cost of conducting a business enterprise.6

Dollars for labor man-hours, pounds of material, operating fuel, etc., may be quoted as to their current value or as to their value for the future year when the product goes into manufacture. Where comparative values alone are important, the time period selected for determining the dollar value is not usually critical, as long as all the parameters are treated with the same value of the dollar within the same time period.

---

CHAPTER III

VALUE ENGINEERING UTILIZATION

Value engineering is only one of a multitude of program development approaches which have come into use since World War II. In reviewing the many approaches, it is interesting to note that they all have areas of commonality, and that value engineering is an inferred part of each. There are even different names for approaches which are the same in all other respects. Configuration management, for example, is also sometimes called systems management. A few examples of the various approaches to program development are:

- Configuration Management
- Systems Management
- Program Management
- Systems Engineering
- Cost Effectiveness

All the techniques appear to have a goal which is very similar to the goal of value engineering. The difference between each of the approaches lies in their emphasis on cost as a factor in system selection.

Feasibility of the application of value engineering to all phases of program activity is inherent in the inclusion of engineering economics in the definitions of each of the above techniques. Cost effectiveness, for example, is defined by E. S. Quade
of the Rand Corporation as:

A stage of systems analysis comparing alternative courses of action in terms of their costs and their effectiveness in attaining a specified objective; normally excludes other broader policy advice besides comparing alternatives such as specification of sensible objectives, determination of a satisfactory way to measure performance, influence of considerations which can't be quantified, or the design of better alternatives.¹

Mr. C. J. Hitch, also of the Rand Corporation, has a somewhat similar definition of cost effectiveness:

A type of system analysis (a reasoned approach to problems of decision of broad orientation) applying methods of quantitative economic analysis and scientific method to aid in the allocation of limited resources under conditions of uncertainty. It is now the heart of the program planning budgetary process at the highest levels in DOD and one of the major factors for aiding choosing between competing systems at even fairly low levels in DOD.²

There are two primary goals of cost effectiveness. The first of these goals is "effectiveness"—a measure of function accomplishment. The other goal of cost effectiveness is the achievement of the required functions for the least cost.

Mr. J. J. Cody, Major General, United States Air Force, in a paper presented to the 1966 SAVE National Convention, discusses the relationship between value engineering and configuration management. In Figure 11, Cody illustrates the value engineering activity—configuration management plan—superimposed upon the


Fig. 11--System Life Cycle-Value Engineering Highlights

normal system life cycle. Figure 11 presents value engineering in gross terms only, showing plans and programs but not detailed activity. It does not specify value engineering activity at all during the Conceptual Phase.

Concept Formulation Phase

The actual contribution of value engineering to the Concept Formulation Phase is revealed by an examination of the details of a concept formulation example. Figure 12 is a facsimile of an actual product development plan utilized during a concept formulation program at the Lockheed-California Company. During the process of concept development, Figure 12, value engineering tasks are required in several activities. Functional analysis is of prime importance in the diagram's flow.

T. C. Connor, in a paper presented to the 1968 SAVE National Conference, cites the importance of functional and cost analysis as follows:

Through Systems Design Product Analysis, the value engineering group task effort can be channeled into examining the contemplated product design from an overall or customer's viewpoint, with the added benefit of the knowledge and access to information known only to the company itself. This tends to reduce compartmentalization of departments and areas, and limits roadblocks created by both lack of information and direction. It also interacts with other disciplines such as Reliability, Maintainability, Design Review, and Safety Engineering and coalesces these activities toward the common goal of creating a product which is both functionally and value oriented.3

---

Fig. 12--Concept Formulation Flow Diagram
The Weapon System Effectiveness Industry Advisory Committee reports provide evidence that value engineering is an integral part of "effectiveness" and must be included in trade-off studies between the disciplines comprising system effectiveness. Figure 13, taken from the Task Group 3 report on data collection and management indicates that "effectiveness" is a function of availability, dependability, capability, and cost, which in turn are functions of reliability, value engineering, maintainability, etc.

Additional breakdown of the Figure 12 flow diagram gives further insight into the contribution value engineering can make to concept formulation. Figure 14 illustrates the lower-level task description which parallels the flow diagram. Those tasks to which value engineering contributes a major effort are indicated by an asterisk.

Examination of the processes shown in Figure 14 discloses a marked similarity to the value engineering job plan outlined in Figure 7. For the purpose of parallel comparison, Figure 7 and Figure 14 have been combined in Figure 15.

The Value Engineer, in applying a job plan to the tasks of concept formulation, can utilize the value engineering techniques developed by Larry D. Miles and others to better develop the product design. These improvements in initial product design will result in "cost prevention" rather than "cost reduction" in a later phase. The following discussion defines the application of value engineering techniques to various segments of the concept formulation task.
Fig. 13—Components of Effectiveness

Source: Weapon System Effectiveness Industry Advisory Committee
1. Functional and Operational Requirements  
   *A. Determine desired functions of the system.  
   B. Prepare function characteristics in gross terms.  
   C. Develop mission profiles in gross terms.  
   D. Establish minimum performance constraints.  

2. Functional Analysis  
   A. Determine characteristics for deployment of the system.  
   B. Establish mission availability and reliability constraints for the system.  
   *C. Establish producibility state-of-the-art for the era of application.  
   D. Establish dimensions constraining utilization of the system.  

3. Computer Program  
   Prepare computerized evaluation model inputs.  

4. Synthesis of Alternatives  
   *A. Select design alternative candidates.  
   B. Prepare sketches of candidates.  

5. Measure of Preference  
   Determine effectiveness parameters for desired functions.  

6. Analysis of Alternatives  
   A. Eliminate candidates unfavorable to schedule.  
   B. Prepare comparison matrix.  
   C. Review the concepts for technology status and risk.  
   D. Prepare preliminary trade-off list.  
   *E. Prepare material trade-off needs.  
   *F. Review concepts for reliability, maintainability, and producibility constraints.  
   G. Prepare preliminary trade-off evaluations.  
   H. Complete preliminary trade-off analyses.  

7. Evaluation of Alternatives  
   *A. Apply Measure of Preference to alternatives.  
   *B. Complete evaluation matrix with quantitative and qualitative analyses.  

8. Prepare production schedule for product quantities for costing of development and production.  

9. Selection of Prime Candidates  

Fig. 14—Concept Formulation Task Plan  

*Tasks to which value engineering contributes a major effort.  

NOTE: The above tasks constitute the effort leading to selection of a limited number of alternative candidates. Successive applications of these tasks in later stages lead to the narrowing of the candidates to one prime alternative.
<table>
<thead>
<tr>
<th>Value Engineering Job Plan (Figure 7)</th>
<th>Concept Formulation Flow Diagram (Figure 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Definition and Function Analysis</td>
<td>Functional and Operational Requirements</td>
</tr>
<tr>
<td>Establishment of Alternatives</td>
<td>Functional Analysis</td>
</tr>
<tr>
<td>Analysis of Alternatives</td>
<td>Synthesis of Alternatives</td>
</tr>
<tr>
<td>Evaluation and Trade Studies</td>
<td>Measure of Preference</td>
</tr>
<tr>
<td>Planning and Implementation</td>
<td>Analysis of Alternatives</td>
</tr>
<tr>
<td></td>
<td>Evaluation of Alternatives</td>
</tr>
<tr>
<td></td>
<td>Computer Programs</td>
</tr>
<tr>
<td></td>
<td>Prepare production schedule for costing of development and production</td>
</tr>
<tr>
<td></td>
<td>Selection of Prime Alternatives</td>
</tr>
</tbody>
</table>

Fig. 15—Comparison of the Value Engineering Job Plan with the Concept Formulation Flow Diagram

**Functional and Operational Requirements.** Fulfillment of the functional and operational requirements task involves a determination of what is to be accomplished by the system being developed. To this end, all available information must be studied, e.g., the Standard Operating Requirements issued by a military procurement agency, if such is the customer.

Functions or missions of the top-level work breakdown structure system and subsystem are usually specified by the customer, but the contractor may need to expand, refine, and possibly add to these functions. The value engineering technique of defining functions with simple one-verb and one-noun combinations is applicable to the task, and the Value Engineer is especially adept in this field.
Function Analysis. With functions defined in simple terms, some may fall into the category of "poor value" and become subject to trade-off. The remaining functions will be more clearly understood with the delineation of prime functions and supporting or secondary functions.

Synthesis of Alternatives. The development of a method of accomplishing a function is normal design activity. Value engineering contributes to this process the techniques of (1) brainstorming, (2) creating, (3) blasting, and (4) refining. From these creative processes, alternative methods of function accomplishment are developed. These value engineering techniques are utilized best by the type of team effort employed by BuShips and RCA.

Measure of Preference. Measure of preference is the term applied to the measure of effectiveness of the means of function accomplishment. In value engineering terms, it is the "value" or "worth" of the function. For example, in military weapon systems, kills/mission/life cycle cost might be a measure of preference by which all the weapon systems or hardware functions are evaluated. In the case of commercial transports, the measure of preference might be direct operating cost, or perhaps dollars/seat/mile.

The Value Engineer should be involved in the establishment of the measure of preference since the measure will be used in the evaluation of alternatives and during trade-offs where value is of major importance.

Evaluation of Alternatives. Comparison of alternatives against the measure of preference requires the assignment of
dollar values to all the elements of cost for each component of the alternative systems. Cost is usually determined for the life cycle of the product through the development, design, production, operation, and support phases.

The alternative concept which provides the desired function for the least over-all life cycle cost is usually selected as the desired design. Where cost for achieving a stated function is excessively high, trade-offs may be made, resulting in a compromise between cost and function. Some functions, such as those effecting personnel safety, may be inviolate, however.

Production Schedule. The value engineering team, usually composed of members from engineering, manufacturing, and procurement, can be especially effective in developing production schedules and other manufacturing and procurement data. These data will have an impact upon material and labor costs (including the effect of learning curves) used in the evaluation of alternatives.

Selection of Alternatives. Selection of alternatives is the culmination of the value analysis of alternatives and should be well documented. In the value engineering job plan, also, documentation is part of the sales program used to effect implementation or adoption of alternative selections. The Value Engineer is well qualified to participate in this effort, and his contributions can prove invaluable.

The above tasks, repeated as required, bring concept formulation to a completion and establish the Program Requirements Baseline shown in Figure 13. If value engineering is applied as indicated, functions at the top level of the system are well
defined, and the alternatives are selected which should provide those functions for the least cost. If value engineering is withheld during the concept formulation stage, design becomes "locked-in" and changes become more difficult to negotiate in later phases.

R. Glenn Woodward, of the Senior Staff of Operations Research Incorporated, expresses the need for the early application of the decision refinement process in a paper presented to the 1966 SAVE National Convention. His statement is as follows:

The basic problem facing management in moving a development program forward is the conflict between schedule, cost, and system performance. In order to meet schedule and cost constraints, he may try to freeze the design quickly, running the risk of later costly retrofit or unnecessary operational limitations, or he may delay final decisions as long as possible, continuing his analysis of alternatives until he is in real danger of schedule and cost slippage because of downstream uncertainties of which he cannot be sure until he commits himself.

In any development, there are always downstream uncertainties. The purpose of analysis, or of qualification testing, quality control, and other activities is to remove these uncertainties to the extent possible with the information and resources available. They cannot all be removed during early analysis, or during design tests; in fact, the last residual uncertainty is only removed during operational use of the system. It is management's job to so allocate its resources as to reduce this total program uncertainty as rapidly as possible.4

Definition Phase
Each phase of program development carries the analysis of the system to deeper levels of the subsystem, hardware, service, and organization. Again quoting from Mr. Woodward's 1966 address:

The output of the concept phase of the development pro-
gram provides a rather crude description of the embry-
onic system, indicates the kind of inputs and outputs
which each subsystem will use, and develops a range of
parameter values which appear feasible.

A first cut at design (in the definition phase) might
be to tailor each subsystem to the midpoint of the
range of values for each parameter, to develop the de-
tailed functional equations governing the system, and
to match calculated system output against required
output.

At this point, three kinds of activity usually develop
the information necessary for design optimization:

1. Tests are conducted on breadboard circuits to
   confirm performance characteristics.
2. An engineering/analytical model of the system
   is developed for exploring the consequences
   of design alternatives on system performance.
3. Cost and function models are developed and
   cost reduction (and cost prevention) possibil-
   ities are reviewed.

The Value Engineer has a role to play in all three
areas. His contribution stems from his continuing re-
sponsibility to provide an overview of program inter-
actions and costs.5

The primary product of the Definition Phase of design activ-
ity is the development of a basic design concept for which further
design-guidance specifications can be written. This basic design
is called a "design requirements baseline." The subsequent design-
guidance specifications, which are called "Part 1" or "design to"
specifications, are then prepared as controls for subcontractor
design effort. It is therefore ideal to have prevented high
costs, insofar as possible, in the development of this baseline
design.

5 Ibid., p. 169.
Development Phase

During the Development Phase, functional analysis is concentrated upon the detail hardware, services, and organizational levels of the work breakdown structure. The functions of the upper levels have been established in previous phases.

The Development Phase is the final phase before production begins. It is therefore the last major opportunity for "cost prevention" in lieu of "cost reduction." There are opportunities for cost reduction, however, since previous decisions are now subject to possible change. As indicated in Figure 11, the Value Engineer can begin to initiate Value Engineering Change Proposals (VECP's) during this phase.

Production Phase

Classic value engineering, as it is universally accepted, comes into play during the Production Phase. The design will have been released to manufacturing, and hardware will be in production. Feasibility of value engineering during the Production Phase and the Operational Phase will be discussed in the next chapter.
CHAPTER IV

DEVELOPING AND TESTING THE VALUE MODEL

The contractor is motivated to apply value engineering techniques during the Production and Operational phases by three incentives: (1) higher profits through increased margins between the costs of production and the sales price, (2) a share in cost reductions, and (3) increased favor from the customer who also wishes to reduce the cost of the product and the cost of its operation and maintenance. The profit motive might be said to be present in all these incentives. If the customer is not pleased with cost reduction efforts, he may be reluctant to do business with the contractor in the future, thereby affecting future profits. The extent to which the contractor will conduct value engineering without monetary gain will depend upon the cost of the efforts beyond their break-even points and upon the value of the anticipated good will.

Before initiating any program in the Production and/or Operational phases, a company should thoroughly investigate the program's feasibility. Investigation can be conducted through analysis and testing, utilizing a series of formulas comprising a value model. James B. Allis of Sylvania Electronics Systems, in a paper presented to the 1968 SAVE National Conference, discusses
the importance of the "cost model" as a tool in the value engi-
neering effort as follows:

It has been pointed out that factual cost information is
needed at the inception of each project/program. The
retrieval and examination of historical cost data,
directly related to the same or similar functions, can
be equated to the new assignment when appropriate. Due
consideration should, of course, be given to escalation
factors.

This initial step can be extended to include pertinent
"quotations" from each knowledgeable segment of the
organization that will ultimately become involved. The
composite information can be then suitably refined to
to serve as a reference base for the cost model. This
same material is usually the basis for the contract
quoted price. After the contract is awarded, the cost
model can be updated and periodically expanded as need
dictates.

It provides a useful monitoring device which identifies
the cost of functions of the system or particular end-
item. Through a process of evolution compatible with
design progress, it becomes increasingly definite and
ultimately encompasses every item of cost down to the
component or part level. It has been our experience
that the continuously expanding cost model provides the
greatest reward by exposing costs that prompt design
engineers to take specific remedial action wherever, in
their opinion, the figures belie the true value of the
function.

Effective results are normally achieved when a course
of action is programmed and implemented on the basis of
up-to-date, reliable cost information coupled with a
high-level of confidence that worthwhile economics can
be realized.

Actions taken to eliminate unnecessary costs not only
benefit the contractor by helping him to achieve the
contract cost objective, but also result in future
savings to the customer. This is reflected in the
price the customer pays for the equipment or item in
follow-on contracts. Theoretically at least, an end-
item product which has all unnecessary costs removed is
of the greatest value to the customer.

The purpose of the cost model concept is to provide
assurance to the contractor and customer alike that
attention and direct effort is being given to produce
the product on schedule, a product that functions pro-
perly, and a product that costs neither more nor less than is absolutely necessary. You will recognize this as the value engineering objective. It follows that the cost model is one of the most important tools used in value engineering.¹

Developing a Value Model

Allis, in the above quotation, established the need for a cost model to provide assurance that a product will give the required functions for the least cost and in a timely manner. More than this is required, however, to determine the economic feasibility of making changes to a product for purposes of reducing its cost.

The author, in this thesis, has taken into account the factors which contribute to the cost of implementation of value engineering, cost reduction changes, and compares them with the possible product unit cost reductions.

Many factors are involved in the cost of implementation of product changes. The question of breaking even on cost for any specific change proposal can be solved by the following equation:

\[
\text{Break Even} = \frac{\text{Total one time cost of making the change}}{\text{Unit cost reduction}}
\]

Break even represents the number of units which must be sold in order for the anticipated savings to pay for the cost of making the change.

The feasibility of making the change is not only a function

of break even but is also a function of the number of units it can be safely predicted will be sold. Feasibility, then, can first be assumed when:

\[
\frac{\text{Total predictable sales}}{\text{Break Even}} > 1
\]

If this ratio is equal to one, then there will be no actual dollar savings realized. In fact, there is always the possibility of unforeseen increases in costs to make the change, overlooked costs, or increased cost of the new or revised unit. It is therefore desirable to accept the change proposal as feasible only when:

\[
\frac{\text{Total predictable sales}}{\text{Break Even}} \geq \frac{1}{F_c}
\]

\(F_c\) represents a confidence factor which must be based upon the contractor's experience with (1) previous sales, (2) cost estimating, and (3) past cost savings. It may represent a product of individual confidence factors as follows:

\[
F_c = F_s \times F_e \times F_r
\]

where:

\(F_c = \text{Total confidence factor}\)
\(F_s = \text{Confidence in sales}\)
\(F_e = \text{Confidence in estimating}\)
\(F_r = \text{Confidence in cost reduction}\)

If, for example, the confidence of each factor is 90 per cent:

\[F_c = .90 \times .90 \times .90 = .729\]
and feasibility can be assumed when:

\[
\frac{\text{Total predicted sales}}{\text{Break Even}} \geq \frac{1}{.729} \text{ or } 1.37
\]

The question of feasibility, or break even, for an entire value engineering program, although basically similar to the above, is much more complex. There are many factors to be considered. Those which are most significant and which will be used in the feasibility value model are shown with their abbreviated symbols in Figure 16.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change rate capability</td>
<td>(C_M)</td>
</tr>
<tr>
<td>Cost of value engineering per change</td>
<td>(C_P)</td>
</tr>
<tr>
<td>Number of product units affected</td>
<td>(Q_E)</td>
</tr>
<tr>
<td>Average savings potential</td>
<td>(S_A)</td>
</tr>
<tr>
<td>Average anticipated break-even point</td>
<td>(B_A)</td>
</tr>
<tr>
<td>Hardware procurement lead time</td>
<td>(K_1)</td>
</tr>
<tr>
<td>Production rate schedule</td>
<td>(R_P)</td>
</tr>
<tr>
<td>Months to first value engineering change approval</td>
<td>(M_1)</td>
</tr>
<tr>
<td>Value engineering program completion lag</td>
<td>(K_2)</td>
</tr>
<tr>
<td>Number of total product units</td>
<td>(Q_T)</td>
</tr>
<tr>
<td>Anticipated value engineering changes per month</td>
<td>(C_T)</td>
</tr>
</tbody>
</table>

Fig. 16--Significant Value Model Factors

The values of many of the factors in Figure 16 must be estimated on the basis of the experience of the company anticipating
use of the value model. The assignment of values to some of the other factors will require a knowledge of the product category and the state-of-the-art to be utilized. The total anticipated savings effected by a value engineering cost-reduction program can be developed from the following factors:

**Change Rate Capability - C_M.** The number of engineering changes which can be developed and processed per month will vary for different companies and for different product lines. The complexity of the change procedure cannot be entirely conquered by simply putting more men on the job. The inevitable law of diminishing returns will apply, and a point will be reached where added personnel will produce little added results. Consequently, by study and experience, a probable average number of changes can be predicted for the company and the product line concerned.

**Cost of Value Engineering Per Change - C_p.** Here again, experience with the company organization and the product line is required in order to develop the dollar-per-change factor. It will be necessary to estimate (1) the number of men required to conduct value engineering analyses, (2) the pay scales for each of these men, (3) the overhead factors, and (4) the time required for an average change development for the product line. The man-hours included are those for the value engineering team effort only.

**Number of Product Units Affected - Q_B.** The Q_B factor is a function of the spans of effort of other factors and will be developed below.

**Average Savings Potential - S_A.** The savings involved in the S_A factor are those resulting from the difference between future
life cycle costs for the existing product design and future life cycle costs for the proposed design. An average saving is a function of the product line and can be estimated from experience with the line.

**Average Anticipated Break-Even Point - \( B_A \).** The \( B_A \) factor must also be based upon company experience with the product line and is expressed as "units to break even."

**Hardware Procurement Lead Time - \( K_1 \).** Lead time varies as a function of the product state-of-the-art. Experience indicates the number of months which should be allowed between the time of change approval and the delivery of the hardware to the production line.

**Production Rate Schedule - \( R_p \).** The monthly rate of production is negotiated between the contractor and the customer.

**Months to First Value Engineering Change Approval - \( M_1 \).** After initiation of the value engineering program, the \( M_1 \) monthly time lapse must be allowed for development and approval of the first cost reduction change. The allowance is made on the basis of experience with the company organizations and on required customer review and approval time spans.

**Value Engineering Program Completion Lag - \( K_2 \).** The \( K_2 \) factor, expressed in months, is similar to the \( M_1 \) factor, except that it occurs at the end of the program. Consequently, modification may be required.

**Number of Total Products - \( Q_T \).** It may be difficult to obtain a commitment from the customer(s) as to the anticipated program duration and the quantity of units to be ordered. If such is the
case, an assumption will need to be made for the $Q_T$ factor.

**Anticipated Value Engineering Changes per Month - $C_T$.** Quantities for the $C_T$ factor can also be estimated based on a knowledge and understanding of company capabilities for the product line.

The total production unit hardware savings can be calculated from:

(4) \[ \text{Dollars Saved} = Q_E \cdot \frac{C_T}{R_P} \cdot S_A \]

The cost of value engineering change development and implementation can be calculated from:

(5) \[ \text{Dollars Spent} = Q_E \cdot \frac{C_T}{R_P} \cdot C_P \]

Combining equations (4) and (5), the general equation for total program savings can be written as:

(6) \[ S = Q_E \cdot \frac{C_T}{R_P} \cdot S_A - Q_E \cdot \frac{C_T}{R_P} \cdot C_P \]

or

(7) \[ S = Q_E \cdot \frac{C_T}{R_P} \left( Q_E \cdot S_A - C_P \right) \]

where: \( S = \text{Total Program Savings} \).

The total number of product units affected by the change can be developed from the following equation:

(8) \[ Q_E = Q_T - M_1 R_P - B_A - K_1 R_P - R_P K_2 \]
where: \( M_{1RP} \) is the number of units manufactured pending the first value engineering change approval; \( K_{1RP} \) is the number of units manufactured to the original design concept pending receipt of hardware necessary for implementation of the first change; and, \( K_{2RP} \) is the number of units manufactured at the end of a program while a final value engineering change is awaiting implementation.

Total program savings can be calculated from equations (7) and (8).

The quantity of products required to break even on a value engineering cost reduction program can be determined by establishing the resultant program savings at zero and solving for \( QT \) in equations (6) and (8).

Thus from (6) with \( S = 0 \),

\[
\text{(9)} \quad Q_E^2 \frac{C_T}{R_P} S_A = Q_E \frac{C_T}{R_P} C_P
\]

and dividing by \( Q_E \frac{C_T}{R_P} \),

\[
\text{(10)} \quad Q_E S_A = C_P
\]
or

\[
\text{(11)} \quad Q_E = \frac{C_P}{S_A}
\]

and combining with (8),

\[
\text{(12)} \quad Q_T - M_{1RP} - B_A - K_{1RP} - K_{2RP} = \frac{C_P}{S_A}
\]
and transposing,

\[ Q_T = \frac{C_P}{S_A} + M_1 R_P + B_A + K_1 R_P + K_2 R_P \]  

The above break-even equation requires that the funding of the value engineering program be the responsibility of whoever receives all the savings benefits. As stated previously, equations (6) and (8) can be used to determine the total savings which will be realized from a feasible program. A determination of funding and sharing ratios can then be negotiated to assure the contractor a profit on his investment.

Testing the Value Model

A value model has now been developed, and it is essential that the model be tested to determine its validity and accuracy. For the purpose of testing the model, three cost reduction program proposals were chosen from the Lockheed-California Company records. In an effort to provide variations in testing of the model, the examples were selected on the basis of their particular, unique characteristics. Test Example No. 1 evaluates a simple, low-cost value engineering program, while Test Examples No. 2 and No. 3 consider more complex programs. Variations in product line would have been desirable, but data were not available.

Test Example No. 1. In this case, a prime contractor originated a proposal to initiate a Class II cost reduction on a fighter aircraft contract. Class II changes are generally simple, requiring a minimum amount of drawing changes. Consequently, unit savings are usually low. These changes do not require the cus-
tomers approval prior to the contractor's decision to implement them. The model designation of the aircraft is insignificant to this thesis and will not be disclosed for proprietary reasons.

Since the Class II changes are relatively simple, they can usually be processed rapidly and with a minimum amount of investigative man-hours. This type of change involves low-cost components; thus, cost reduction changes will be correspondingly low per product unit.

The value model factors pertaining to this cost reduction program proposal are shown below with their approximately true, estimated values:

\[ C_p = \$1,000 \text{ per value engineering change—Average} \]
\[ S_A = \$25 \text{ per value engineering change per aircraft quantity—Average} \]
\[ B_A = \text{fifteen aircraft per value engineering change—Average} \]
\[ K_1 = \text{six months} \]
\[ R_P = \text{five aircraft per month} \]
\[ M_1 = \text{four months} \]
\[ K_2 = \text{six months} \]
\[ C_T = \text{four changes per month} \]

Substituting these estimated factors into equation (13),

\[ Q_T = \frac{1,000}{25} + 20 + 15 + 30 + 30 \]
\[ = 135 \text{ aircraft to break even} \]

The procurement contract called for thirty-five aircraft. It can be seen from the above equation that the program would not have been feasible. The program, in fact, was not carried out based upon another treatment of the factors shown above and upon the
Test Example No. 2. This case examines a proposal to initiate a Class I cost reduction program on a patrol aircraft. Class I changes require the customer's approval prior to implementation because they usually cover items which affect product performance and safety of operation, and because of their high unit product cost. The changes can range from levels of low value to levels of extremely high value and may include operational savings outside of the procurement contract. Here, too, the model designation is insignificant and will not be disclosed for proprietary reasons.

The factors pertaining to the cost reduction program proposal are shown below with their approximately true, estimated values:

\[
\begin{align*}
C_P &= $3,000 \text{ per value engineering change--Average} \\
S_A &= $1,000 \text{ per value engineering change per aircraft quantity--Average} \\
B_A &= \text{thirty aircraft per value engineering change--Average} \\
K_1 &= \text{eight months} \\
R_A &= \text{four aircraft per month} \\
M_1 &= \text{four months} \\
K_2 &= \text{eight months} \\
C_T &= \text{one change per month}
\end{align*}
\]

Substituting these estimated factors into equation (13),

\[
Q_{BE} = \frac{3,000}{1,000} + 16 + 30 + 32 + 32
\]

= 113 aircraft to break even

The customer was willing to allow feasibility to be based upon an assumption of future procurement of up to three hundred aircraft.
The value model equation indicates the program is well within the range of feasibility.

Potential savings from the program can be calculated, once break even has been determined, from equations (7) and (8) of the value model. The procedure is as follows:

Substituting in equation (8),

\[ Q_B = 300 - 16 - 30 - 32 - 32 \]

\[ = 190 \text{ aircraft} \]

Substituting this factor and those above into equation (7),

\[ S = 190 \times \frac{1}{4} ( (190 \times 1,000) - 3,000 ) \]

\[ = 48 (190,000 - 3,000) \]

\[ = \$8,976,000 \text{ program savings} \]

The program was initiated on this aircraft and has produced program savings approximately equal to this calculated prediction.

**Test Example No. 3.** In the case of a helicopter production contract, the customer specifies implementation of value engineering for a Class I cost reduction program. The contract called out an incentive clause under the Firm Fixed Price Category. The hardware systems in this particular aircraft, especially the avionics systems, required extensive development in the state-of-the-art. For this reason, subsequent changes would also involve extensive development, and the estimated costs of these changes should be considered in evaluating the value model factors.
The factors pertaining to this example are shown below with their approximately true, estimated values:

\[ C_p = \$4,000 \text{ per value engineering change--Average} \]
\[ S_A = \$1,000 \text{ per value engineering change per aircraft quantity--Average} \]
\[ B_A = \text{forty aircraft per value engineering change--Average} \]
\[ K_1 = \text{twelve months} \]
\[ R_P = \text{five aircraft per month} \]
\[ M_1 = \text{four months} \]
\[ K_2 = \text{eight months} \]
\[ C_T = \text{one per month} \]

Substituting these estimated factors into equation (13),

\[ Q_{T_{BE}} = \frac{4,000}{1,000} + 20 + 40 + 60 + 40 \]

\[ = 164 \text{ aircraft to break even} \]

The contract called for an order of 375 aircraft, well above the break-even quantity of 164.

Potential savings for this program can be calculated from equations (7) and (8) of the value model as follows:

Substituting in equation (8),

\[ Q_E = 375 - 20 - 40 - 60 - 40 \]

\[ = 215 \text{ aircraft} \]

Substituting this factor and those above into equation (7),

\[ S = 215 \times \frac{1}{5} ( (216 \times 1,000) - 4,000 ) \]

\[ = 43 (216,000 - 4,000) \]

\[ = $9,116,000 \text{ program savings} \]
Because this project is relatively new, there are at present no results which can positively prove the validity of the value model. The relatively low break-even quantity, compared to the contract-order quantity, indicates that there is little doubt of the program's feasibility. Only the accuracy of the forecast would seem to require verification.
CHAPTER V

SUMMARY

Value engineering is an arrangement of techniques designed to provide required functions for their least cost. As such, value engineering has become an effective tool in the crusade against high costs in both industrial and governmental activities. The discipline has received the support of the Federal Government and many private organizations.

Lawrence D. Miles initiated the first value engineering program at the General Electric Company in 1940. This original concept has since been adopted, modified, and expanded by countless other firms, as well as by agencies of the Government. An examination of the value engineering programs of several firms reveals that these companies have realized considerable savings by applying value engineering techniques.

The Federal Government, through the Department of Defense, has indicated particular interest in the development of value engineering. This interest has taken form in several DOD documents issued to guide contractors in implementing, expanding, and accelerating their value engineering efforts. The Government's concern with value engineering is evidence of their interest in its development and expresses their confidence in the contribution
which they feel value engineering can make to cost-prevention and cost-reduction efforts.

Persons responsible for program analyses became aware early in the development of value engineering that some organized, investigative approach was needed. As a result, job plans were designed to aid in the organization of value engineering effort to produce definition of purpose and economy of effort. The job plan outlines a step-by-step procedure for conducting cost studies.

During the value engineering process, two or more alternatives are compared in an effort to provide the desired function for the least cost. Comparative analysis requires that all the elements of cost which might be incurred during the product life cycle be considered. Furthermore, the scale of measurement must be uniform for each parameter pertinent to the analysis. Some examples of costs which affect value engineering decisions are: (1) engineering costs, (2) planning and tooling costs, (3) production development costs, (4) training and training devices, (5) spare parts, and (6) production costs.

It is not always possible to assign dollar values to all the parameters involved in a particular analysis. In cases where no dollar values are applied, the analysis becomes subjective as a whole. Usually, however, analysis is made on the basis of comparative dollar savings augmented by subjective evaluations. Whatever the method for determining the dollar value, care must be taken to ensure that all the parameters are treated with the same dollar value within the same time period.
Management now recognizes that value engineering is applicable to all phases of program activity. In fact, they have been utilizing value engineering in conjunction with other new management tools such as systems engineering and cost effectiveness. All of the many approaches to program development differ only in their emphasis on cost as a factor in alternative concept selection.

During the Concept Formulation Phase, value engineering is required in several activities. It is here that the technique finds its most important task of improved product design. Value engineering savings during the Concept Formulation Phase result in cost prevention rather than cost reduction. When value engineering is not applied during this phase, designs become "locked-in" and it becomes more difficult to make changes in later phases. Other phases of the product life cycle to which value engineering effort may be applied are the Definition Phase, the Development Phase, and the Production Phase.

Proposed programs may be investigated, analyzed, and tested utilizing a series of formulas comprising a value model. The break-even point is of prime importance in determining the feasibility of making any change. The change proposal can be accepted as feasible only when:

\[
\frac{\text{Total predictable sales}}{\text{Break Even}} \geq \frac{1}{F_c}
\]

The question of feasibility involves the consideration of many variables. The significant variables used in the development of
the value model presented in this thesis were outlined in Figure 16.

The number of units which must be sold in order to pay for the cost of the proposed change (break even) can be solved by the following equation:

\[ Q_T = \frac{C_P}{S_A} + M_1 R_P + B_A + K_1 R_P + K_2 R_P \]  

(13)

Once break even has been determined, total program savings can be estimated. The first step is to calculate the total number of product units affected by the change:

\[ Q_E = Q_T - M_1 R_P - B_A - K_1 R_P - K_2 R_P \]  

(8)

Then, substituting the result of equation (8) and the other pertinent variables, total program savings can be calculated using the following equation:

\[ S = Q_E \frac{C_P}{R_P} (Q_E S_A - C_P) \]  

(7)

To test the feasibility of the value model, three examples of cost reduction program proposals were selected from the Lockheed-California Company records. In selecting the cases, care was taken to assure a representative sample. A broader coverage of the Aerospace Industry would have provided a more valid test for the value model; however, this was not possible.

Test Example No. 1 considered a simple Class II cost reduction on a fighter aircraft contract. The procurement contract on this program called for thirty-five aircraft. By substituting the estimated factors pertinent to the project into equation (13),
it was determined that 135 aircraft were required to break even. The company decided not to proceed with the program based on another treatment of the variables.

Test Example No. 2 concerned a proposal to initiate a Class I cost reduction program on a patrol aircraft. The customer allowed feasibility to be based on a future procurement of three hundred aircraft. The value model equation indicated that only 113 aircraft were required to break even. Total program savings were estimated to be $8,976,000 using equations (7) and (8). Based on another weighting of the factors, the program was initiated and has been very successful. Evidence indicates that the actual program savings are approximately equal to the estimated savings.

Test Example No. 3 called for a Class I cost reduction on a helicopter production contract. The contract called for 375 aircraft. Break-even analysis revealed that 164 aircraft were required, and potential program savings were estimated to be $9,116,000. Evidence indicates that the program is feasible; only the estimated savings will require later verification.

**CONCLUSIONS AND RECOMMENDATIONS**

The feasibility of value engineering application was demonstrated by the results of the three value model test examples. In each case, the program's outcome was predicted using the equations in the value model. In reality, management decisions concerning the disposition of the programs were based on some other treatment of the variables. The conclusions reached by management and the predictions of the value model, however, were basically
the same.

There has been considerable confusion in the past concerning where, when, and to what extent value engineering should be applied. This thesis has provided insight into these questions. To assure greater confidence in the capabilities of value modeling, however, more extensive research covering a larger segment of the Aerospace Industry is recommended.
BIBLIOGRAPHY
BIBLIOGRAPHY

Books


Government Publications


U. S. Department of Defense, Armed Services Procurement Regulation (ASPR), Revision 3, Section 1, Part 17, 1963.


Reports


Key Techniques to Value Engineering. A report prepared in 1963 by the Lockheed-California Company, Burbank, California.


APPENDICES
Mr. 

Dear Sir:

You have been recommended by Mr. J. F. Coulon of the Value Engineering organization at the Lockheed-California Company as a possible source of information for my master's degree thesis.

The title of my thesis is "Feasibility Parameters in the Modern Value Engineering Function." I am enclosing a copy of the rough draft of Chapters IV and V, along with a brief questionnaire. I need data for testing and possibly adjusting the value model developed in Chapter IV. I would very much appreciate any assistance you can give by filling out the questionnaire.

In order to respect proprietary data, I will not identify the projects used in the testing of the model, but will give credit to the persons and companies from which the information comes.

I would appreciate an early response as I am attempting to complete the thesis this semester.

Sincerely,

Gex B. Coons
APPENDIX B

THESIS DATA QUESTIONNAIRE

Name:

Company:

Type of product for which data is furnished, i.e., fighter aircraft, helicopter, propulsion system, missile, etc.

Estimated potential average value engineering changes per month which could be expected. \( (C_T \text{ in the model}) \)

Average expected saving per product unit per value engineering change. \( (S_A \text{ in the model}) \)

Average break even in product units per value engineering change. \( (B_A \text{ in the model}) \)

Average hardware lead time, in months, for the types of changes anticipated. \( (K_1 \text{ in the model}) \)

Production rate in product units per month. \( (R_P \text{ in the model}) \)

Months required to develop the first approved value engineering change after initiating the value engineering program. \( (M_1 \text{ in the model}) \)

Months required to implement the last value engineering change after its approval. \( (K_2 \text{ in the model}) \)

Number of total program quantity product units which can be used for planning purposes. \( (Q_T \text{ in the model}) \)

Was a value engineering program carried out on the product during any of its life cycle?

Was the program successful?