ESD-TR-66-579

ELECTRONIC SYSTEMS DIVISION

ADVANTAGEOUS DEFINITIONS CONCERNING SYSTEM VALUE

Bert Decker, Lt. Colonel, USAF

October 1966

VALUE ENGINEERING DIVISION
TECHNICAL REQUIREMENTS AND STANDARDS OFFICE
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

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FOREWORD

Basically, all scientific and industrial innovation has invariably been a semantic clarification of a certain situation. At ESD, in a combined 407L SPO-ESD-AFSC-DOD value engineering effort, something new was being tried. In general, the effort was to:

1. Utilize, in every stage of system acquisition from concept through acquisition, the improved cost visibility of a Value Engineering Functional Cost Analysis (VEFCA) traditionally used only in the product improvement stage of system acquisition.

2. Do a complete System Value Engineering task on a highly complex system rather than merely doing "piece-meal" value engineering of components.

Value engineering a simple product requires a considerable amount of semantic clarification. The more precise concept of value must be understood, functions must be defined advantageously, and the many steps in the Value Engineering Job Plan must be clarified. Because of the many disciplines involved, the problem becomes much more complex with huge systems.

Much of this paper was the result of discussions with Mr. Ray Gilbert and Mr. Gordon Frank, members of the DOD Value Engineering Office who participated in the 407L effort. Discussions were also held with Mr. George Allen of the ESD Technical Requirements and Standards Office and ideas were solicited from members of the Boston "Paul Revere" Chapter of the Society of American Value Engineers.

The author appreciates the contributions of those noted above, but assumes all responsibility for the contents. He also assumes that creative evaluation of this paper will result in more advantageous clarifications concerning the opportunities inherent in the value engineering program.

Review and Approval

This Technical Documentary Report has been reviewed and is approved.

FRANK E. BRANDEBERRY
Colonel, USAF
Chief, Tech Rqmts & Stds Office

ABSTRACT

Advantageous definitions of Value Engineering (VE), the "System Approach" (SA), System Value Engineering (SVE), the Value Engineering Functional Cost Analysis (VEFCA), and Traditional Cost Analysis (TCA) are given to simplify discussion and communications and stress the specific actions required to optimize the value of military systems. Value decision making is also covered.

SECTION I

PURPOSE

1. The purpose of this paper is to advantageously define and clarify the differences between Value Engineering (VE) and Cost Effectiveness (CE), Value Engineering (VE) and System Value Engineering (SVE), the Value Engineering Functional Cost Analysis (VEFCA) and Traditional Cost Analysis (TCA), and Value Engineering at different levels of abstraction in order to:

1.1 Simplify discussion and communications.

1.2 Utilize the improved cost visibility of the VEFCA in decision making.

1.3 Clarify and stress the specific VE actions required to improve the value of military systems.

SECTION II

ASSUMPTIONS

2.1 The semantic, scientific, and value engineering assumptions upon which the advantageous definition of words used in a value engineering (VE) task are covered in Section II, "Assumptions," of "Advantageous Definitions Concerning Value," ESD-TR-66-282, dated April 1966. Other assumptions required by the purpose of this paper follow.

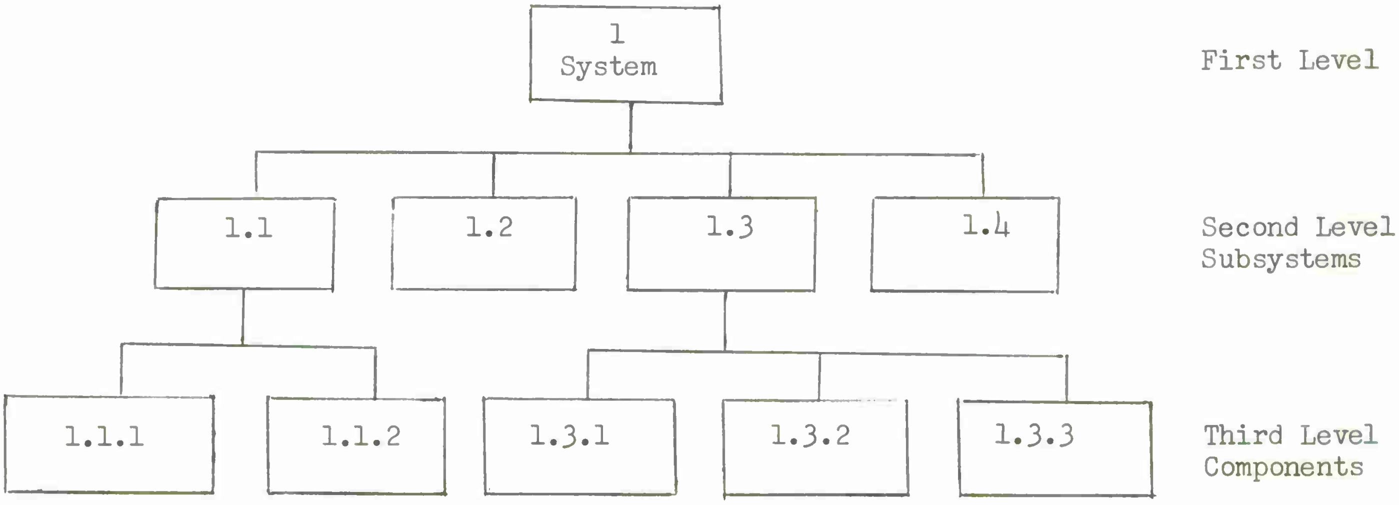
2.2 Semantic Assumptions: Semantic assumptions required by the purpose of this paper follow:

2.2.1 A Word Has No Meaning By Itself. For example, in "A sharp soldier sat in a sharp wind cutting sharp cheese with a sharp knife," the word sharp has four different meanings.

2.2.2 Only Relationships Provide Meaning. "Sharp" related to "soldier" means one thing, but "sharp" related to "wind" means another. It is relationships which provide meaning, and the history of science indicates that relationships between measurables provide the most advantageous meanings.

2.2.3 Functions Provide Meaningful Relationships. In both mathematics and science, functions have provided advantageous meanings because they indicated a relationship between a demonstrable operation and a measurable or measurables.

2.2.4 Levels of Abstraction can be enumerated as follows:



2.2.5 We Abstract By Ignoring Differences. Joe and Jim have sameness and differences. We ignore their differences (abstract), move up the ladder of abstraction, and call each a "man." Likewise, a radio and radar are different, but we abstract and call both a "component" or "system."

2.2.5.1 We Abstract In Relation To Time. An RCA radio in 1940 was different from an RCA radio in 1966, but we abstract and say, "RCA radio." This can lead to poor evaluations.

2.2.5.2 We Abstract In Relation to Tasks. Reliability and Configuration Management have sameness and differences. We ignore differences and call both, "disciplines."

2.2.5.3 We Abstract In Terms Of Any Known Differences, but can only do so advantageously when the resulting abstractions contain measurable dimensions which, when mathematically manipulated, can still be related directly to actuality.

2.2.6 Multiordinal words are abstractions which have different meanings at different levels of abstractions; i.e., in the sentences, "The bracket supports weight," and "The United States supports the United Nations," the word "supports" has different meanings.

2.2.6.1 Note. Failure to note that words such as "value engineering," "cost effectiveness," etc., have different meanings at different levels of abstraction is the basis for much linguistic confusion in system acquisition discussions.

2.2.7 Notation. Korzybski, in his book, "Science and Sanity," has stressed the value of annotating words to indicate that they are being used at a different level of abstraction or are multiordinal; i.e., supports^{1} - meaning "support used on the top level of abstraction" - is not the same as support^{2} - "support used on the second level of abstraction."

SECTION III

DEFINITIONS AND NOTATION

3.1 Because of the assumptions of Section II, it is deemed advantageous to define the following words as follows:

3.1.1 A function is a meaningful relationship indicated by a verb and a noun.

3.1.2 A verifiable function is a relationship between a demonstrable verb and a measurable or countable noun; i.e., "supports/weight," "transmits/bits."

3.1.3 An operational requirement is a functional need or needs. Examples are "provide/communications," "provide/fighter cover," "move/weight," "provide/deterrence." An operational requirement as first defined may or may not be verifiable. For instance, "provide/deterrence," is not verifiable since deterrence cannot be realistically measured in advance. It is part of the value engineering task to redefine and reduce operational requirements which are not verifiable to verifiable functions.

3.1.4 A basic function is a verifiable function which most advantageously defines the value engineering task. It should be realized that a basic function rarely defines all the operational requirements. For instance, the advantageous definition of many weapon systems is "moves/weight." A weapon system must also "provide/destruction," and "pinpoint/target," but with most weapon systems moving weight is its most costly function. A land mine may seem an exception, yet its advantageously defined function is only more specific; i.e., "move/hard bits of weight suddenly."

3.1.5 A secondary function is a verifiable function on the same level of abstraction as the basic function which is not required by the basic function, but is required by the operational requirement; i.e., the basic function of a pencil is to "make/marks," a secondary function is, "erase/marks." Likewise, the basic function of a car is to "move/weight," while secondary functions are, "provide/comfort," "provide/safety," "provide/esteem."

3.1.6 A supporting function is a verifiable function on levels of abstraction below a basic or secondary function and without which the operational requirement cannot be fulfilled except at excessive cost; i.e., the basic function of a bomber is advantageously defined as, "moves/weight." A supporting function to the performance of moving weight is "pinpoint/destination." However, a bomber has a secondary function of "provide/destruction," and that secondary function has supporting functions such as "release/bomb," "pinpoint/target," etc.

3.2 To eliminate confusion concerning levels of abstraction and the multiordinal aspects of the verb value engineer, it is deemed advantageous to define value engineering and use notation as follows:

3.2.1 To value engineer in general is to:

3.2.1.1 Define required functions advantageously.

3.2.1.2 Determine supporting functions which will provide those required functions at the least cost.

3.2.2 Value Engineering^{1} (VE^{1}) the required function (basic or secondary) <u>at the first level</u> determines the many ways of performing that function, and the cost of those ways; i.e., if the basic function is "moves/weight," VE^{1} determines the many ways of moving weight such as by jet, train, truck, boat, or pipeline, and each way's ton-miles per hour per dollar.

3.2.3 Value Engineering^{2} (VE^{2}) the required function <u>at the second level</u> determines and costs the supporting functions of <u>one</u> way of performing the basic function; i.e., if the basic function is moves/weight, VE^{2} determines and costs the supporting functions of a plane <u>or</u> a truck <u>or</u> a pipeline.

3.2.4 Value Engineering^{1,2} ($VE^{1,2}$) the required function <u>at the first</u> and <u>second level</u> determines and costs all ways of performing the function and also determines and costs the second level supporting functions of all ways of performing the required function.

3.2.5 Value Engineering^{1,N} ($VE^{1,N}$) the required function <u>in depth to the Nth level</u> determines and costs all ways of performing <u>all</u> required functions down to and including the Nth level.

3.3 To advantageously define from a value viewpoint, abstractions used in system acquisition, the following definitions are recommended:

3.3.1 A system is a group of verifiable functions required to provide a group of operational requirements.

3.3.2 The "System Approach" (SA) is a process or procedure which considers whether more operational requirements can be fulfilled by a system without adding prohibitive costs. SA "broadens the scope," reviews all operational requirements and their required verifiable functions in order to ascertain one optimum system which will provide the greatest number of operational requirements at the least cost.

3.3.3 It should be noted that, although value engineers sometimes use the Systems Approach while attempting to define the required functions, in general, their improved cost visibility is the result of value engineering in depth and placing costs upon alternate ways of performing supporting functions; i.e., value engineers usually move down the ladder of abstraction.

3.3.4 In contrast with value engineering, the SA moves up the ladder of abstraction including more operational requirements in every step up. An example follows:

3.3.4.1 Assume at first that the system includes only on-base teletype distribution requirements.

3.3.4.2 The system is broadened to include all on-base data transmission requirements including the teletype requirement and logistic and personnel statistical control.

3.3.4.3 The system is broadened again to include other operational requirements such as, "type/letters," thus, utilizing an IBM Selectric typewriter which can both "type/letters," and serve as a data-transmission input/output device.

3.3.4.4 The system is further broadened to "handle/information," which includes all above, plus automation requirements such as water distribution pump control, sewer pump control, aircraft generation data distribution and display.

3.3.4.5 The power of the SA is that it ignores passe solutions, thinks in terms of functional requirements, and considers many more creative alternatives and especially ways of combining required functions advantageously.

3.4 System Value Engineering (SVE). It is possible and advantageous to define SVE, in general, as an optimum approach which combines both the Value Engineering ($VE^{1,N}$) approach and the System Approach (SA). Further, this SVE approach can be more specifically defined as doing the following:

3.4.1 Considers the system as a whole; i.e., considers all possible operational requirements which might be provided by the system.

3.4.4 Develops a family tree of required functions (ladder of abstraction) and:

3.4.4.1 Places a Cost Target, Cost Standard, and/or a Cost-To-Standard Ratio on the highest level of verifiable functions; i.e., it does not merely place costs upon higher level operational requirements which cannot be stated in verifiable functions.

3.4.4.2 Integrates outputs from operational analysis, system cost effectiveness, reliability cost effectiveness, maintainability cost effectiveness which are actually Value Engineering^{1} (VE^{1}) at one specified level of abstraction.

3.4.4.3 Value Engineers^{1,N} ($VE^{1,N}$) in greater functional depth as system acquisition progress from system concept, system definition, etc.

3.4.5 Avoids traditional System Engineering (SE) practices which are detrimental to system value. In practice, SE has traditionally broken the task of producing a system down into subsystems and assigned different groups of engineers (sometimes different corporations) the task of producing each subsystem. Another group of "interface" engineers (or the Integrating Engineer) is given the task of making sure those subsystems will work together. This means different groups of people isolated from each other, make value decisions on the same level of abstraction, but in different subsystems which would be highly apt to be better decisions if made together by all groups or by a Value Team considering several levels of abstraction straight across all subsystems; i.e., if the subsystem is level 2, a $VE^{2,3,4}$ or $VE^{2,3,4,5}$ study of all subsystems would be made which would eliminate redundant functions (functions unnecessarily duplicated in each subsystem) and/or improve reliability without providing excessive redundancy.

3.5 The Value Engineering Functional Cost Analysis (VEFCA). It is possible and advantageous to define the VEFCA, in general, as a family tree of functions (ladder of abstraction) which reveals the required verifiable functions of a system and their costs. Further, it is deemed advantageous to:

3.5.1 Annotate each VEFCA with numbers as in VE^{1}, VE^{2}, etc., to indicate on what levels of abstraction that VEFCA has determined functions and their costs; i.e., a $VEFCA^{1,N}$ would be the result of $VE^{1,N}$.

3.5.2 Keep the system equipment functions and acquisition costs separate from the system data acquisition costs; i.e., develop a VEFCA for system equipment and another VEFCA for system data. (This does not mean the $VE^{1,N}$ of equipment ignores data costs.)

3.5.3 Realize how the VEFCA differs from Traditional Cost Analysis (TCA) in that:

3.5.3.1 The VEFCA utilizes TCA, but adds to it and improves cost visibility because it does add to it.

3.5.3.2 TCA obtains all the organizational costs which pertain to the total costs of a product at a specified level of abstraction, but does not specify the functions and their costs of that product. See Chart 1 for a simplified example.

3.5.3.3 A VEFCA obtains all the organizational costs which pertain to each function of a product. See Chart 2 for a simplified example.

3.5.4 Note how Value Engineering can exploit the creative principle of, "Defer Judgment," by not making a decision concerning how to perform a function on one specified level until the costs of supporting functions are ascertained; i.e., TCA bases decisions on the cost-functional relationship at one level of abstraction while VE considers the function-cost relationship at several levels of abstraction before making decisions.

3.5.5 Note that VE places a cost on a function, (an operational requirement) rather than upon a thing (component) which too often is a passé solution rather than a requirement.

3.5.6 Note that a VEFCA is multiordinal in relation to time; i.e., a VEFCA of the same equipment is not the same in 1966 as in 1967. For instance, the $VEFCA^{66}$ may contain estimated cost targets while the $VEFCA^{67}$ may contain actual costs.

3.6 It is deemed advantageous to develop a separate VEFCA for data alone. There are several reasons for this. First, it is assumed that the basic function of a SVE task is to "product/system (equipment) value." It is a secondary, but essential task to "provide/system data value." Later, it will be discussed how these two VEFCAs must be related. Second, the value engineering of equipment is basically different, and it is deemed advantageous to apply the creative principle of "divide and conquer" to them. The differences in VE equipment and VE data follow:

3.6.1 The VE of equipment is one task which relates equipment functions directly to:

3.6.1.1 The organizational costs, (engineering, development, production, reliability, test transportation, overhead, etc., costs) which product each function.

3.6.1.2 Data costs which become necessary because that equipment function (or functions) is produced.

3.6.1.3 Logistic and operational costs which become necessary because that function (or functions) is produced.

3.6.2 The VE of data consists of two VE tasks unrelated cost-wise as follows:

3.6.2.1 The value engineering of information presentation including:

3.6.2.1.1 The physical data materials (paper, microfilm, etc.,) which display the required information.

3.6.2.1.2 The reproduction means of placing the required information on the data material.

3.6.2.1.3 The economic layout of the required information on the data material.

3.6.2.2 The value engineering of information development including:

3.6.2.2.1 Manhours of engineering, etc.

3.6.2.2.2 Computer costs to solve problems, keep statistics, etc.

3.6.2.2.3 Record keeping.

3.6.2.2.4 An evaluation of the need for the information.

SECTION IV

CORRELATIONS

4.1 System acquisition is a complex task of coordinating the actions of many disciplines. Further, most specialists speak a language of their own and use certain key words differently. The purpose of this section is to clarify the use of certain key words and phrases used differently by various disciplines.

4.2 The Total Package Procurement Concept (TPPC) is a procedure for placing all costs considered by a System Value Engineering effort under one contract to the degree practical. However, this does mean that every SVE should or does result in a TPPC contract.

4.3 AFSCL 173-1, "Cost Estimating Procedures," October 1965, reveals that:

4.3.1 The word "function" or "functional" usually refers to an organizational function; i.e., to departments such as, "engineering, tooling, quality control," etc., and rarely refers - if at all - to product function.

4.3.2 "Functional costs" refer to organizational department costs and not to product function costs as used by value engineers.

4.3.3 Level 4, "The Work Breakdown Structure," (WBS) is an attempt to deal with the "physical work performed" as the manual on page 2-4 states. However, that level actually names a system such as Missile, Aircraft, Command & Control and can, therefore, be considered level 1 of a VEFCA.

4.3.4 For all practical purposes, levels 4, 5, 6, and 7 referred to in AFSCL 173-1 are the same levels of abstraction as levels 1, 2, 3, and 4 of a system VEFCA since they refer to systems, subsystems, components and subcomponents. However, those levels are indicated by the name of the system, subsystem, etc., rather than by the advantageously defined function it provides.

4.3.5 According to Figure 3-2 on page 3-13, the functional levels below level 7 refer to organizational functions (departments) and not to system equipment functions.

4.4 Traditionally, any Cost Effectiveness Study is the same as a Value Engineering (VE^{1}) at one level of abstraction while, traditionally, any Value Engineering study considers several levels of abstraction; i.e., are $VE^{1,N}$ efforts. This $VE^{1,N}$ results in a vastly improved cost visibility.

4.5 Traditionally, "Reliability Costs," refer to "Staff Reliability Costs;" that is, to costs generated by Reliability specialists and reliability testing. However, in Value Engineering, where a cost is placed on every function, those functions which contribute to structural and/or electronic reliability can be annotated and, "Product Reliability Costs," can be thus more realistically estimated.

4.6 Traditionally, the $VEFCA^{1,N}$ has been used during product improvement. However, herein, it is assumed that the improved cost visibility of the VEFCA can be profitably used from concept to grave and, especially, during design reviews.

4.7 Traditionally, costs have been placed upon "things." This resulted in a complex, three-part contingency in which costs were related to things and functions were related to things, but costs were not related directly to functions. In VE, costs are related to functions. This has two advantages as follows:

4.7.1 Operational requirements are stated in functional terms and can be more realistically estimated if function costs are known.

4.7.2 There are millions of "things" in the Air Force inventory, but less than 400 known functions. If function costs were used, the search and retrieval problem of cost estimating would be drastically reduced.

4.8 To advantageously correlate required cost information, four ladders of abstraction should be considered.

4.8.1 The VEFCA of the system equipment herein indicated as the SE VEFCA. (Simplified example, Attachment #1)

4.8.2 The VEFCA of the system data. For practical purposes, this is the Data List plus costs. For value engineering purposes, computer programing is considered data.

4.8.3 The Table of Organization of the concern producing the system and which generates all acquisition costs except other government costs outside the contract.

4.8.4 Operational and Logistic Costs

4.9 Unfortunately, traditional cost analysis (TCA) does not provide a direct one-to-one correspondence between all the functions in the four ladders of abstraction of 4.8 except at some high levels of abstraction. Nor does value engineering. However, with value engineering, we move from a poor correlation to a better correlation, from inadequate cost visibility to a better cost visibility, to less one-to-one correspondence to more.

4.10 Normally, there is a one-to-one correspondence between Contract End Items (CEI) (Level 6 - WBS in AFSCL 173-1), and the total organizational costs involved in providing those Contract End Items (except for government furnished CEIs in the system.) However, there is no one-to-one correspondence between the functions in each CEI and the cost connected with each function of each CEI. For this reason, the costs of redundant and excessively costly functions are not visible.

4.11 The degree to which correlations are made between these four ladders of abstraction is actually a matter of value engineering judgment. For instance, it is rarely practical to correlate low-level component functions with the data those low-level functions generate. However, evaluations considering component changes should consider the impact of those changes on data costs as well as upon operational and logistics costs.

SECTION V

VALUE DECISION MAKING

5.1 Value decisions in modern organizations are made by many highly trained specialized people at all levels of the organization. However, most of the decisions which cause costs are made at lower levels or are based upon lower level recommendations. Further, most such decisions are made in isolation, and people making them do not have access to information which reveals the impact of those decisions upon acquisition cost much less total costs. In fact, many specialists by regulation and directives are forced to place military specifications upon systems without having access to information which indicates the impact upon total system costs of that specification. Usually, they try to generalize too much (not tie people down) and such generalizations often cause unnecessary costs. For instance, one specification in a military system called for a circuit current from 50ma to 1 ampere. Thousands of diodes were involved. A reliable 50ma diode cost at that time 15¢. A reliable one amp diode cost over $2.00. For some reason, perhaps because it was a Cost Plus Contract, the contractor thought the Air Force should have the one amp diode.

5.2 Basically, the purpose of a SVE task is to provide an improved cost visibility which allows system decision makers to make better value decisions; i.e., obtain verifiable functions for less cost. It is the VEFCA which should provide that cost visibility.

5.3 Ideally, no value decisions would be made until a $SVE^{1,N}$ task was completed in infinite detail down to very low functional detail (N would be a large number). Time makes such an ideal highly impractical although in the future realistic Value Standards and computer techniques (a modified Critical Path Method, for instance) will come closer to that ideal. The question is, of course, how large should N be? How far below Traditional Cost Analysis should the VEFCA go to improve cost visibility to a practical degree? This, again, is a matter of value engineering judgment, but some guidance can be provided.

5.4 One fact is immediately obvious. To improve cost visibility, a VEFCA must go below the level at which TCA now places a cost for the Air Force. This is usually at the component or the

Contract End Item level. Second, it would be impractical to value engineer and improve the cost visibility of those components which cost only a small percent of the system. The VEFCA must improve the cost visibility where the high costs occur. It must not be overlooked, however, that some component functions may cost only a small percent of small-cost components, but becuase they are repeated again and again across the system add up to a considerable percent of system costs.

5.5 The next obvious question is, "How far below the TCA must the VEFCA go?" The specific answer is again a matter of value engineering judgment since it will vary function by function depending upon:

5.5.1 What percent of the component cost that function costs.

5.5.2 To what degree the function is repeated across the system.

5.5.3 To what degree modification of the function would have upon reliability, other desired system characteristics, and operational and logistic costs.

Note: In one VE training session, it was noted that 17% of the costs of a small component part was connector costs while 83% was a specific logic circuit. Naturally, the Value Team was interested in the 83% until it was pointed out that the connector costs could obviously be cut in half and since the connectors were not only standard in the division for all components, but standard across all divisions of the corporation while the logic part was not, the greatest savings would occur by value engineering the connectors.

5.6 Most important to value decision making is the fact that the improved cost and function visibility provided by the VEFCA allows the creative principles of "Defer Judgment, Quantity Breed Quality, etc.," to be used since, with several levels of abstractions being considered rather than just one, many more possibilities can be considered.

5.7 Actually, value decisions cannot be optimized in traditional organization without doing something different than normal since modern organization with its split capabilities, split responsibilities and split authority is very effectively structured to cause unnecessary costs. With everyone responsible for value, no one is. To correct this, the top manager must be very value conscious, aware of the organizational discrepancies which cause unnecessary costs and how people must be organized to provide a VEFCA whose improved cost visibility allows better value decisions. The steps required to value engineer and manage value are found in, "Advantageous Definitions Concerning Value."

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13. ABSTRACT

Advantageous definitions of Value Engineering (VE), the "System Approach" (SA), System Value Engineering (SVE), the Value Engineering Functional Cost Analysis (VEFCA), and Traditional Cost Analysis (TCA) are given to simplify discussion and communications and stress the specific actions required to optimize the value of military systems. Value decision making is also covered.

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14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

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