NPS-GSBPP-09-006

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

Gap Analysis: Application to Earned Value Analysis

19 August 2009

by

Gary O. Langford, Lecturer,

Graduate School of Engineering & Applied Sciences

Raymond (Chip) Franck, Senior Lecturer,

Graduate School of Business & Public Policy

Naval Postgraduate School

Prepared for: Naval Postgraduate School, Monterey, California 93943

Naval Postgraduate School
Monterey, California

Daniel T. Oliver
President

Leonard A. Ferrari
Provost

The Acquisition Chair, Graduate School of Business & Public Policy, Naval Postgraduate School supported the funding of the research presented herein.

The report was prepared by:

____
Gary Langford, Lecturer
Graduate School of Engineering & Applied Sciences

____
Raymond Frank, Senior Lecturer
Graduate School of Business & Public Policy

Reviewed by:

____
William R. Gates, Ph.D.
Dean, Graduate School of Business & Public Policy

Released by:

____
Karl van Bibber, Ph.D.
Vice President and
Dean of Research

REPORT DOCUMENTATION PAGE

Form approved
OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	**2. REPORT DATE** 19 August 2009	**3. REPORT TYPE AND DATES COVERED** 1 October 2007 through 30 September 2008

4. TITLE AND SUBTITLE
Gap Analysis: Application to Earned Value Analysis

5. FUNDING

6. AUTHOR (S)
Gary O. Langford and Raymond (Chip) Franck

7. PERFORMING ORGANIZATION NAME (S) AND ADDRESS (ES)
NAVAL POSTGRADUATE SCHOOL
GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY
555 DYER ROAD
MONTEREY, CA 93943-5103

8. PERFORMING ORGANIZATION REPORT NUMBER
NPS-GSBPP-09-006

9. SPONSORING/MONITORING AGENCY NAME (S) AND ADDRESS (ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words.)

Earned Value is regarded as a useful tool to monitor commercial and defense system acquisitions. This paper applies the theoretical foundations and systematics of Gap Analysis to improve Earned Value Management. As currently implemented, Earned Value inaccurately provides a higher value for the work performed. This preliminary research indicates that Earned Value calculations can be corrected. Value Analysis, properly defined and enacted, clarifies management strategies to facilitate appropriate investment decisions.

14. SUBJECT TERMS
Earned Value, Value Analysis, Value Acquisition, Value Systems Engineering, Systems Engineering, Value Engineering

15. NUMBER OF PAGES
53

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT: UNCLASSIFIED	**18. SECURITY CLASSIFICATION OF THIS PAGE:** UNCLASSIFIED	**19. SECURITY CLASSIFICATION OF ABSTRACT:** UNCLASSIFIED	**20. LIMITATION OF ABSTRACT:** UU

NSN 7540-01-280-5800

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Abstract

Earned Value is regarded as a useful tool to monitor commercial and defense system acquisitions. This paper applies the theoretical foundations and systematics of Gap Analysis to improve Earned Value Management. As currently implemented, Earned Value inaccurately provides a higher value for the work performed. This preliminary research indicates that Earned Value calculations can be corrected. Value Analysis, properly defined and enacted, clarifies management strategies to facilitate appropriate investment decisions.

Keywords: Earned Value, Value Analysis, Value Acquisition, Value Systems Engineering, Systems Engineering, Value Engineering

THIS PAGE INTENTIONALLY LEFT BLANK

Acknowledgements

The authors acknowledge the interest and support from James Greene, RADM, USN, (Ret) Acquisition Chair, Graduate School of Business and Public Policy; Robert Beck, former Dean, Graduate School of Business and Public Policy; and Keith Snider, Associate Professor, Graduate School of Business and Public Policy. Thank you for your kind support and encouragement.

THIS PAGE INTENTIONALLY LEFT BLANK

About the Authors

Gary Langford is a Lecturer in the Systems Engineering Department at the Naval Postgraduate School in Monterey, California. He teaches systems engineering, combat systems, and project management. His research interests include the theory of systems engineering and its application to military and commercial competitiveness. Additionally, Mr. Langford founded and ran five corporations—one of which is listed on NASDAQ. He was a NASA Ames Fellow, 1996-2000. Langford received his MS in Physics from Cal State, Hayward, and his AB in Astronomy from the University of California, Berkeley.

Gary O. Langford
Department of Systems Engineering
Graduate School of Engineering and Applied Sciences
Naval Postgraduate School
222 Bullard Hall
777 Dyer Road
Monterey, CA 93943-5000
Email: golangfo@nps.edu

Raymond E. Franck is a Senior Lecturer in the School of Business and Public Policy at the Naval Postgraduate School (NPS). He teaches economics (generally) and pursues research primarily in the areas of military innovation and defense acquisition. Prior to joining the NPS faculty, Dr. Franck served for 33-years in the Air Force, retiring as a Brigadier General in 2000. His NPS service has included serving as Interim Chair of the Systems Engineering Department from 2002 to 2004. His undergraduate degree is from the Air Force Academy, and his doctorate is from Harvard University.

Raymond E. Franck
Graduate School of Business and Public Policy
Naval Postgraduate School
203 Ingersoll Hall
555 Dyer Road
Monterey, CA 93943-5103
Email: refranck@nps.edu

THIS PAGE INTENTIONALLY LEFT BLANK

NPS-GSBPP-09-006

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

Gap Analysis: Application to Earned Value Analysis

19 August 2009

by

Gary O. Langford, Lecturer,

Graduate School of Engineering & Applied Sciences

Raymond (Chip) Franck, Senior Lecturer,

Graduate School of Business & Public Policy

Naval Postgraduate School

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

THIS PAGE INTENTIONALLY LEFT BLANK

Executive Summary

The Department of Defense's traditional style of Gap Analysis can benefit from a broadly based methodology that combines value engineering and systems engineering. Value engineering improves the value of goods and service by being effective and efficient, while systems engineering focuses on development and organization of complex systems. Both rely on functional approaches that are analytical by their means and methodical by their natures. Gap Analysis is an assessment methodology that compares a system's actual performance with its potential. Gap Analysis embodies both the notions of beginning and ending points as well as the path betwixt to achieve a desired capability. Combining value engineering with systems engineering offers a robust means to evaluate both the appropriate system requirements as well as the efficacy of fulfilling a stated mission objective given a set of alternatives. In order to facilitate such a success, we conjoined value engineering and systems engineering and built metrics and measures, ensuring (1) delivery of lowest lifecycle cost acquisitions consistent with required performance, (2) strict adherence to appropriate requirements, and (3) alignment of budgets with acquisition decisions.

THIS PAGE INTENTIONALLY LEFT BLANK

Introduction

The challenge of developing a new product is premised on the manager's ability to exert control over the project development process. With control, the managers and planners can guide the work by allocating resources, changing investments, and directing human capital. The concept of control denotes the limits of operations—the demarcations of requirements, allocation of resources, monitoring of performance, and identification of corrective actions. One envisions that optimal management control depends on collecting and interpreting a set of measures that represent the performance of the salient aspects of the project. These aspects must be significative of the project's activities and processes typified by required accuracies and precisions. With legitimate means available to influence the rate at which contract money is exchanged and converted into tangible results, managers can better determine the progress towards completing the work. One such method of monitoring and reporting work status is "earned value."

Earned Value is a method for managing programs and projects that (1) orchestrates an integration of the organization and organizational behaviors with work tasks; (2) accounts for costs; (3) reports schedule and cost variances of work tasks; (4) reconciles budgets and changes to tasks; and (5) characterizes project dollars in terms of cost, schedule, and technical performance on tasks with defined deliverables. The fundamental idea behind Earned Value Management (EVM) is the integrative and interactive effects that differ from the planned course of work on a project. Schedule, cost, and performance on planned tasks can change due to their near one-to-one couplings. Each factor influences the other two, and, by those effects, it influences itself. EVM assesses the project's well-being from the perspective of the work effort in terms of the uses of time, money, and outputs. However, errors educe when inadequate measures and metrics are reported. Accurate assessments are further complicated by poor understanding of (1) the interaction of related financial arrangements and relationships with the schedule and delivery of work packages, (2) amount of level-of-effort work and its interactivities with defined work tasks, and (3) inadequate accounting of undiscovered rework.

To determine the status of a work effort, managers must understand the consequences of the interactions between schedule, cost, and performance when satisfying requirements and aligning work tasks with the organization's processes. The worth of EVM to managers is embodied in its (1) relevance to predicting the total costs, delivery schedule, and satisfaction of requirements, and (2) accuracy and precision of the data that will be used to orchestrate and control the work.

The three dimensions of EVM are the planned value (budgeted costs of the work scheduled); actual cost of the work performed; and Earned Value.

Planned value is the aggregated (or full) cost budgeted for the work that is scheduled. The aggregate costs are the sum of variable costs (e.g., expenditures, resources, people, equipment, and material) plus the fixed costs (those costs that remain constant regardless of activity, size, or volume, e.g., utility and insurance costs). The budgeted costs of the work scheduled are the Earned Value. Earned Value is defined as the actual work accomplished as represented by the authorized budget for that work. Planned value answers the questions, "How much work should be done?" and "How much of the budget should have been spent?" Planned Value, referred to as BCWS (budgeted cost of the work scheduled), is calculated as the cumulative time-phased costs of the work associated with milestones (or notable events). Answers to these questions require a baseline cost from which to make a comparison. The BCWS serves as the basis for comparison with the actual cost that is or will be incurred.

Actual Cost is the cumulative total of *all* costs incurred when performing and supporting the work activity. Every activity, process, and function that is enacted in the accomplishment of work makes up the Actual Cost of the work. The Actual Cost of the work accomplished (ACWP) is an independent variable. Actual Cost answers the question, "How much did the actual work cost?"

Earned Value is the budgeted cost of the work performed (BCWP). It is based on the cumulative value of all milestones achieved by a specified time. As with the BCWS and the ACWP, Earned Value is calculated as of a particular time.

The difference between the budgeted cost for the work performed (BCWP) and the actual cost of the work performed (ACWP) is the cost variance. The difference between the budgeted cost of the work performed (BCWP) and the budgeted cost of the work scheduled (BCWS) is the schedule variance. A cost performance index (CPI) percentage relates the BCWP to the ACWP while a schedule index (SPI) relates the BCWP to the BCWS. Both indices are helpful in suggesting trends based on a linear extrapolation of data from a specific time. Figure 1 illustrates the basic three parameters used in EVM, along with the additional two parameters: scheduled time for the work planned (STWP) and actual time for the work planned (ATWP).

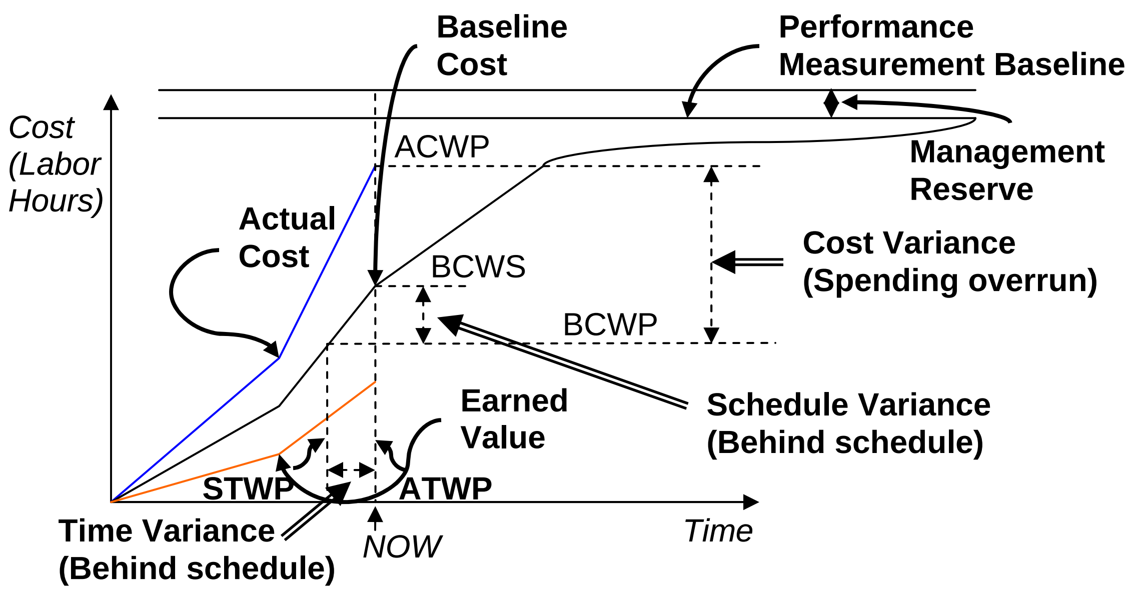

Figure 1. Earned Value Chart

EVM focuses on schedule, costs, and performance. While EVM helps identify budget and delivery date overrun conditions, it is problematic for managers to base their actions on information that is unsubstantiated by a wider range of measures and metrics. At issue is the applicability of the standard Earned Value measures when it is the job of management to evaluate the impacts of actions *before* the actions are begun. Earned Value focuses on the results of management. The difference between the proactive stance and the recording of the results through EVM can be a lengthy delay. Managers necessarily need to respond to work issues faster than the reporting and analysis cycle that results from EVM. The structures and theory of Gap Analysis afford an opportunity to be more involved with symptoms and causes before problems fester and extend their maladies into the general work environment. At issue are the management of scope and quality of work. Scope relates to the functions delivered, while quality relates to the lifecycle costs of deliverables. Thus, the purpose of this report is to extend and apply the general formulation of Gap Analysis theory developed under the Graduate School of Business and Public Policy at the Naval Postgraduate School (Project #: F07-031, Dated: 29 November 2006 FY07) to improving EVM.

Specifically, it should be the number one goal of EVM (or its revised/derivative technique) to suggest how management can obtain the best-value solution for the taxpayer's money. And further, best value should be twined with management direction and controls that emphasize strategies and tactics that change work behaviors. Ideally, that change would be enacted *before* problems arise. It should also be an additional requirement that EVM afford the most opportunity for managers to benefit from the analysis.

As such, the result of cost-effectiveness is a particularly attractive outcome of EVM. Cost-effectiveness emphasizes the relative nature of management's role—to achieve more for less, more for same, same for less, or more for more.

Gap Analysis Applied to Earned Value Management

If managers perceive a deficiency or a desired goal that differs from that which the actual work auspicates, there could exist a basis for gap in intentions versus what has been achieved, and, therefore, a desire to close that gap. The goal of Gap Analysis with regard to EVM is to maximize the difference in achieving cost-effectiveness by employing one (or more) of possible management strategies versus others out of the set of alternatives.

What a manager desires versus what a manager has is, in essence, a Management Gap, or, more pertinently, a Value Gap. The Value Gap is as much the relationship between what is perceived to be *important* and the derived difference between performance and expectations. The methodology and analysis of that difference is the descriptive foundation for Gap Analysis that was developed by Langford (2007a) and Langford, and Huynh. (2007). From a management perspective, a Value Gap may consist of deficiencies in organization, current or planned operations, processes, technology maturity and readiness, integration and standards, misunderstood requirements, work performance, and task performance. A Value Gap is determined by two factors. First, the starting and ending points of the work (i.e., its boundary conditions) delineate the situation(s) that characterizes the work and bind the Value Gap. The boundary conditions include the beginning scenario and the end goal, resource allocations, human capital needs and fulfillments, equipment, facilities, processes, and political/economic support. Second, the difference between the starting and ending points exemplifies the task sequence(s) or paths that encompass the work. Quantifying the boundaries and constraints involves evaluating a number of work situations and operations scenarios in concert with the planned actions. Stated more generally, guidance from policy and goals sets the standards for defining Measures of Effectiveness (MOEs) that form the standards from which to determine how well a work activity satisfies a requirement (Sproles 2002). MOEs are distinguishable from Measures of Performance (MOPs) in that MOEs offer the external view, while MOPs are more consistent with the internal view. The external view captures the system’s beginning and ending points, while the MOE of the candidate work tasks are implemented to fill the Value Gap. The internal view involves measures of how well one fills the gap through the MOPs. Therefore, one must formulate both MOEs and MOPs to fully define a Value Gap. However, *CJCSI 3170.01D* the *Joint Capabilities Integration and Development System* (2004, 12 March) focuses on MOEs while there is no mention of MOPs. There is an implied admixture of MOEs and MOPs defined as

MOEs, but the essential qualities of performance-based metrics are missing for carrying out activities and actions, for measuring functions, and for determining economic and numeric impacts. This report addresses a quantitative method to measure both MOEs and MOPs through value structures.

Gap Analysis is deeply embedded and fully institutionalized as a cornerstone of the United States Department of Defense (DoD) acquisition strategy, particularly in the critical process called Management Valuation of Alternative (MVoA). Applied to the management of work efforts, Value Gap Analysis offers a quantifiable structure in which to determine value. Within this context, the purpose of tailoring Gap Analysis to management processes is to report on the evaluation of task performance, the effectiveness of tasks, the suitability of work processes as well as to estimate costs of planned and alternative work activities to meet schedule, budget, and delivery requirements. The MVoA can be structured to assess both the Earned Value of completed work in addition to giving insight into the advantages and disadvantages of alternative strategies and tactics to use during upcoming work.

The goal of the Value Gap Analysis (VGA) is to compare current actions to the set of requirements (performance, schedule, and budget). Where differences arise, gaps are identified and quantified, and mitigations are prioritized and planned. This paper addresses the theoretical foundations and systematics of VGA with extensions to illustrate its utility as a useful management tool. VGA is based on EVM formulations and the fundamentals of Gap Analysis. Without a considered theoretical foundation from which to conduct Value Gap Analysis, an inadequate level of guidance regarding appropriate methodology and analytical methods may well result. The metrics of VGA are defined on the basis of system value (Langford, 2006; Langford & Huynh, 2007) and assessed consequences of the chosen management plans.

Discussion

For the US Department of Defense (DoD), the acquisition of goods and services follows the policies outlined in Directives, the Joint Capabilities Integration and Development System (JCIDS), and the Defense Acquisition Guidebook *DoD 5000* (the structure and operation of the defense acquisition system). In this context, Gap Analysis is a method for identifying the degree to which a current system satisfies a set of requirements. The goal of Gap Analysis is to align an anticipated future outcome with a future reality that can be formulated, defined, and established or constructed. However, Gap Analysis is not intended to close the space between the most distant extremes or the rarest occurrences. Gap Analysis is instead centered on the larger, more general aspects that are by and large not part of the present reality (referred to as the current reference frame). For US DoD, Gap Analysis grew out of the realization that relying solely on a threat-based approach (used as a primary driver of requirements until 2000) or a technology-based approach to determining future needs is both costly and largely ineffective. One of the concerns with threat-based methods lies with the notion of being guided by the will and intentions of others, as exemplified through an analysis of threats, their efficacy and robustness, rather than by relying on our competitive advantages to define and frame future engagements. The logical extrapolation of threat-based methods is to commensurately link risk analysis with management and risk management with Earned Value. The difficulty lies with the assessment of risk. Even with past program data and a considered lessons-learned analysis, managers are faced often with new issues and complexities that obviate even the best intentioned correspondence between past and planned projects/programs. Threat-based acquisition was superseded.

Alternatively, a performance-centered approach was implemented. While this was open-ended and optimized to be consistent with lifecycle cost issues, the management issues were compounded by complex software work, commercial off-the-shelf technology, technology readiness and maturity, and integration problems. Developments that are based only on a risk-based approach are typically plagued by the credibility of the risk—the absolute measure of what problems will be and their impacts on planned work.

Accordingly, neither the technology nor the risk-based approaches address some of the persistent issues that fundamentally impact the implementations of Gap Analysis for managing work packages.

US DoD then concentrated on a capabilities-based approach, with defining capabilities identified top-down. The capabilities were imbued with characteristics such as measures of effectiveness, supportability, time, distance, effect (including scale) and obstacles to overcome. Capability is defined by an operational user as the ability to execute a specified course of action (Chairman, 2004). However, in the course of changing management strategies, EVM did not keep pace.

Value Gap Analysis Background

The antecedents of Value Gap Analysis (VGA) were introduced by Gary Langford in publications beginning in 2005 at the Naval Postgraduate School (Langford, 2005; Langford, 2007a). The basis for VGA was the pioneering work by the authors to redefine Gap Analysis by its theoretical foundation. The notion of ascribing value structures to Gap Analysis evolved from the authors reevaluating the inefficiencies of managing systems engineering developments coupled with revising the fundamental structures of systems based on an analysis of value and worth. Our evolution of thought derived from the series of instructions from the Chairman of the Joint Chiefs of Staff that was promulgated throughout the 1990s. The statements defined gaps in capabilities that necessitated material solutions. By the late 1990s, US DoD infused a form of Gap Analysis into the acquisition process—comparing future threat-based assessments to current capability. Gap Analysis had come into being and thrived within the structure of the JCIDS process. Then, the determinant factor for acquisition moved from a threat-based premise to a capabilities-based identification of needs. The evolution from the premise of threat-based to capabilities-based acquisition helped to clarify the Gap Analysis process. And that same clarification is essential for VGA. VGA is predicated on establishing an analogous correspondence between risk and the capability of management to enact changes that impact the success of the work tasks.

Further, there is a inverse relationship between the performance of work and investment to achieve that performance. But the crux in the determination of value must also include the losses that are incurred as a result of that performance and that investment. This report discusses the relationship between the value earned by the work that is planned to be done, performance, investment, risk, and schedule.

In essence, value accrued over a given period of time (i.e., Earned Value) is only part of the issue. Currently, there is aggressive estimation of value embedded in the manner in which Earned Value is determined. Omitted are undiscovered rework; level-of-effort; and the unknown, yet upcoming changes that may alter the previously

Earned Value. The current means of calculating Earned Value clearly begs the question, “How do we know what we do not know?” More value is credited earlier than represents the actual status of the work performance according to the plan. For example, if the requirements for the quality of a work output do not identify the maximum number of types of defects, the calculation and reporting of Earned Value will over-report the progress. Of course, there will be estimates of the number of defects based on historical data from previous projects or work tasks. Estimates of defects are widely used to approximate typical work and rework cycles. However, they are ineffective determinants of BCWP. It is, therefore, often the case that the work “earns” up to full value BCWP even with large numbers of defects that will require rework. For medium complexity, C++ software efforts of 18 months duration rework can easily exceed three times that required for the initial coding.

While VGA should be neither solely performance-driven nor risk-driven, it is an approach that largely uses performance and risk as inputs to a value-driven future. VGA is based on the high-level systems view of *what is needed*, rather than what is being done. VGA compares what is being done with what is planned and with what is ultimately needed. As programs and projects respond to changes in requirements and insufficiency of resources, human capital, or timely investments, management reinforces their goals through the requirements-management process. Changes in requirements are tracked through Earned Value and the implications of the changes are debited from previously Earned Value. The net of the Earned Value is the actual Earned Value. The actual Earned Value is compared to the planned Earned Value and a measure of work status is achieved. The problem with this formulation of VGA is in determining (1) what constitutes the foundation data, (2) which data are relevant to future requirements, (3) how the relevant data should be structured to deal with the future issues within the proper context, (4) what assumptions and scaling rules should be used to extend the current state of work output, technology advances, and engineering developments, and (5) what process or methodology enforces consistency of performing Value Gap Analysis. In this report, the authors deal with the general formulations of EVM as it applies through the notion of gap analysis. We anticipate dealing with the specific problem areas identified above in subsequent reports.

Research Objectives

Management must both identify the gaps that differentiate the actual work from the planned—in essence, the goal. Management is required to close the performance, schedule, and cost gaps. Further, these gaps are an absolute measure of value. The difference between what is planned versus what is actually done is the difference in value between what is expected versus what is delivered. In general, large gaps have larger value than small gaps. This is an omni-dimensional problem that encompasses management strategy, operations, systems engineering processes, and the compositional elements of the system.

The first step in proposing Value Gap Analysis is to determine the underlying premises and fundamental metrics of such an analysis. This paper investigates the theoretical issues of Value Gap Analysis and proposes metrics based on quantifiable formulations of worth, value, and risk. By developing the theory of Value Gap Analysis into a form that can be applied in a clear and consistent manner for managers, (1) value metrics can be compared with Earned Value; (2) worth metrics can be applied to a critical examination of foundation data; (3) risk metrics can be used to interpret the relevancy of data; (4) an enterprise framework (which displays worth and risk metrics) can be used to illustrate context at a given time; and (5) assumptions can be scrutinized definitively. To better understand and determine the applicability of VGA for management, a final step in this work is to identify the general limitations of VGA and the general impositions that VGA places on the success of the management process.

Theory

Beginning with the basic structures of gaps, VGA builds on causal histories—the telelogic argument that gaps in value exist and can be ameliorated by goal-directed actions.

We define Value Gaps in terms of the functional requirements, their performances, and their losses due to those performances. Further, all Value Gaps can be characterized in terms of capability of human capital. By reference, EVM was implemented to specifically address measuring gaps between planned and actual performance. But since not all performance gaps require a human capital solution set, VGA must be modified. Changes or enactments of policy, organization, training, materiel, leadership and education, and facilities are considered candidates to close Value Gaps. These factors are usually formally evaluated before recommending the start of a new development effort. The result is that the process of managing work tasks is functionally decomposed to allow the assessment and identification of Value Gaps. Many such types of Value Gaps can (and should) be identified during the planning stages of a project. It is at this early point that Value Gaps representing such factors (e.g., policy) can be dealt with most proficiently and economically.

While Value Gaps can be identified and sometimes corrected *before* the work begins, a certain measure of uncertainty remains. As shown in Table 1, according to the best practices in systems engineering, (GAO, 2001) when organizations match the expectations of the work to the resources, schedule delays and cost growths are significantly less than when expectations and resources are poorly matched at the onset of the project. The net result of dealing with Value Gap early is to proffer a better alignment of resources, performance, budget, and schedule. Planning and execution of work benefit from this early perspective.

Table 1. Matching of Expectations to Resources and Product Development Outcomes
(GAO, 2001)

Programs	Expectations and resources adequately matched before launch	Product development cost growth	Product development schedule delays
Caterpillar 797 mining truck	Yes	5 percent	0 percent
NASA FUSE	Yes	20 percent	0 percent
Radio Frequency Countermeasures system	No	197 percent	23 percent
Crusader artillery vehicle	No	55 percent	26 percent
Comanche helicopter	No	127 percent	119 percent
Brilliant Anti-armor Submunition	No	99 percent	46 percent
Bombardier BRJ-X[a]	Yes	On target	On target
Tactical Unmanned Aerial Vehicle[a]	Yes	On target	On target
Global Hawk Unmanned Vehicle[a]	Yes	On target	On target

Value Gap Analysis is in part based on the work by Lawrence Miles to formally recognize and focus attention on functions of a product. Product functions create (or cause) certain levels of performances that are related to the expenditures (costs). In turn, these performances are both a measure of management's relevancy and effectiveness.

Yet, as discussed previously, Gap Analysis is concerned with the difference between the present and the future, the reality and the expected, but, as will be shown, not with the time or discrete time-steps between these disparities. While management typically formulates its development plans and milestones in a temporal domain (e.g., a timeline of activities), the development activities are construed and managed as a discrete set of events. The two views of progress are correlated, but sometimes weakly. Individual performance is expected to reflect the schedule constraints. Costs are expected to be planned in advance (e.g., in the hiring and promotion stage of the development of the project's human capital assets). People are expected to estimate accurately. However, should their estimates prove inadequate; those people are expected to figure out ways in which to increase their efficiency. In total, these systems of behavior are weakly coupled, with the manager holding few tools and strategies to influence behaviors. Therefore, Value Gap Analysis must contend with the coupling of these systems and provide a set of measures to better quantify the relationships as they apply to Earned Value.

Additionally, it is one of the purposes of the Systems Engineering Process Models to reinforce the notion of when to move from one stage of product development to the next stage, as well as what tasks need to be completed within each stage. At each stage, management is engaged in adjusting behaviors that will change performance to be in line with budget and schedule expectations. These stages are marked by milestone reviews that include budget, schedule, and performance. Consequently, the notion of a temporal juxtaposition of activities is less relevant to the event-driven outcomes which characterize a future set of circumstances. In other words, Value Gap Analysis does not quantify when something will actually happen, only that when it happens, it will have a value that is more or less than planned. This definition of a Value Gap lends itself naturally to a display of intentions that accurately reflect the constraints of event-based management.

In total, the redaction of Value Gap Analysis into events rather than timelines eliminates the actual propositional attributes of the undefined value structures but retains the notional attributes. Propositional attributes iterate the validity of management beliefs and attitudes (i.e., I know what I know, I know what I want). Notional attributes include intentions and wishes (i.e., the end result is not influenced by the proposer's illative skills) (Duzi, 2002). Temporal considerations (i.e., I know when I want it) can be added as an attribute of the Enterprise Framework after forming a situational awareness in event-space. There are alternative interpretations of Enterprise Frameworks, most notably for software applications (Hafedh, Fayad, Brugali, Hamu & Dori, 2002). But the general notion is valid that such theories can be used to surmise a means of enforcing consistency in process, application, and interpretation of Value Gaps.

Value

The prime distinguishing characteristic of Value Analysis (or as it is sometimes referred to, value engineering) is the use of functional (or function) analysis (Miles, 1972) as a means to appreciate what performance *does* rather than what it *is*. Value Analysis is a management process used to optimize the use of human capital within the constraints of schedule and cost. Alternatively, Value Analysis provides a view of the performance that associates it with what is necessary to accomplish a work activity at the lowest cost. In essence, analyzing value that is earned, i.e., Earned Value, is the means of analyzing productivity, selecting alternative management strategies, and otherwise manipulating the ratio of Performance to Investment. It is this ratio that determines the value of work done. And it is the accumulation of Performance to Investment between milestones that is used to determine the real measure of Earned Value. The basis for Value Analysis is formed by coupling value with the loss that ensues from a given level of performance (e.g., hours and dollars spent for less than desired work output). Value Analysis is typically concerned with productivity and the use of labor and materials within time constraints to achieve a certain level of performance. Lowered levels of performance are a loss.

We broaden this perspective of loss due to performance by replacing the temporal aspects of a project that define the time from one point to another point with the events that delineate the beginning and ending milestones between which value is analyzed. The result is an event-based analysis of value rather than a time-based analysis of value.

The term value has many colloquial definitions, including the often disguised use and misuse of the term to mean promoting various popularized concepts. But in the main, all constructs of value are without merit and meaning unless there is a relationship between the defining functions, and, therefore, by reference to system objective(s) or use(s). Though related, Value is not synonymous with cost or investment. Value for given functionality is performance of a workforce divided by the investment to deliver or sustain that performance. Further, Value is distinguishable from Worth. Worth is a measure of Value given risk (discussed in next section). There are different types of Value (use, esteem, cost, exchange, scrap, and so forth). For the purposes of this report, the authors do distinguish between the types of Value. Value is as previously described: performance divided by investment.

Value is attributed to the development of functionality, i.e., for the use one receives versus what one invested (Langford, 2006). This notion of Value explicitly requires a manager-worker model to determine Value. The manager-worker model presupposes there is always a “source and a sink,” an “input and an output,” a pre-condition and a post-condition that is the determinant of Value*.* Therefore, Value for functionality is the ratio of the defining characteristics of the product (i.e., performances) divided by the investment to achieve that functionality and performance. Value is measured in absolute terms. For example, “the worker shall develop a function with a specified performance.” That function does fifty percent of what was paid for (as perceived from the point of view of the developer). Or perhaps, the performance was measured at 90% of the requirement. The investment expended to achieve that functionality and performance was as planned. Therefore, the value was less than desired from the developer’s perspective. The Value Function (Equation 1) relates the System Value to the System Use(s) or to the System function(s) and their related performances divided by the investment.

Equation 1. Value Function

$$V_F(t) = \frac{\sum P(t)}{I(t)}$$

Where *F(t)*is a function (or sum of functions) performed by the system; *P(t)* is the performance measure of the function *F(t)*, or sum of functions; *I(t)* is the investment, or sum of investments that correspond to the individual or aggregate events, e.g., dollars or other equivalent convenience of at-risk assets; and the time, *t*, is measured relative to the onset of initial investment in the project (or replaced entirely by individual events or sequences of events. The unit of *V(t)* is that of *P(t)*, performance (e.g., units of work or energy) divided by Investment (which could be quantified in terms of dollars or another meaningful measure an investment).*F(t)* is dimensionless.

Value Systems Engineering is the activity which identifies and analyzes the value(s) of functions of products and services based on the ratio of Performance to Investment. This value metric can be used to specify the *Value* of requirements that need to be built, sustained, and disposed.

When applied to Gap Analysis, the metrics used for analyzing requirements are Value and *Risk.* Value is captured by the cost of functions and their performances, and investment (measured in cost or investment). In a common-sense fashion, Value is a measure of appreciation of assets (or conversely, the transformation/conversion of investment(s)) into performance. The result of performance is a product. Performance may be objective or subjective, and, likewise, Value may be objective or subjective. Objective value relates the independence of assessments as viewed from various perspectives—a consensus opinion of truth. Subjective value relates what is expected (the sum of all corporal and abstract happenings from which you benefit and expect from a situation if you participate in a certain fashion). *Value* is improved by minimizing cost or its time equivalency to develop a product. Alternatively, *Value* is the use that users expect (e.g., the functions and performance) for the investment(s) that they are willing to make. Further, *Value* is a key consideration of lifecycle costs and lifecycle time that expresses the transformation of enterprise assets into profitability. In this case, *Value* is characterized through Equation 1 by the results of performance for a given investment. Each function is an activity that the product does with certain performance attributes. For each function, there can be several performance requirements. However, there is never a function without at least one of performance.

Worth

Worth extends the concept of Value to include the notion of loss as the result of a given level of performance. For example, “I have $20. Please give me $20 worth of gasoline.” If the price and quality of gasoline fluctuates, then in one purchase you might receive 2 gallons, but in a second purchase, after shopping around, you might receive 2 gallons for only $10. With the first 2 gallons of gasoline, you were able to travel 40 miles. But with the second 2 gallons of gasoline, you were only able to travel 20 miles. With performance divided by cost equal to 40 miles/$20 for the first transaction and 20 miles/$10 for the second transaction, the *Value* received for the first transaction was 2 miles/dollar and for the second transaction 2 miles/dollar. The *Value* for both transactions was the same: 2 miles/dollar. Unfortunately, the less expensive gas purchased in the second transaction resulted in engine wear that significantly shortened the life of the engine. Was the less expensive gas worth it? The loss due to lower performance from the second purchase of gas is captured in a quadratic-loss function.

Worth is the Value *V(t)* for each function multiplied by the Quality *Q(t)* as measured by a loss function. To a first order, Worth is a linear function. Measures of performance indicate how well a function is performed by the system. We refer to quality as the consistency of performance (or tolerance that signifies how good the performance is) in reference to the amount of pain or loss that results from the inconsistency as described by Taguchi (1990). In essence, functions result in capabilities; performances differentiate competing products; and quality affects the lifecycle cost of the product. For each function, there is at least one pair of requirements—performance and quality. The quality requirement indicates the variation and impact of the variation on the performance requirement of a function. Both performance and quality requirements should be specified and tracked in Value Analysis. A system function may have different measures of performance, and the quality of a performance may have different measures. The summation in Equation 1 is thus overall values of performance and quality, for all time, and incorporating all uncertainties due to loss. Equation 2 indicates the Worth of a system, as it references *Value*.

Equation 2. Worth Function

$$W_F(t) = V_F(t) * Q(t) = \frac{\sum P(t) * Q(t)}{I(t)}$$

Where *Q(t)*is quality (the tolerance assigned to the performance measures) and the time, *t*, is measured relative to the milestone from which one measures Earned Value. We refer to the delineation of a function in terms of its performance and the quality of the performance as the triadic decomposition of the function. In other words, traditional functional decomposition is followed naturally by performance decomposition and then by quality requirement's decomposition. If the unit of *Q(t)* can be converted to the unit of *I(t)* (Equation 1), then the unit of *W(t)* is that of *P(t)*, since *F(t)*is dimensionless. *Q(t)* can be thought of as a loss that is incurred. Triadic decomposition forms the basis for a management tool to measure Earned Value.

The Value of a product is thus quantified according to Equation 1 and the Worth of a product is quantified according to Equation 2. From the manufacturer's point of view, a product's worth is viewed as having met some investment criteria to achieve Value for the desired set of functionality, performance, and quality requirements. From the purchaser's (consumer's) point of view, the expression in Equation 2 aids in the analysis of alternatives between the applicability of a purchased product (in terms of the item's functionality, performance, and quality) and the total cost and time invested in the purchase and use of the product.

Value and Worth are calculated at the moment of the agreed exchange of products and services for a given amount or recompense. Worth reflects the uncertainties based on losses that are associated with the exchange. These exchanges (or interactions between elements) are quantifiable and may have a net impact on the Value and Worth of the system, or in the exchange between two or more systems through their respective elements. We are interested in the interactions that have consequences that are measurable in the lifecycle of the product or service. Traditional Earned Value (using the proposed redefinition of value) incorporates this level of minimum interest. We introduce the concept of a Net Impact that is defined as a consequence that exceeds a threshold determined to be of interest. Earned Value must exceed a minimum level to be measured. This minimum level can be achieved artificially by allocation of Earned Value at the beginning of the work, or alternatively at the halfway point. Or, Earned Value can be calculated from first principles using Equation 1, along with the consequences of that Earned Value in Equation 2.

Worth Transfer Function

In control theory, a transfer function is a mathematical representation of the relationship between the input and output of a system. A Worth Transfer Function (WTF) between two elements of a system is defined as the exchange of Worth between the two elements. Worth is what is received (in terms of usefulness) for an investment. This exchange necessarily assumes some measure of risk. Given risk, a WTF can thus be either a manifestation of the state, (or a change in the state of a system) or a tool to evaluate differences between the state of a system and the state of another system, or between the states of two systems in a system of systems. In essence, the WTF represents various impact(s) on the state(s) of a system. The WTF can be a nested hierarchy of WTFs, all related through functional decomposition. Depending on the worth ascribed to each of the WTFs, the state(s) of the system(s) may be impacted to varying degrees. The result is that a small number of WTFs may be equivalent to a large number of irreducible WTFs.

A system is a set of elements that are either dependent or independent but that interact as a pair—temporally or physically—in order to achieve a purpose. The elements form the boundary of the system. This definition takes into account both the permanent and episodic interactions among elements of a system or of a system of systems. It thus includes the lasting and occasional interactions, as well as emergent properties and behaviors, of a system. These interactions effect and facilitate transfer of energy, materiel, data, information, and services. They can be cooperative or competitive in nature, and they can enhance or degrade the system Worth, which is defined below. The paired interaction transfers a measure of worth from one element of a pair to the other element. We term the measure of the transferred worth the Worth Transfer Function (WTF).

Risk

Using the logic of Lowrance (1976) and of Lewis (2006), simple risk can be defined as a function of three variables: threat, vulnerability, and damage. Replacing damage with Worth, Langford and Huynh (2007) capture risk through threat, vulnerability and Worth. An element, *e*, of a project is associated with a risk, R_e, defined by Equation 3 below:

Equation 3. Element Risk Equation

$$R_e = X_e * U_e * W_e = X_e * (1 - a_e) * W_e$$

where, * indicates the convolution that expresses the overlap and blending of factors; and where, threat, X_e is a set of harmful events that could impact the element; vulnerability, U_e is the probability that element *e* is degraded or fails in some specific way, if attacked; Worth, $W_e = V[1 - L_e]$, where L_e is the loss that results from a successful degrading off element e; and susceptibility, a_e, is the likelihood that an asset or activity will survive or be degraded. W_e is given by Equation (2). It may be loss of productivity, casualties, loss of capital equipment, loss of time, or loss of dollars. Susceptibility is the complement of vulnerability. Equation (3) reflects these tentative affinities. One finds vulnerabilities in a worthy project from the threats to that project.

Since an element in a project may be connected to more than one element, the number of WTFs associated with the element is the degree of the element. Subscribing to Al Mannai and Lewis (2007), we obtain Equation 4, the system risk,R_e, as:

Equation 4. Total Risk Equation

$$R = \sum_{i=1}^{n+m} X_i * (1 - a_i) * g_i W_i$$

in which n denotes the number of elements, m the number of links or WTFs, and g_i denotes the degree of connectedness (i.e., the number of connections) to the i^{th} element.

As a result of the WTF between two elements, e_1 and e_2, at the moment of their interaction, we have Equation 5. It is the expression in Equation 5 that forms the basis for complexity management.

Equation 5. Value/Risk Equation

$$\frac{W_{e_1}}{R_{e_1}} = \frac{W_{e_2}}{R_{e_2}}$$

Discussion

This approach to Value and Worth extends the published and private works of Langford to identify and apply measurable objectives to characterizing and analyzing Value Analysis. The two basic metrics are competitive Worth and a Investment *to risk* ratio, Value. Both are calculable as Earned Value and displayable in an Enterprise Framework.

Value Analysis fits into the overall scheme of project management in product development by providing managers with a structured and objective set of measures from which to track work status that corresponds with defined needs. The desired results of Value Analysis are to (1) predict what is needed to postulate an event, (2) compare one alternative to another to determine what is needed in order to deliver what is required, (3) identify those tasks that need to be changed or added along with the amount of investment in time and money required, and (4) define the potential limitation of future capabilities (e.g., functions, performances, and quality). Recognizing that there may be no means of maintaining an optimal relationship between the two limits—what is needed and what potential limitations in capabilities result from the performance of the work—we rely on the principles and best practices of engineering.

Further, we use generally accepted economics terminology, extended to encompass the notion that the price one pays for a product assumes and accounts for the loss realized to make the purchase (Taguchi, Chowdhury & Wu, 2005). That is, the purchase price of a product includes the cost of procurement—for example, the $1 purchase of a pen must be increased to $5 to include $0.50 of gasoline, the amortized cost of maintenance, insurance, and depreciation as well as the labor rate times travel time to drive to and from the store in order to make the purchase, etc. This notion states a willingness to spend (or lose) $*x* to purchase a $1 item.

Following the accepted systems engineering process, product requirements are defined hierarchically with each successive level offering greater detail via decomposition. However, unlike the different types of requirements that attach to various process models (e.g., functional and non-functional requirements), we define all processes and products by three measures: their functions, performances, and qualities (Langford, 2007a; 2008). Relative to the investment (or cost per item or its equivalent) to bring a product to operational capability, the product has determinable Worth. That Worth is expressed as a ratio of total value (i.e., operational capability or use as measured in terms of a unit of performance, e.g., work, throughput…) multiplied by Quality (effectively divided by the potential losses that could be incurred) and then divided by total lifecycle investment, i.e., expected cost for the use). As an example, if this ratio is less than 1, then the product has lower than expected worth.

Worth is related to both the vulnerabilities of the work to be done and to the worker's outputs. The risks are a function of the threats and vulnerabilities, where threats are typed by magnitudes and frequencies and vulnerabilities are determined by the likelihoods of success (US Department of Defense, 2006). The work outputs from the development (i.e., performances on work tasks) are related to the vulnerabilities through the price-demand elasticity curves (Lemarechal, 2001). The competition for resources and the impacts on work determine the threats, the management strategy determines the vulnerabilities, and the triad of requirements (i.e., functions and quality) determine the Worth (Langford, 2007a).

To investigate the multivariate probability-density functions of the Risk Equation (Equation 3), a step-wise, two-variable analysis reveals both the boundary conditions and the relationships. A product that has Worth (quantified by Equation 2, the Worth Function) from the manager's point of view is one that has met the investment criteria for the desired set of functionality, performance, and quality requirements. From the worker's point of view, the Worth Function emphasizes the trade that is made between the applicability of the assigned work (in terms of the item's functionality, performance, and quality) and the incremental (or total cost) and incremental time (or total time) needed to deliver the requested work.

The relative ratios of Worth/Risk for an activity, a process, or a work package may be displayed as probability-density functions, or summarized as single-data points for display purposes.

General Formulation of Results

This report defines an approach for analyzing Earned Value using *Value*. Further, the consequences of management decisions (i.e., strategy implemented through activities and processes) are viewed as consequences of these actions. Consequences are defined and analyzed as the worth of management decisions. The combination of these management parameters (reflecting operations and strategy) and the product development parameters (functions, performance, and qualities) is understood through the structure of an expression of *Risk* (Equation 3).

In the case of Value Analysis, Equation 2 has proven to provide additional insight into the makeup of and changes in the boundary conditions and key drivers for the work tasks. There are different types of Value Gap Analysis "domains." Some of these domains are constrained by organizational demands, sometimes by personality issues, and sometimes by other circumstances related to the specifics of the work tasks. The internal structure of the Value Analysis domains are arranged in particular patterns within an organization. Continuous functions (or patterns) are built and sustained by authoritative proclamation. Over time, such structures evolve to a mature environment that supports decision fitness and reliability in process planning. However, when the Value Analysis territory is invoked, organized, structured, and enacted in response to stimuli, the outcomes of the work are predictably inconsistent and generally low in efficacy (Langford et al., 2006). Therefore it is important to consider issues and factors that go beyond the specific work tasks. This is an extremely important point that deserves reiteration.

Earned Value is singularly focused on the aggregation of individual tasks through the construction of the work breakdown structure. In fact, the tasks are not separable and errors in calculating Earned Value are based on such accumulation. Work tasks are intertwined with processes, inputs from other tasks, sharing of resources, and broadly applied actions that are non-optimized for individual tasks. The result for EVM is a *net* increase in the calculated value for each work task.

THIS PAGE INTENTIONALLY LEFT BLANK

Summary and Conclusions

Earned Value is fundamental to the US DoD acquisition system. The dismal results of time and cost overruns, ineffective use of constrained resources, and missed opportunities to make improvements without jeopardizing schedule and cost drove a critical evaluation of DoD acquisition (Rumsfeld, 2001). Since the cost and the success of acquisition are constrained by the initial conditions, it is prudent to develop and apply tools that can help improve both the evaluation and the processes of acquisition.

Reviewing the theoretical foundations of Gap Analysis, one of the key early-phase drivers of the acquisition process, has significant implications for understanding Earned Value. The key point of this paper can be succinctly stated: calculating Earned Value based on individual work tasks overestimates the actual amount of work performed. The formulation of Value and Worth reveal that error.

This paper discusses the Systems Engineering Value Equation (Value Engineering) and the Worth Function in the context of the ratio of triadic decomposition of requirements based on functions, performance, and quality to the investment in time and cost. Managers have expectations about products they support. These expectations necessarily need to be complemented with a rigorous analysis of gaps. The notion has general adaptability and applicability to commercial and DoD acquisition. In the commercial sense, the Gap Analysis tools can be used to better position products in competitive market space. For US DoD, more effective use of constrained resources can be applied to military development activities.

The application of Value Analysis to the general problem of managing product development is challenged by more than simply improving methodology. Methodology that is encumbered with time-consuming steps and overburdened processes does not improve Value Analysis. The forces and consequences of acquisition are better served only through streamlining of Value Analysis that is efficacious, effective, and efficient.

Future research on Value Analysis will use case study methodology to better appreciate the inadequacies of EVM.

List of References

Chairman of the Joint Chiefs of Staff. (2004, 12 March). *Joint capabilities integration and development system* (CJCSI 3170.01D). Washington, DC: Author.

Duzi, M. (2002). *Notional attitudes*. Grant GACR: 401/03/1403 – Report on the Principles of logical analysis of language expressions and intensional Logic, VSB-Technical University of Ostrava, Czech Republic.

GAO report GAO-01-2888, March 2001, *U.S. General Accounting Office Report to the Chairman and Ranking Member*).

Hafedh, M., Fayad, M., Brugali, D., Hamu, D., & Dori, D. (2002). Enterprise frameworks: Issues and research directions. *Software Practice and Experience*, *32*, 801-831. (DOI:10.1002/spe.460).

Langford, G. (2006). Reducing risk of new business start-ups using rapid systems engineering (Paper #140). In *Proceedings* of the Fourth Annual Conference on Systems Engineering Research. April 7-8, 2006), Los Angeles.

Langford, G. (2007a, March 23-24). Gap analysis (Paper # 19). In *Proceedings* of the Asia-Pacific Systems Engineering Conference, Sinagpore.

Langford, G. (2007b, March 23-24). Reducing risk in designing new products using rapid systems engineering (Paper # 18). In *Proceedings* of the Asia-Pacific Systems Engineering Conference, Singapore.

Langford, G., & Huynh, T. (2007, October). *A methodology for managing complexity*. Systems Engineering Test and Evaluation—Complex Systems and Sustainability Conference, Sydney, Australia.

Langford, G., & Lim, H. (2007, March 23-24). Predicting and assessing disruptive technologies using event space modeling (Paper # 40). In *Proceedings* of the Asia-Pacific Systems Engineering Conference, Singapore.

Langford, G.O., Franck, R., Lewis, I., Huynh, T., Osmundson, J., & Sullivan, N. (2006, December). *Gap analysis.* Contract sponsored by the US Office of Secretary of Defense, Report NPS-07-051.

Lemarechal, C. (2001, January). Computational combinatorial optimization: Optimal or probably near-optimal solutions. *Lecture Notes in Computer Science*, *2241*, 112.

Lewis, T. (2006). *Critical infrastructure protection in homeland security.* New Jersey: John Wiley & Sons.

Lowrance, W.W. (1976). *Of acceptable risk.* Menlo Park, California: William Kaufman.

Al Mannai, W.I. & Lewis, T.G.. (2007). Minimizing network risk and application to critical infrastructure protection. preprint from *Journal of Information Warfare*, *6*(2), 52-68.

Miles, L. (1972). *Techniques for value analysis and engineering*(2nd ed.). New York: McGrawHill.

Rumsfeld, D. (2001, September 10). *Remarks on DoD acquisition and logistics excellence week kickoff—Bureaucracy to battlefield*. Retrieved September 22, 2007, from http://www.defenselink.mil/speeches/2001/s20010910-secdef.html

Sproles, N. (2002).Formulating measures of effectiveness. *Journal of Systems Engineering*, *5*, 253-263.

Taguchi, G. (1990). Introduction to quality engineering*. Asian Productivity Organization,* Tokyo, Japan*.*

Taguchi, G., Chowdhury, S., & Wu, Y. (2005). *Taguchi's quality engineering handbook.* Hoboken, New Jersey: Wiley.

US Department of Defense. (16 December 2004. *Defense acquisition guidebook.* Chapter 1.3. Retrieved June 20, 2006, from http://akss.dau.mil/dag/.

2003 - 2008 Sponsored Research Topics

Acquisition Management

- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- BCA: Contractor vs. Organic Growth
- Defense Industry Consolidation
- EU-US Defense Industrial Relationships
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Managing Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21st Century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities Based Planning
- Capital Budgeting for DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-tem Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC Aegis Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to Aegis and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Eared Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

A complete listing and electronic copies of published research are available on our website: www.acquisitionresearch.org

THIS PAGE INTENTIONALLY LEFT BLANK

Initial Distribution List

1.	Defense Technical Information Center 8725 John J. Kingman Rd., STE 0944; Ft. Belvoir, VA 22060-6218	2
2.	Dudley Knox Library, Code 013 Naval Postgraduate School, Monterey, CA 93943-5100	2
3.	Research Office, Code 09 Naval Postgraduate School, Monterey, CA 93943-5138	1
4.	William R. Gates Dean, GSBPP Naval Postgraduate School, Monterey, CA 93943-5138	1
5.	Stephen Mehay Associate Dean for Research, GB Naval Postgraduate School, Monterey, CA 93943-5138	1
6.	Gary Langford Lecturer, SE Naval Postgraduate School, Monterey, CA 93943-5138	1
7.	Raymond Franck Senior Lecturer, GB Naval Postgraduate School, Monterey, CA 93943-5138	1

Copies of the Acquisition Sponsored Research Reports may be printed from our website: www.acquisitionresearch.org