

NPS-AM-03-004



ACQUISITION RESEARCH SPONSORED REPORT SERIES

Reduction of Total Ownership Cost

30 September 2003

by

Michael W. Boudreau

Brad R. Naegle

Approved for public release, distribution unlimited.

Prepared for: Naval Sea Systems Command and
Naval Postgraduate School, Monterey, California 93943



ACQUISITION RESEARCH
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

The Acquisition Chair, Graduate School of Business & Public Policy, Naval Postgraduate School supported the funding of the research presented herein. Reproduction of all or part of this report is authorized.

To request Defense Acquisition Research or to become a research sponsor, please contact:

NPS Acquisition Research Program
Attn: Rear Admiral Jim Greene, USN, (Ret)
Acquisition Chair
Graduate School of Business and Public Policy
Naval Postgraduate School
555 Dyer Road, Room 332
Monterey, CA 93943-5103

Tel: (831) 656-2092

e-mail: jbgreene@nps.navy.mil

www.nps.navy.mil/gsbpp/acqn



ACQUISITION RESEARCH
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

ABSTRACT

Total Ownership Cost (TOC) is the current initiative to manage costs over the entire life cycle of a weapon system. There are several major categories of costs that contribute to Total Ownership Cost but the principal categories are (1) R&D, (2) Production, (3) Operating and Support, and (4) Disposal. System TOC is the same as Life Cycle Cost (LCC) and has implications for Cost As an Independent Variable (CAIV), cost-performance tradeoffs, affordability, and cost to achieve required operational availability. The Program Manager (PM) is responsible for developing and managing system TOC, with input from key stakeholders, such as the sponsor and users. This paper addresses incentives that can be employed to encourage life cycle cost perspective. It examines the critical issues associated with understanding and implementing the TOC concept and provides recommendations to assist PMs to knowledgeably execute a TOC plan. Metrics necessary to ensure appropriate implementation are explored. Various methods of controlling and reducing TOC are evaluated, including communication among stakeholders, CAIV documentation, tradeoff analysis, Reliability-Centered Maintenance (RCM); Performance-Based Logistics (PBL), Commercial Operations & Support Savings Initiative (COSSI), Earned Value Management System (EVMS), Activity-Based Costing (ABC), Value Engineering, and lessons from R-TOC Pilots.



ACKNOWLEDGEMENTS

Many thanks to RADM (Ret) Jim Greene who obtained sponsor funding for acquisition research and later provided very helpful insights to make the report more useful. Special thanks to Dr. David Lamm who went out of his way to help get the process started. Both RADM Greene and Dr. Lamm provided us great encouragement to venture into unfamiliar territory and do practitioner-based research.

Our sincere thanks to Mr. Ozzie Watterson, who contributed valuable insights into Total Ownership Cost Reduction from his former position as Technical Program Manager during SEAWOLF's early acquisition milestones and development. Our thanks also go to Mr. Larry Rogers of NAVSEA, and Messrs. Duane Embree, Matt Craig, Eugene Dutkowski, and Kip Hoffer, of Crane Naval Surface Warfare Center who provided information describing the highly successful cost reduction effort on the AEGIS Crossed-Field Amplifier.

Finally, our thanks and appreciation to Ms. Karey Shaffer for her work in formatting this report to improve its organization, appearance, and readability.



ABOUT THE AUTHORS

Michael W. Boudreau, Colonel, US Army (Ret), has been a senior lecturer at the Naval Postgraduate School since 1995. While an active duty Army Officer, he was the Project Manager, Family of Medium Tactical Vehicles, 1992-1995. He commanded the Materiel Support Center, Korea, 1989-1991 and the Detroit Arsenal Tank Plant, 1982-1984. COL Boudreau is a graduate of the Industrial College of the Armed Forces; Defense Systems Management College; Army Command and General Staff College; Long Armour-Infantry Course, Royal Armoured Corps Centre, United Kingdom; and Ordnance Officer Basic and Advanced courses. He holds a Bachelor of Mechanical Engineering degree and Master of Business degree from Santa Clara University, California.

Brad R. Naegle, Lieutenant Colonel, US Army Retired, is a Lecturer and Academic Associate for Program Management Curricula at the Naval Post Graduate School, Monterey California. While on active duty, LTC (ret) Naegle was assigned as the Product Manager for the 2 ½ Ton Extended Service Program (ESP) from 1994 to 1996 and the Deputy Project Manager for Light Tactical Vehicles from 1996 to 1997. He was the 7th Infantry Division (Light) Division Materiel Officer from 1990 to 1993 and the 34th Support Group Director of Security, Plans and Operations from 1986 to 1987. Prior to that, LTC (ret) Naegle held positions in Test and Evaluations and Logistics fields. He earned a Master's Degree in Systems Acquisition Management (with Distinction) from the Naval Postgraduate School and an undergraduate degree from Weber State University in Economics. He is a graduate of the Command and General Staff College, Combined Arms and Services Staff School, and Ordnance Corps Advanced and Basic Courses.



**ACQUISITION RESEARCH
SPONSORED REPORT SERIES**

Reduction of Total Ownership Cost

30 September 2003

by

**Michael W. Boudreau
Brad R. Naegle**

Disclaimer: The views represented in this report are those of the author and do not reflect the official policy position of the Navy, the Department of Defense, or the Federal Government.



**ACQUISITION RESEARCH
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL**

TABLE OF CONTENTS

CHAPTER I: INTRODUCTION	1
A. Definitions	1
B. Scope of this Study	2
C. TOC Processes: CAIV and R-TOC.....	2
D. TOC Obstacles	4
E. Management of TOC	8
CHAPTER II: METHODOLOGY.....	9
CHAPTER III: LITERATURE REVIEW	10
CHAPTER IV: DATA AND ANALYSIS.....	12
A. Overview	12
B. Leadership, Motivation, and Stakeholder Involvement	12
C. Documents	18
D. Tradeoff Analysis through AoAs, CPIPTs, and other IPTs.....	22
E. Metrics	23
F. Databases and Data Collection.....	33
G. Activities and Tools that Support CAIV and R-TOC	35
H. Risk Management.....	43
I. Why we may have Difficulty Seeing and Proving TOC Reduction.....	46
J. Activity During the Various Phases	48
CHAPTER V: CONSIDERATIONS OF TOTAL OWNERSHIP COST RELATED TO SPECIFIC PHASES	49
Part 1: Concept Refinement and Technology Development Phases	50
A. Overview of the Two Phases	50
B. Leadership, Motivation, and Stakeholder Involvement	51
C. Documents	54
D. Tradeoff Analysis through AoAs, CPIPTs and other IPTs.....	55
E. Metrics	57
F. Database & Data Collection	59
G. Activities and Tools that Support CAIV and R-TOC	59
H. Risk Management.....	60
I. Summary.....	61



Part 2: System Development and Demonstration	63
A. Overview of the Phase.....	63
B. Leadership Focus Motivation and Stakeholder Involvement.....	63
C. Documents	66
D. Tradeoff Analysis through CPIPTs and other IPTs	67
E. Metrics	68
F. Database and Data Collection	69
G. Activities and Tools that Support CAIV and R-TOC	70
H. Risk Management.....	71
Part 3: Risks Production Phase and Deployment to the Field or Fleet.....	72
A. Overview of the Phase.....	72
B. Leadership Focus Motivation and Stakeholder Involvement.....	73
C. Documents	75
D. Tradeoff Analysis through CPIPTs and other IPTs	75
E. Metrics	75
F. Database and Data Collection	76
G. Activities and Tools that Support CAIV and R-TOC	77
H. Risk Management.....	79
Part 4: Sustainment Phase.....	80
A. Overview of the Phase.....	80
B. Leadership Focus Motivation and Stakeholder Involvement.....	80
C. Documents	80
D. Tradeoff Analysis through Teams.....	81
E. Metrics	81
F. Database and Data Collection	81
G. Activities and Tools that Support CAIV and R-TOC	82
H. Risk Management.....	82
CHAPTER VI: FINDINGS AND CONCLUSIONS.....	83
APPENDICES.....	87
ACRONYM LIST	87
CROSSWALK BETWEEN CJCSI 3170.01C AND CJCSI 3170.01B	92
DODI 5000.2 SPECIFIC GUIDANCE RELATED TO OWNERSHIP COST .	94
REFERENCE LIST	95



CHAPTER I: INTRODUCTION

A. Definitions

Total Ownership Cost (TOC) has two definitions; the first is very broad, looking from the DoD or service perspective.

DoD TOC is the sum of all financial resources necessary to organize, equip, train, sustain, and operate military forces sufficient to meet national goals in compliance with all laws, all policies applicable to DoD, all standards in effect for readiness, safety, and quality of life, and all other official measures of performance for DoD and its Components. DoD TOC is comprised of costs to research, develop, acquire, own, operate, and dispose of weapon and support systems, other equipment and real property, the costs to recruit, train, retain, separate and otherwise support military and civilian personnel, and all other costs of business operations of the DoD.¹

Much of the activity described in this definition is beyond the capability of a weapon system Program Manager to influence. However, it is deliberately broad in scope to include the many different possibilities for various stakeholders to reduce ownership cost.

The second definition is deliberately written from the vantage point of the program manager of the warfighting system.

Defense Systems TOC is defined as Life Cycle Cost (LCC). LCC (per DoD 5000.4M) includes not only acquisition program direct costs, but also the indirect costs attributable to the acquisition program (i.e., costs that would not occur if the program did not exist). For example, indirect costs would include the infrastructure that plans, manages, and executes a program over its full life and common support items and systems. The

¹ Gansler, Jacques S. Memorandum: Definition of Total Ownership Cost (TOC), Life Cycle Cost, and the Responsibilities of Program Managers. Office of the Secretary of Defense. 13 November 1998.



responsibility of program managers in support of reducing DoD TOC is the continuous reduction of LCC for their systems.²

As Dr. Gansler said in his 1998 memorandum from which the above definitions were extracted, the program manager's job, in trying to reduce TOC, is a very difficult one and that Program Managers should seek help wherever they can to reduce ownership costs.

B. Scope of this Study

This study will examine TOC from the perspective of the program manager of the warfighting system, but occasionally will extend that perspective to suggest the possibility of affecting TOC within the broader definition.

C. TOC Processes: CAIV and R-TOC

Pursuit of Total Ownership Cost reduction at the level of the warfighting system may be separated into two major approaches that are connected, end-to-end, along a life cycle time line. During the developmental phases, the effort or process is called Cost As an Independent Variable, (CAIV). For systems in the field or fleet, the process or goal becomes Reduction of Total Ownership Cost (R-TOC). The chart at figure 1 is a typical depiction of the CAIV/R-TOC relationship.

² Ibid.



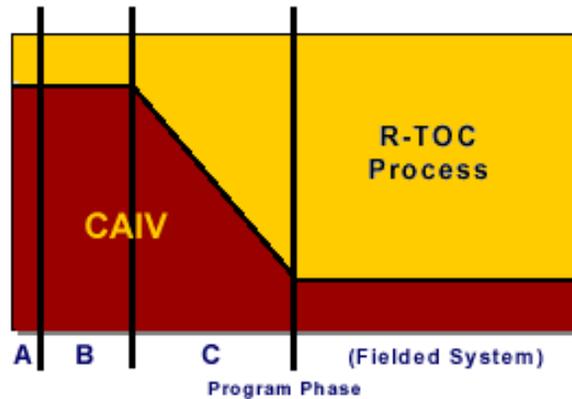


Figure 1. CAIV / R-TOC Relationship³

The first approach, Cost As an Independent Variable (CAIV) addresses Total Ownership Cost during the warfighting system's developmental phases, beginning with the Concept Refinement phase. The focus of CAIV is to establish cost targets based on affordability and requirements and then to manage to those targets, thereby controlling TOC. CAIV includes consideration of costs for development, production, operations and support, and disposal. An example of the CAIV process would be to set specific cost and reliability targets for each subsystem or component of a weapon system in development, such that the warfighting system will be able to achieve the required operational availability (A_0) at the specified cost.

Employing the CAIV concept early in the developmental process offers, potentially, the greatest opportunity for TOC reduction at the lowest possible investment cost. As an example, the TOC impacts of using two different power plants presents an opportunity to use the CAIV evaluation technique to estimate the TOC impact and make a best-value decision. For illustrative purposes, consider a standard internal combustion engine at a cost of \$7,500 versus a hybrid-electric power plant costing \$19,000. The impact to the acquisition cost is evident, but excludes the cost savings

³ Kaye, Michael A., Mark S. Sobota, David R. Graham, and Allen L. Gotwald. "Cost As An Independent Variable: Principles and Implementation." *Acquisition Review Quarterly*. Fall 2000.



associated with fuel consumption over the life of the system. If the system's operational mode indicates an average usage of 15,000 miles per year and an Economic Useful Life (EUL) of 20 years, the total miles expected is 300,000. If the standard engine in our comparison is estimated at 10 miles per gallon and the hybrid engine is estimated at 25 miles per gallon, the estimated fuel saved by the hybrid-powered system would be 18,000 gallons. At a current estimate of \$1.25 per gallon, the operating and support impact is \$22,500 per system (TOC improvement: \$11,000 less expensive than the standard engine) and there are other reductions in fuel supply assets and attendant personnel that apply.

The second approach to TOC is the Reduction of Total Ownership Cost (R-TOC) and focuses on the reduction of average procurement unit cost (APUC) and weapon system sustainment cost, that is, operating & support (O&S) costs. R-TOC is employed as the warfighting system is produced and placed in service. Examples of R-TOC would be a value engineering change proposal (VECP) to reduce the cost of manufacturing a component by improving the process yield (the percentage the manufactured item that are defect-free) or a VECP to reduce the operating and support cost by improving the reliability of an expensive subsystem or component. Often there are the secondary benefits of enhanced performance (i.e., improved reliability and operational availability), but the forcing function is the reduction of operating and support costs, the largest constituent of TOC.

D. TOC Obstacles

Someone who is not involved with program management might wonder what is especially difficult about containing and controlling TOC. In truth, there are many difficulties. Below, is a description of some of the obstacles that get in the way of controlling or reducing Total Ownership Cost. All of these are well known but are entrenched and difficult to overcome.



Competing interests of users, developers, prime contractors, subcontractors, Office of the Secretary of Defense (OSD), service headquarters, maintainers, buying commands, and Congress may negatively impact Total Ownership Cost. The “user” who establishes requirements for a new system may be transfixed by the technical performance and may not clearly establish requirements for ownership cost to achieve specified system availability. Materiel developers may be too focused on acquisition cost and schedule (a typical complaint from the user community) and ignore future logistics support issues. Prime contractors may concentrate on production costs, with less regard for system sustainment costs, particularly if their contract directs them toward reduction in production costs or they sense that their customer is not interested in sustainment issues. OSD and Service headquarters may encourage poor TOC decisions through funding instability and failure to demand life-cycle affordable solutions. Maintainers may contribute to poor R-TOC by failing to speak out loudly on lessons-learned from previous systems. Buying commands may contribute to increased ownership costs by failing to look aggressively for cost drivers that need to be redesigned for lower cost of operation and improved reliability. The Congress may restrict R-TOC by constraining the choices of cost-effective sustainment approaches.

Balancing Total Ownership Cost Goals That Are Conflicting - Successful program management includes the ability to achieve balance within a program. Indeed, program managers are directed by DoDD 5000.1 to manage their programs in a balanced way.⁴ Facets and perspectives that need to be balanced are manifold. Four elements of TOC that require balancing are development costs, procurement costs, operating and support costs, and disposal costs. Development costs, the expenditure of resources during system development, may pay off in terms of reduced production and / or sustainment costs; producibility studies may save significant manufacturing costs, and reliability testing early in a program may avoid sustainment costs over the service life of the weapon system. Occasionally, procurement or production cost constraints may

⁴ Department of Defense. “The Defense Acquisition System.” DoD Directive 5000.1. May 12, 2003.



conflict with sustainment cost targets; for example, heavy pressure to reduce production costs may lead to the selection of components that are inexpensive but not reliable. Such choices would reduce production cost but increase sustainment costs and very possibly result in an increase of Total Ownership Cost. When such cost goals conflict, a reasonable metric for maintaining balance would appear to be minimization of Total Ownership Cost, i.e., life-cycle cost, but often, TOC is sub-optimized due to these competing pressures.

Balancing Cost, Schedule, System Performance, Sustainment, Quality, and Risk-

In the same way that ownership cost goals must be balanced and harmonized, system solutions must be found that balance Total Ownership Costs against procurement cost goals, program schedule goals, system technical performance, equipment quality, ease of maintenance, and availability.

DoD is relying on sophisticated, software-intensive systems to improve survivability and lethality, but software is susceptible to high TOC. Software is difficult to accurately estimate, sensitive to changing requirements, and its complexity, interface requirements, and relative ease in adding capability tend to make it maintenance-intensive.⁵

During each life cycle phase, the approach to TOC reduction and the methodology may change somewhat, while ownership cost goals and targets become more refined. For example, tradeoff processes used in Concept Refinement may be beneficial during that phase but be inadequate for the System Design and Demonstration (SDD) phase without the inclusion of specific contractor incentives.

Materiel Developer Instability - Key members of the materiel developer team change over time. For example, the program manager during System Integration would be unlikely to remain in that position through the Production and Fielding phase. As key

⁵ Humphrey, Watts S. *Managing the Software Process*. Addison-Wesley Publishing Company. 1990.



personnel — program managers, chief engineers, senior logisticians, business-financial managers — change, program emphasis shifts, at least subtly. These personnel changes, which are a “fact of life,” may reflect in program missteps, including missed TOC targets.

Funding Instability - Resources tend to be unstable and subject to unanticipated, unexpected changes. Funding instability is also a “fact of life” in Government acquisition programs. Each time that funding is cut from a program, decision-makers adjust the program by postponing or eliminating some activity or system attribute. Decisions are made that will keep the program viable, and often the choice is to omit a system feature or a near-term activity that won’t reflect negatively on TOC until later. Easing back on O&S cost targets is a tempting sacrifice when program funding gets cut. For example, reliability-centered maintenance studies cut to reduce cost during SDD would not affect the program noticeably until later on, when operational systems are in the fleet; the associated effect to Total Ownership Cost might be substantial. Eliminating onboard diagnostics / prognostics would certainly help meet funding cuts during the procurement phase, but would likely be extremely costly in terms of maintainer training, diagnostics time, erroneous fault isolation, errant parts ordering, and associated maintenance man-hours, for the life of the system.

Sticker Shock - The fact that a system’s TOC “price tag” is extremely high when compared to its contract unit price may tend to keep the stakeholders from discussing TOC in any open forum, fearing that “sticker shock” might cause an adverse reaction from a decision-maker or politically powerful individual accustomed to seeing much lower cost figures. As an example, consider a system with an average procurement unit cost (APUC) of \$1.5 million and a program acquisition cost of \$2 million.⁶ Typically,

⁶ APUC is the total procurement cost divided by the total procurement quantity. Program acquisition cost includes APUC, facilities, RDT&E, and other procurement costs. These terms are discussed in more detail, beginning on page 25.



program acquisition cost would represent only about 28 percent of each individual system's TOC, with the remaining 72% representing O&S and disposal costs of about \$5 million: for a TOC of \$7 million per each weapon system. With an acquisition objective of 2,000 systems, the total procurement cost would be \$3 billion, with a Total Ownership Cost estimate of approximately \$14 billion. If unfamiliar with TOC estimates and without a readily available basis for comparison, a decision-maker might mistakenly conclude that the system would be unaffordable and cancel the program. Concern for such a scenario may create an impediment to widespread use of TOC goals.

E. Management of TOC

There is a wide body of knowledge related to the control of TOC. There have been “flagship programs” and “pilot programs” designated to lead the way to the Total Ownership Cost reduction and stave off the “death spiral.”⁷ Every program manager tries different approaches to reduce costs. Additionally, commercial best practices have been recognized and suggested for use within the Department of Defense.⁸

The purpose of this working paper is to gather together the various approaches for controlling and reducing Total Ownership Cost, to describe tools and methods to assist PMs in addressing TOC more effectively, and to identify the various approaches appropriate for each life cycle phase.

⁷ Gansler, Jacques S. “The Revolution in Business Affairs—The Need to Act Now.” *Program Manager*. September-October 1998. Reprinted from a speech given by Dr. Gansler to the Association of the United States Army, Falls Church, VA. September 2, 1998.

⁸ U.S. General Accounting Office. “Best Practices: Setting Requirements Differently Could Reduce Weapon Systems’ Total Ownership Costs.” Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-03-57. February 2003.



CHAPTER II: METHODOLOGY

Library Research

This technical paper is a library research effort. Data is collected through a literature review and is arranged and analyzed as follows.

- The practices and approaches are compiled in a logical order, in an array that is user-friendly to PMs, systems command personnel, users, and contractors. User personnel, acquisition practitioners, and other stakeholders should be able to use this paper to suggest possible approaches to control TOC, whatever the life-cycle stage of a warfighting system.
- Mechanisms for use in managing TOC are described, analyzed, and synthesized.
- Flaws in our acquisition system that may present or permit obstacles to effective control and management of TOC are highlighted.
- Conclusions are drawn regarding the control of TOC within the Department of Defense.



CHAPTER III: LITERATURE REVIEW

Regulatory Guidance, Including DOD and the Services

There is a body of mandatory and discretionary guidance published by the Office of the Secretary of Defense and by each of the Services. Much of this material is available on the Legacy Defense Acquisition Deskbook website, <http://legacydeskbook.dau.mil/>; some of these materials may be out-of-date, because the Deskbook is no longer being maintained. Nevertheless, the site provides a Calendar Year 2000 view of the guidance on CAIV and R-TOC and includes some best practices. The Defense Acquisition University (DAU) operates the AT&L Knowledge Sharing System, <http://deskbook.dau.mil/jsp/default.jsp>, for the Under Secretary of Defense (Acquisition, Technology and Logistics), USD(AT&L). The site provides current web-based materials on TOC and also provides a portal to the Legacy Defense Acquisition Deskbook.

Published Materials: Books, Journals, Periodicals, Government Documents, Reports, Best Practices, Theses, Studies, Speeches, and Briefs

Much has been written on the subjects of Life-Cycle Cost (LCC), Total Ownership Cost, Cost As an Independent Variable (CAIV), Reduction of Total Ownership Cost (R-TOC), procurement unit costs, and operating and support costs (O&S). There are numerous reports on Flagship Programs and Pilot Programs that are, or were, experimenting in cost reduction methodologies. Students at the Naval Postgraduate School have accomplished considerable research and published numerous Master's theses related to management of Total Ownership Cost. The General Accounting Office has published significant work comparing commercial best practices to DoD acquisition.

The Defense Acquisition University has developed educational materials on Total Ownership Cost (TOC) and Cost As an Independent Variable (CAIV) best practices



http://pmcop.dau.mil/simplify/ev.php?URL_ID=1205&URL_DO=DO_TOPIC&URL_SECTION=201&reload=1034872330).

This site may also be reached from the AT&L Knowledge Sharing System website, by selecting “Total Ownership Cost CoP,” identified under “Business Practice” located in the “Communities and Sharing” box.

The Institute for Defense Analysis (IDA) maintains an informative website, “Reduction of Total Ownership Costs,” that has collected the lessons-learned and best practices garnered from the R-TOC Pilot programs (<http://rtoc.ida.org/rtoc/rtoc.html>).



CHAPTER IV: DATA AND ANALYSIS

A. Overview

There are numerous possible ways to array and analyze the collection of materials on the subject of Total Ownership Cost. This report establishes a framework for the data and analysis and maintains it during discussion of TOC for each of the life cycle phases, discussed in Chapter V. The arrangement of material in this chapter is congruent with the discussion of each acquisition phase, presented in Chapter V; the intent is that the reader be able easily to go back-and-forth between the general discussion and the discussion specific to a life cycle phase. The basic template used in this paper is depicted as follows:

- Leadership, Motivation, and Stakeholder Involvement
- Documents
- Tradeoff Analysis through AoAs, CPIPTs, and Other IPTs
- Metrics
- Data Collection and Databases
- Activities and Tools that Support CAIV and R-TOC
- Risk Management

B. Leadership, Motivation, and Stakeholder Involvement

Leadership - DoD leadership sets the policies and establishes the environment and culture wherein the workforce operates. Control of costs has long been the policy of the Department of Defense; within the acquisition community, program offices have worked hard to control the cost of programs. However, in the past, the overriding focus toward acquisition of new programs has been on system capability or performance, not on the cost. In a severely resource constrained environment, such as the one we are currently operating in and anticipate for the foreseeable future, the focus on minimizing



TOC has never been greater and, indeed, R-TOC and CAIV are manifestations of the attempt to address these resource constraints.

Senior leaders within OSD and the Services have influence over the developmental process and can bring attention to Total Ownership Cost from their collective positions of influence. A recent GAO report criticizes DoD because there are too many different organizational participants.⁹ This criticism could be attenuated if the leadership would speak with one voice on the requirement for reduction in Total Ownership Cost.

Those who establish weapon system requirements, together with those who acquire, operate, and sustain those systems, recognize the need for TOC reduction and need to synchronize their efforts to that end. Part of that combined effort is to speak with one voice to articulate the affordability limits and then “lead from the front” to stay within those limits. When the leadership embarks on the process to obtain a new system capability, the process needs always to include the establishment of affordability constraints; those constraints are stated as Total Ownership Cost goals, and the leadership needs to insist that those goals and the associated follow-on cost targets be established and then adhered to.

Leadership determination and follow-up is demonstrated by asking the cost and readiness questions. After establishing O&S cost targets that are needed to achieve a specific readiness or reliability level, the Service and OSD leadership must be resolute in making sponsors and materiel developers answerable for achieving the stated cost goals or targets. The program management offices and user representatives are adept at reading and following the leadership focus and guidance. If the leadership is interested in TOC, the workforce will be interested.

⁹ U.S. General Accounting Office. “Best Practices: Setting Requirements Differently Could Reduce Weapon Systems’ Total Ownership Costs.” Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-03-57. February 2003.



The leadership in sustainment organizations has a major part to play in reduction of TOC. Determination in controlling the size of supporting organizations, consistent with the work to be accomplished, is a continual leadership responsibility, which is necessary to control the indirect costs of weapon system sustainment. Even though it is gut-wrenching activity, the leadership of sustaining organizations must vigorously control the size of workforce, consistent with the size of the workload. Prime Vendor (PV) support or other venues that shift the workload for improved efficiency may leave large pockets of employees not fully employed. For example, software-intensive systems are rapidly replacing hardware systems and software is typically supported through a Contractor Logistics Support arrangement. Resultant overstaffing of supporting organizations must be recognized as a drain on scarce resources, and as difficult as it must certainly be, leaders must act to correct the condition. These actions are beyond the control of program offices, yet they influence a weapon system's TOC.

Other Motivation - Besides the encouragement of DoD senior leaders to bring attention to TOC, there are other incentives that are needed to motivate different stakeholders to reduce TOC. The DoD acquisition community has used an array of incentives for many years. The basic approach is to try to align personal and organizational objectives, as described below.

Materiel Developer - Materiel developer practitioners need to be personally and organizationally aligned with the goals of the DoD and the Service; typically, this is accomplished by synchronizing organizational and personal goals and objectives with those of the Department and the Service. An example of this is Management By Objectives (MBO), in which organizational goals are pushed down through succeeding layers, all the way to the performance objectives of the individual. A manifestation of MBO is the Acquisition Program Baseline (APB), wherein the Service objectives are established specifically for a program. Achieving or failing to achieve APB goals can impact the individual performance appraisal of members of the program office, including the program manager. There is also a need to extend MBO to participants who are



assigned to supporting organizations; MBO can effectively connect the goals of separate organizations, but only if there is leadership agreement on common goals.

Government Employees - In the instance of acquisition practitioners who are Government civilians, monetary awards may be given for achievement of particular warfighting system performance. For military officers, military awards may be given for achieving or surpassing the required level of system performance within the established cost target. Beyond awards, successful performance in program offices often leads to promotion in rank and assignment to jobs of higher responsibility. Promotion and career enhancing assignments can be powerful motivators.

A significant motivator for the program office is being able to recoup the savings and use those funds where needed elsewhere within the program. This has been an area of discussion during the R-TOC Pilot quarterly meetings, but as late as April 2003, the formal process for retention of savings remains undefined.¹⁰ As the funding saved is returned to the US Treasury, the program rarely sees the benefit of its hard work and this serves as a disincentive for R-TOC initiatives.

It has often been said that PMs and responsible personnel within PM offices should be rewarded, based on actual life-cycle performance and cost. However, life cycle cost plays out over many years and, unfortunately, no practical scheme of metrics and payments (or collections) has been instituted to date to reward or penalize program managers or key staff. In lieu of motivation for LCC effective systems, other, more measurable incentives tend to motivate PMs and their key personnel. For instance, all PM offices are incentivized by the clearly stated program schedule and procurement cost goals outlined in the APB. These APB goals may become more important to the PM than TOC goals that will not be realized until long after the PM has departed for a new assignment or retired. If PMs and their key personnel sacrifice TOC-improving

¹⁰ Sullivan, Robert. "Precision Fires Rocket and Missile System Pilot Update (FOUO)." Briefing to 14th R-TOC Quarterly Pilot Program Forum. 29-30 April 2003.



actions and features to procure more systems, the effect is the Service procures more systems that will be *more expensive to operate and maintain*, while rewarding the PM for that same action.

Contractors - Contractor organizations may be incentivized through their Government contracts in numerous ways that might reduce TOC. One of the expected approaches might be to offer monetary incentive to the contractor in response for his control of life-cycle costs. If shared procurement cost savings are part of the contractor incentive package and TOC related features and functions are not incentivized, there is a strong motivation to reduce the cost of procurement; this choice would occur at the expense of desirable, but not required, TOC attributes, such as high reliability, diagnostic function, design for maintainability, or other valued attribute. Another way that contractors may be motivated is through share arrangements, such as Value Engineering or the sharing of technology. Contractors may also be incentivized through use of award fees, which are a typical way of rewarding innovation where direct, objective measurement of the desired result is not feasible. Occasionally, incentive arrangements are set up in such a way that part of the monetary incentive flows through the company directly to the responsible employees or subcontractors / vendors. Finally, an enormously strong contractor incentive is competition for future work; no doubt this motivator might also influence company employees and subcontractors / vendors as well.

Weapon System Sponsor and Users - The sponsor and user are important stakeholders with the potential to influence Total Ownership Cost. These participants can be agents for affordable operating and support cost by specifying TOC-related thresholds and goals in the Initial Concept Document (ICD) and subsequent requirements documents. If motivated to “lobby” for manageable O&S costs, they could make a substantial difference. Their participation depends on being motivated by their leadership and having specific cost and readiness goals that they are willing to “buy into.”



Sustaining Organizations - “Wholesale” and “retail” support organizations should be invited to participate in the developmental process, because they will eventually become responsible for sustainment of the warfighting system. Representatives of the various sustaining organizations, together with the Program Manager, can organize responsive, competitive, and innovative support systems capable of efficiently and effectively supporting the warfighting system. The sustaining organizations may not be motivated to establish affordable sustainment that meets readiness requirements, because most are funded through the volume of sales or transactions processed by their organizations and improving efficiency or subsystem reliability may negatively impact their flow of funding, workforce level, or capacity used. Their expected bias is to be reluctant to try innovative approaches that would take business away from their existing organizations. However, effective sustainment must take precedence over other organizational considerations if scarce defense dollars are to be used to the maximum value. The second step, the decisions on how to achieve that sustainment most affordably then should be addressed through analysis of competitive alternatives and basing the decision on best value, i.e., choosing the best combination of readiness within target O&S cost.

Buy-in from the various stakeholders is an important ingredient for success; failure to achieve “buy-in” will likely result in entrenched organizational resistance to change. Difficulty in achieving “buy-in” is an R-TOC Pilot lesson learned.¹¹ The stakeholders who participate in cost reduction initiatives are more apt to support unpopular downstream actions and work toward their success. Strong leadership support over a long period, can contribute to the buy-in process, but participant buy-in stems from involvement in the process itself. A useful forum for stakeholder participation is the Cost-Performance IPT, or CPIPT, discussed below.

¹¹ Sullivan, Robert. “Precision Fires Rocket and Missile System Pilot Update (FOUO).” Briefing to 14th R-TOC Quarterly Pilot Program Forum. 29-30 April 2003.



C. Documents

Documents that are most important to Total Ownership Cost are the capability documents prepared by the sponsor, the program manager's acquisition strategy, the Acquisition Program Baseline, and the contracting documents, which task the contractor for certain deliverables. Each of these is relevant to TOC reduction because these are documents that describe rationale: that is, what the sponsor thinks is important (the capabilities documents), which are translated into the program manager's strategy and what he agrees to accomplish (the acquisition strategy and acquisition program baseline), and what the contractor is told needs to be done (the RFP and contract). These will be amplified below and then further addressed as they pertain to each life cycle phase.

Capability Documents - Key performance parameters (KPP) are identified within the weapon system's capabilities documents. KPP are those minimum attributes or characteristics considered most essential for an effective military capability. They may be validated by the Joint Requirements Oversight Council, the Functional Capabilities Board, and the DoD Component. Key performance parameters that appear in the Capabilities Development Document (CDD) or Capability Production Document (CPD) are included verbatim in the acquisition program baseline (APB).

There is a choice here. If Cost As an Independent Variable (CAIV) is critical within DoD, then a forceful way to express its importance is to designate Total Ownership Cost limits as a KPP. The GAO has recommended this as a way to mirror commercial best practice.¹² Yet OSD does not require making LCC, or TOC, a KPP. To be more precise, CJCSI 3170.01C, by their definition of KPP, appears to allow LCC to

¹² U.S. General Accounting Office. "Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs." Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-03-57. February 2003.



be a KPP, but does not require it.¹³ There will be additional discussion of capabilities documents in Part 1 of Chapter V, as these documents pertain to the Concept Refinement and Technology Development phases.

The Joint Strike Fighter (JSF) provides an example of KPPs that address Total Ownership Cost. JSF has six KPPs; three of the six address supportability / affordability.¹⁴ (1) Mission reliability directly impacts O&S cost for parts replacement and the associated expenditure of maintenance man-hours. (2) Logistics footprint influences both program acquisition cost and O&S cost; the smaller the footprint, the smaller the acquisition cost and the less expensive to transport and maintain. (3) Sortie generation rate depends on maintenance man-hours per operating hour and heavily influences design-for-maintainability. These three KPPs have brought about the use of autonomics, which includes on-board diagnostics / prognostics and improves the cost effectiveness of maintenance. The KPPs all impact affordability and could be at least partially re-defined in terms of Average Procurement Unit Cost (APUC) and Operating and Support (O&S) costs.

Acquisition Program Baseline (APB) - An Acquisition Program Baseline is required first to be prepared during Technology Development to support a Milestone B decision and is updated throughout the acquisition phases. DoDI 5000.2 guidance pertaining to the APB is as follows: "Each program or increment shall also have an Acquisition Program Baseline establishing program goals—thresholds and objectives—for the minimum number of cost, schedule, and performance parameters that describe the program over its life cycle." The cost parameters that describe the program over its life are its life-cycle costs (LCC), otherwise referred to as TOC. Placing TOC in the

¹³ Office of the Joint Chiefs of Staff. "Joint Capabilities Integration and Development System." Chairman of the Joint Chiefs of Staff Instruction 3170.01C. 24 June 2003. page A-10 and A-11

¹⁴ Hudson, Jack (Major General, USAF). Briefing: "JSF Program Update." Program Executive Officer, Joint Strike Fighter. October 2003.



Acquisition Program Baseline effectively makes TOC part of the “contract” between the program manager, his Service, and OSD.

Acquisition Strategy - The acquisition strategy describes how the program will go about acquiring its new weapon system. More specifically, the acquisition strategy offers an opportunity to emphasize the importance of TOC and how it will be woven into the plans and processes of the acquisition, such as contracting, test and evaluation, logistics support, production, risk management, funding / affordability, and strategy for tradeoff analysis. The acquisition strategy is required at “Program Initiation for Ships” (as early as Milestone A), and for all weapon systems at Milestones B, C, and the Full Rate Production DR [Decision Review].”¹⁵

Request For Proposal (RFP) - The RFP, which includes the Statement of Work, Instructions to Offerors, and Selection Criteria, offers written insights to the contractor specifying those areas of a future contract that the Government considers very important. These particular parts of the RFP do not focus on the product itself, but rather, how to perform the contract satisfactorily. Through these parts of the RFP, DoD can reinforce the importance of facets that impact TOC, such as the need for producibility studies, O&S cost analysis, reliability-centered maintenance analysis, innovative sustainment support planning, or aggressive value engineering.

Supportability Planning Documents - Numerous supportability planning documents help define and shape a system’s TOC attributes, and a few key documents will be discussed here. Beginning with an in-depth Supportability Analysis (SA), these documents play a key role in integrating the supportability concepts into systems development and are most effective when used in conjunction with the Systems Engineering Process. The SA is critical within the evolutionary development concept as the numerous system configurations likely to result will challenge DoD in keeping the

¹⁵ Department of Defense. “Operation of the Defense Acquisition System.” DoD Instruction 5000.2. May 12, 2003.



TOC low in view of the need for user / maintainer training on all configurations, software updates, supply stockage on differing models, etc.

The Post-Production Support Plan helps manage the system supportability through the critical time period between the end of production and system disposal. While in production, there is generally no lack of engineering expertise or vendors for critical parts supporting the system. After production, engineering expertise and vendors may rapidly move to other projects and products, creating an ever-expanding situation DoD calls Diminishing Manufacturing Sources and Material Shortages (DMSMS). A properly designed Post-Production Support Plan identifies potential DMSMS situations and attempts to create a supportability strategy that effectively addresses DMSMS concerns over the system life cycle. As software is likely to be updated much more often than hardware components and requires software engineers as “maintainers,” managing the ongoing engineering support is particularly critical.

Without extensive planning, software-intensive systems are susceptible to significant Operating and Support costs due to their inherent complexity (requiring patches, new version releases, and other “fixes”), integration requirements, and their relative ease in upgrading capabilities.¹⁶ Numerous documents help manage the software supportability including the SA, the Post Deployment Software Support Concept Document (PDSS CD), Computer Resources Life Cycle Management Plan (CRLCMP), and the Computer Resources Integrated Support Document (CRISD).¹⁷

¹⁶ Humphrey, Watts S. *Managing the Software Process*. Addison-Wesley Publishing Company. 1990.

¹⁷ Department of the Air Force. Software Technology Support Center. “Guidelines for Successful Acquisition and Management of Software-Intensive Systems: Weapon Systems, Command and Control Systems, Management Information Systems.” Version 3.0. May 2000.



D. Tradeoff Analysis Through AoAs, CPIPTs, and other IPTs

Weapon system programs need to be managed in accordance with both cost and performance targets; CPIPTs are a commonly recommended structure to balance cost and performance variables.¹⁸

Technical Performance aspects that are addressed by CPIPTs encompass an array of possibilities, to include specific, measurable logistics attributes, such as operational availability (A_0) (i.e., the probability that a system or equipment, when used under stated conditions in an actual operational environment, will operate satisfactorily when called upon),¹⁹ reliability (mean time between failure, MTBF), and average cost of operation (average dollars per mile or some other measure indicative of cost of usage). Maintenance hours per operating hour is a meaningful performance metric. Readiness rates (i.e., percentage of the time that a system is fully mission capable (FMC), mission capable (MC), and non-mission capable (NMC)) are suitable performance metrics for use in cost-performance analysis.²⁰ The various choices (tradeoffs) that must be made during the systems engineering process depend on the inclusion of cost analysts and functional experts, including logisticians. CPIPTs have the potential to be a potent force in controlling costs while achieving the required level of performance: but only if the team is properly constituted. At the subsystem or component levels deep within the work breakdown structure, most cost-performance decisions are the domain of the subordinate IPT that probably does not have the luxury of a full-time cost analyst or logistician. Nevertheless, the decisions must include O&S cost analysis and logistics perspective, albeit obtained on a part time basis and probably accomplished by contractor personnel.

¹⁸ Kaminski, Paul. Memorandum: "Reducing Life Cycle Costs for New and Fielded Systems (with CAIV Working Group Report attached). Office of the Secretary of Defense. December 4, 1995.

¹⁹ Blanchard, Benjamin S. *Logistics Engineering and Management*, 5th ed. Prentice Hall. 1998.

²⁰ Gansler, Jacques S. "Moving Toward a Market-Based Government: The Changing Role of Government as the Provider." IBM Endowment for The Business of Government. University of Maryland. 2003.



Tradeoff analysis is performed to balance technical performance, cost, and schedule, within acceptable risk levels. Tradeoff analysis is an essential function within the System Balance and Control functions that are performed as part of the Systems Engineering Process; tradeoff analyses are implemented through Integrated Product Teams (IPTs). Successful tradeoff analysis requires that major stakeholders participate in the tradeoff process. CPIPTs are central to tradeoff analyses that address cost versus technical performance and are discussed above. A Cost-Benefit Analysis, which is similar in that it compares cost and performance, supports the preparation of the Initial Capabilities Document (ICD), leading up to the Concept Decision. The tradeoff referred to as analysis of alternatives (AoA) occurs in the pre-acquisition phase to compare the estimated costs, suitability, effectiveness, advantages, and disadvantages of the various alternative systems. This is germane to Concept Refinement and Technology Development phases and is further discussed in Appendix 1 to this working paper.

Risk management is discussed elsewhere in this paper. However, it is an important aspect of tradeoff analysis, because perceived levels of risk should shape choices. If the potential consequences of decisions are recognized at the time that decisions are made, not only might the identification of risk influence the tradeoff choice, but it might also initiate risk management activity appropriate to the circumstances.

E. Metrics

Program offices establish and track numerous metrics throughout the developmental process. Many of these metrics eventually transition into the acquisition Program Baseline (APB), which forms a “contract” between the program manager and his leadership in his Service and OSD. APB metrics include measures of technical performance, cost, and schedule. Some of metrics have special significance. For example, certain cost and schedule metrics are of such importance that major deviations (breaches) in performance must be reported to the Congress. Another classification of metrics that takes on special significance is key performance



parameters (KPPs), mentioned briefly in the leadership section, above. KPPs are specified by the sponsor in capability documents and are, by definition, of such significance that the failure to meet a KPP requires an assessment of military utility and may possibly cause an examination of whether the program should be terminated. When costs are designated a key performance parameter, they reach the necessary level of importance where cost growth beyond the threshold *requires* PM action. Control of cost must be made unavoidable, such as is accomplished by KPP designation. DoD has “talked the talk” about CAIV for many years but has, to a large extent, avoided “walking the walk.” Designating TOC a KPP would improve cost discipline and help avoid tradeoffs that favor the procurement cost, but might incur a much higher associated life cycle cost.

Total Ownership Cost metrics are discussed throughout this paper. Cost treatment can be made congruent with other requirements addressed within the Systems Engineering Process: that is, first setting the top level cost requirements, then decomposing larger requirements into smaller cost elements, and then managing the work to achieve the required cost objectives. Considering cost as part of the Systems Engineering Process makes sense because cost metrics should not be considered in a vacuum. Rather, cost has relevance when coupled with what it is able to “buy.” In DoD acquisition, discussion of cost is relevant when hinged to warfighting system performance. Hence the term, “Bang for the buck.” That is, how much performance can be bought for a specified cost? The “bang” is measured in terms of specific performance requirements. The warfighting requirements, or “bang,” typically are given attention during testing to be sure they can be met by the weapon system. However, a facet that affects warfighting ability but sometimes does not receive enough attention during test and evaluation is the amount of resources required to keep the weapon system in operation or quickly return it to operation; these resources can be measured in terms of cost to achieve the required operational availability, A_0 . A major portion of Total Ownership Cost is devoted to keeping a weapon system in operation and,



therefore, it makes sense to connect readiness metrics to a particular TOC metric, O&S cost.

Another TOC metric is average procurement unit cost (APUC). There needs to be a metric that guides the cost of production, which is certainly not a trivial cost. APUC is the total procurement cost divided by the total procurement quantity. This metric can be calculated for the whole program or can be separately calculated for each production lot.²¹

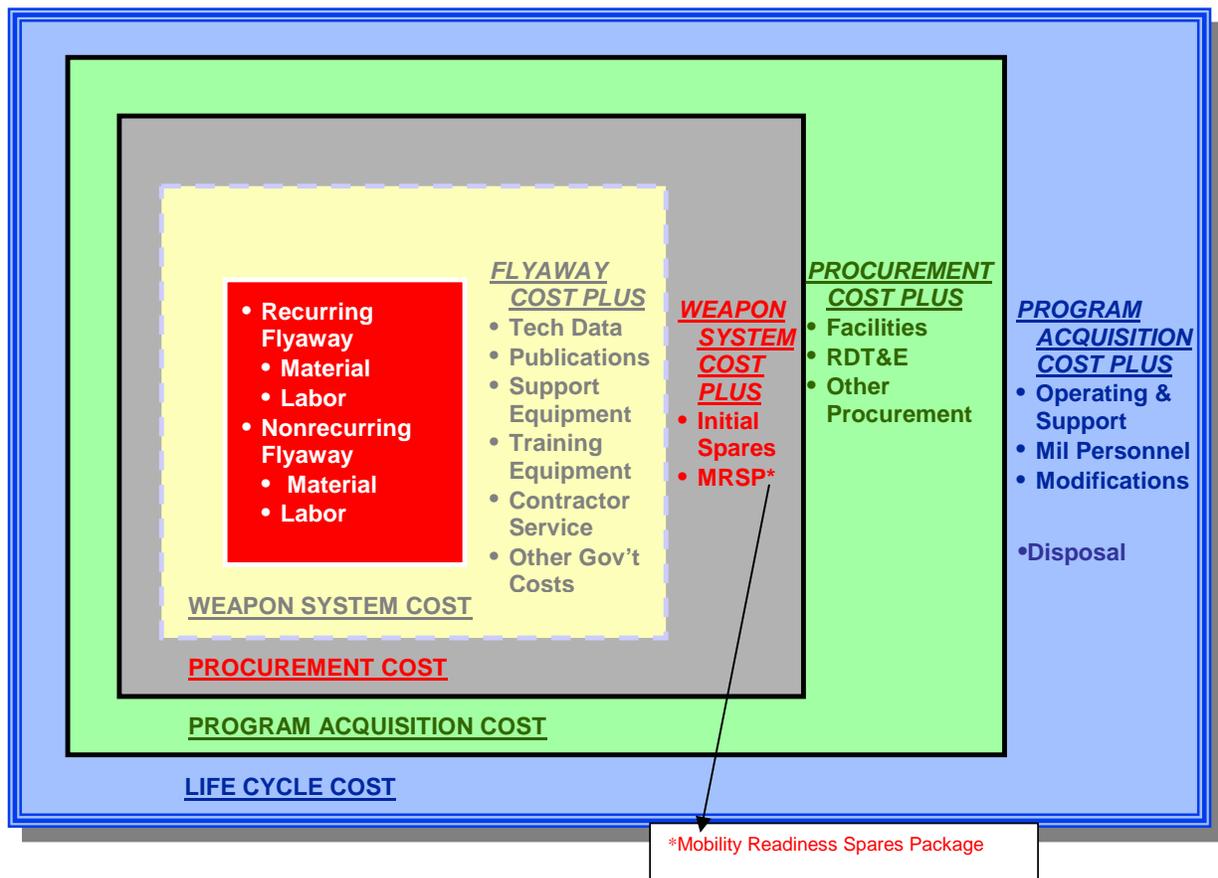


Figure 2, Life Cycle Cost Composition²²

²¹ Rush, Benjamin C. "Cost as an Independent Variable: Concepts and Risks." *Acquisition Review Quarterly*. Spring 1997.

²² Kaminski, Paul. Memorandum: "Reducing Life Cycle Costs for New and Fielded Systems (with CAIV Working Group Report attached). Office of the Secretary of Defense. December 4, 1995.



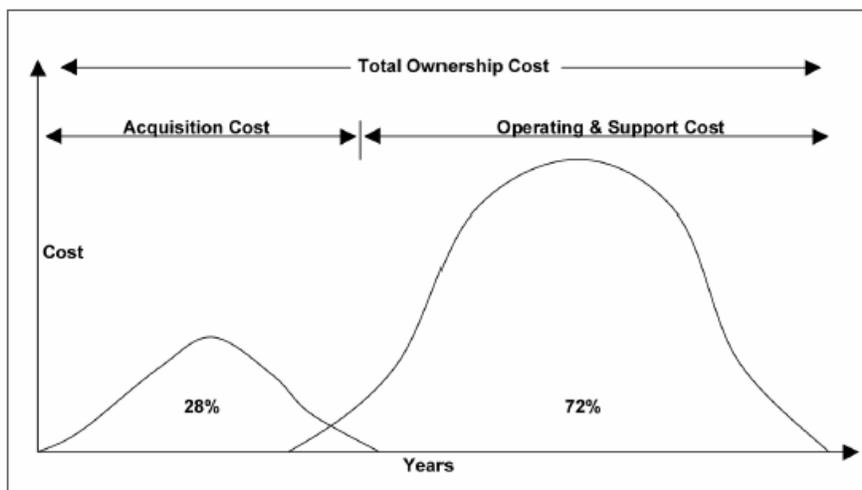
A Little History about cost metrics to illustrate a point - Over the past thirty years, cost metrics have been selected based on particular interests of the time. During the 1970s one of the cost metrics was design to unit production cost (DTUPC). Over roughly the same time period, acquisition cost metrics have included Flyaway Cost, Weapon System Cost, Procurement Cost, Program Acquisition Cost, and Life Cycle Cost. The component structure of these costs is described in the CAIV Working Group Paper and an adaptation from the referenced document is provided in figure 2.²³ More complete definitions of the various costs are provided in DoD 5000.4-M.²⁴ More recently cost metrics have included average procurement unit costs (APUC), an important component of TOC.²⁵ However, reliance on only one of the cost metrics depicted in the chart, except for Life Cycle Cost, falls short. That is, except for the LCC metric, each one, looked at individually, provides an incomplete picture of the Total Ownership Cost. Acquisition cost, traditionally the most relevant cost for a PM, represents only about twenty-eight percent of the TOC (See figure 3). TOC needs to be considered holistically, because as is apparent, it is the sum of numerous different costs. Each of the different costs can be reduced individually, but sometimes reducing one component of TOC can cause the aggregate cost to rise. However, the real goal is to reduce the aggregate cost, that is, the Total Ownership Cost.

²³ Ibid.

²⁴ Assistant Secretary of Defense (Program Analysis and Evaluation). "Cost Analysis Guidance and Procedures." Department of Defense. DoD 5000.4-M. December 1992.

²⁵ U.S. General Accounting Office. "Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs." Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-03-57. February 2003.





Source: Defense Systems Management College's Acquisition Guide.

Figure 3: Nominal Life-Cycle Cost of Typical DoD Acquisition Program with a Thirty-Year Service Life ²⁶

Major cost categories are briefly discussed below, with generic suggestions where cost might be wrung out, shrinking the aggregate Total Ownership Cost. Of course, Total Ownership Cost (the largest components of which are APUC and O&S costs) should be a central concern in any tradeoff analysis. For this to routinely occur, the program manager and other senior and executive leaders must relentlessly stress TOC and ask their questions in terms of impact of TOC.

Research, Development, Test & Evaluation (RDT&E) - This category of costs pays for the program management during development, design and testing of the system, including at least a portion of low rate initial production. It also includes in-service engineering, which covers redesign work to correct O&S cost drivers, and accomplish other redesign while the system is in service. Evolutionary Acquisition modifications to the core capability “shall be funded, developed, and tested in manageable increments.” RDT&E funds the developmental portion of each increment. ²⁷

²⁶ Ibid.

²⁷ Department of Defense. “Operation of the Defense Acquisition System.” DoD Instruction 5000.2. May 12, 2003. pg 3.



During the developmental phases, the opportunities to reduce Total Ownership Cost by reducing RDT&E depend on carefully managing costs within the design effort, possibly via use of Earned Value Management. Sometimes it is possible to gain efficiency in testing, reducing cost through concurrent testing although this dramatically increases risk. Ironically, RDT&E expenditures may open the door to overall reduction in Total Ownership Cost, because use of RDT&E in redesign initiatives may result in more producible and/or more reliable subsystems or components. From this perspective, RDT&E is a very scarce resource that, when expended with the proper focus, may reduce TOC overall. The R-TOC Pilots including CVN-68 Class Aircraft Carrier, CG-47 Class Aegis Cruiser, LPD-17, and AAV provide excellent examples of RDT&E expenditures that are expected to result in large cost savings or avoidance at such time as the new systems or modified components are placed in operational service.

Procurement - Procurement funding pays for production as well as initial spares, special tools, and test equipment.

In rough terms, the nominal cost of production is about 20% of total ownership cost. Average procurement unit cost (APUC) offers a metric that can be used for control of production cost. The APUC metric may be used to control the cost of procuring the entire system or procurement of each production lot. At the weapon system level, APUC is included in the APB, and is also reported in a program's Selected Acquisition Report (SAR).

One of the most effective means to control procurement costs is through competition. Although it is not always possible to use competitive methods, production should be competed, if possible. Where competition is not feasible at the prime contract level, competition at the subcontractor or vendor level may also drive costs down and sometimes it can be encouraged by component breakout.



“Should-cost” or “must-cost” studies may also achieve reductions in procurement cost, but are time consuming to perform. Government should-cost analysis prior to entry into a new contract adds discipline to cost control. If the cost architecture has been tightly controlled throughout the development process, should-cost analysis would seem a logical extension of the effort. Government should-cost analysis would further seem an appropriate activity to cement the understanding of cost between the customer, i.e., the Government, and the contractor.²⁸

Use of Activity-Based Costing (ABC) has the potential to drive down inappropriately applied overhead costs by helping to control overhead, both in contractor and Government organizations. Applied correctly, ABC shows the amount of indirect costs consumed by an activity, for example, a warfighting system. In the hands of competent managers, it is a tool that assists in applying indirect costs logically, statistically, and equitably. At such time as the business base changes, ABC has the potential to identify management actions to control indirect costs applicable to the new base. More specifically, ABC should allow managers to recognize when overhead is too large and needs to be trimmed resulting from a change in level of work.

Operating and support costs - O&S pays for most sustainment costs and administration during the weapon system’s sustainment phase, e.g., repair parts or the labor cost associated with an engine repair. It includes uniformed personnel and civilian labor costs. Operations and Maintenance (O&M) appropriations pay a large part of O&S costs. O&M funds also pay for disposal costs.²⁹

Operating and support costs may be dramatically reduced by identifying O&S cost drivers and correcting them, often, but not always, through redesign. The most efficient time to accomplish this is during the pre-acquisition and development phases,

²⁸ Forsberg, Kevin, Hal Mooz, and Howard Cotterman. *Visualizing Project Management: A Model for Business and Technical Success*. 2nd Edition. John Wiley & Sons, Inc. 2000. p 33.

²⁹ Department of Defense. “Operation of the Defense Acquisition System.” DoD Instruction 5000.2. May 12, 2003.



while the system is only a paper design and may be changed relatively inexpensively. However, cost drivers that are discovered during the production and sustainment phases also may lead to redesign or other actions that can save or avoid significant expenditures. DoD Pilot programs exhibit many useful examples of R-TOC, such as Abrams Tank engine (PROSE), the SH-60 Affordable Readiness Initiatives, Aviation Support Equipment reliability improvement initiatives, the EA-6B Inertial Navigation System, and SLAM-ER Data Link Pod.

The AEGIS system provides an example of a very successful R-TOC effort. Each ship requires microwave-producing equipment that includes a device called a Crossed-Field Amplifier (CFA). Early in AEGIS deployment, the CFA proved to be a cost driver with relatively expensive failures attributable to an arcing condition between the cathode and anode in the microwave tube. This arcing caused the CFA to fail at about 6,000 hours Mean Time Before Failure (MTBF). A change to anode metallurgy, along with other minor changes, reduced arcing and increased MTBF to between 40,000 and 45,000 hours, which drastically reduced the frequency of corrective maintenance, maintenance man-hours, and stockage level requirements, while simultaneously improving the reliability and availability of the microwave system. This dramatic improvement was the result of a team effort among the AEGIS Program Office, Communications and Power Industries (CPI, the vendor that provided the CFA, was formerly part of Varian), Crane Naval Surface Warfare Center (the Navy In-Service Engineering Agent for AEGIS microwave tubes), the Navy MANTECH Office, and Raytheon (the prime contractor, located in Sudbury, MA). This TOC reduction affects twenty-seven AEGIS Cruisers, each of which has 76 CFAs and forty AEGIS Destroyers, equipped with 38 CFAs. In 2002 dollars, the annual cost avoidance averages about \$1.9 million per AEGIS Cruiser and \$950 thousand per AEGIS Destroyer. Eventually, TOC reduction will benefit an additional twenty-two AEGIS destroyers that are yet to be completed and deployed, each of which will have thirty-two CFAs.

Another O&S cost driver example applies to the M1 Abrams Tank, a TOC Pilot Program, second only to Apache Helicopter in Army system O&S cost. The AGT-1500



tank engine is the obvious cost driver, resulting from both fuel consumption and maintenance. The engine was recognized from the outset as fuel inefficient, but was selected anyway because it was relatively lighter weight than the alternative 1500 horsepower diesels and the resultant weight savings could be applied to additional armor protection. In the field, AGT-1500 components demonstrated lower reliability than had been expected. Currently there are short-term and long-term initiatives to reduce this cost driver. In the short term, the Government and contractor have entered into a partnership to overhaul engine components, using contractor-provided parts and technical support along with Government skilled-labor and facilities; this partnership is called PROSE, the Partnership to Reduce O&S Costs, Engine initiative. Long-term, the LV100-5 engine program will replace the old AGT-1500 and is expected to reduce engine O&S cost by two-thirds, to reduce fuel consumption by about one-third, and to provide easier access and maintenance. The LV100-5 is a Honeywell and General Electric partnership effort.³⁰

Sometimes O&S economies may be achieved by contracting for repair parts in conjunction with production contracts.³¹ This approach may be able to take advantage of economies of scale, buying repair parts and production parts at the same time. This creative initiative, highlighted in an article by Michael Bogner *et al.*, requires thorough understanding of component failures for a new weapon system, analysis of the economies of scale that are offered by the contractor, and the storage costs for the repair parts.

O&S funds may be saved, while at the same time effecting better support by competitively sourcing sustainment support. This approach opens the door for choosing the best value sustainment support: organic, depot, commercial, or some combination

³⁰ Hoffer, Kip. E-mail and telephonic correspondence. Crane Naval Surface Warfare Center, In-Service Agent for AEGIS Microwave Tubes. November 17-19, 2003.

³¹ Bogner, Michael, Chuck Wong, and Bernie Price. "Quantity Discounts/Economic Order Quantity: New Quantity Discount Analysis Tool Lets DoD Buyers Save on Total Cost and Receive More Goods." *Program Manager*. September-October 2002.



thereof. Software support, in the form of software engineers / programmers, is mainly available through commercial sources, but can be planned for in a similar manner. Pilot programs that have used creative approaches to sustainment support are Common Ship, LPD-17 Class Amphibious Transport Dock Ship, F-117 Nighthawk, TOW Improved Target Acquisition System (ITAS), and Abrams Tank. Discussion of their initiatives is available on the IDA website for R-TOC.³²

Service Life Extension Programs may offer significant opportunity for cost savings or avoidance. Although not proven to save cost in all instances, there are recognized and validated instances where O&S cost savings are of such a magnitude, that the cost avoidance generates a significant portion of the funding for replacement systems. Cost analysis needs to be done cautiously, and validated by an independent cost estimate to be sure that the expected savings or avoidances are real.³³ R-TOC Pilot programs that have used this approach are Heavy Expanded Mobility Tactical Truck (HEMTT), AH-64 Apache Helicopter, and CH-47 Chinook Cargo Helicopter.³⁴

The Army's 2 ½ Ton Truck Extended Service Program (ESP) is an example of a program specifically designed to reduce O&S costs through reengineering of an existing platform. The ESP goals were to provide a modernized tactical wheeled platform that could be inexpensively procured, add 20 years to the life of the truck, perform at least 60 percent of the new replacement tactical wheeled vehicle requirements, and significantly reduce O&S costs to the field. Key Performance Parameters (KPPs) included a mean-time-between-hardware-mission-failure (MTBHMF) of 2,400 miles – an improvement factor of 2.4 over the existing system, eight miles per gallon (MPG) fuel efficiency – a fuel consumption decrease of 20 percent, and mean-time-to-repair

³² Institute for Defense Analysis. Website: "Reduction of Total Ownership Costs." <http://rtoc.ida.org/rtoc/rtoc.html>. n.d.

³³ Congressional Budget Office. "The Effects of Aging on Costs of Operating and Maintaining Military Equipment." August 2001.

³⁴ Institute for Defense Analysis. Website: "Reduction of Total Ownership Costs." <http://rtoc.ida.org/rtoc/rtoc.html>. n.d.



(MTTR) of one hour per thousand miles of operation – one half of the MTTR achieved by the existing platform. With several Key Performance Parameters focused on TOC efficiencies, system trade-offs served to improve the TOC attributes of the ESP. The results of this TOC focus is evident in the ESP's achieved results: The achieved MTBHMf was 11,300 miles – over four times the KPP threshold and a factor of 11 times greater than the existing platform, fuel economy was 10 mpg – a 25 percent improvement over the threshold and a 67 percent improvement over the existing system, and the MTTR was reduced to 0.65 hours per thousand miles – a 35 percent improvement over the threshold and a 300 percent improvement over the existing system.

Disposal - costs are paid out of O&M funds. In some cases, disposal costs may be avoided by making the system available to an ally through Foreign Military Sales or Military Assistance Program (MAP). There is the potential for recouping funding into the same procurement appropriation line that may then be applied toward funding a replacement system.

More generally, items must be disposed of through Defense Reutilization and Marketing Office (DRMO). Disposal may be a significant expense, depending on whether the weapon system contains hazardous materials. HAZMAT content can be controlled during the development phases and should be considered as part of tradeoff analysis.

According to DoD 5000.4-M, disposal costs, such as demilitarization, detoxification, and long-term storage of hazardous materials are included in cost estimates. One would expect that the costs to de-fuel nuclear power plants are significant and should be a planned O&M expenditure.

F. Databases and Data Collection

Tools for data collection are still evolving. Multiple databases provide data that are then used for analysis and decision-making. A Congressional Budget Office Report



published in August 2001 described anomalies in the data that called the utility of the data into question.³⁵

Software estimation, both in terms of system software resources (throughput, processor speed, storage media, etc.) and in terms of supportability resources (the number of software engineers needed to perform critical sustainment functions) have traditionally been very difficult to estimate.³⁶ The software size, number of function points, and need for support engineers / programmers may or may not be comparable to other similar systems, making it very difficult to use existing databases to accurately estimate a new system's requirements.

Utility for Cost Estimation. Data pulled from multiple databases provide the basis for cost estimation that feeds tradeoff analyses and other decision processes. It is obvious that cost databases provide a critical function and effort should be expended to ensure that they achieve acceptable levels of accuracy and functionality. Part of the database problem is "garbage in, garbage out." But additionally, data to support cost models and cost estimating needs to be fully accessible and integrated. This is a cost of doing business for CAIV and R-TOC. Library research indicates that there is considerable work going on to clean up the data and/or make the data easier to extract and analyze.³⁷ The Navy VAMOSC database, an important contributor of O&S cost information, has undergone considerable clean-up effort. The Air Force system is AFTOC and has been updated.³⁸ Contractor database work includes the Air Force's

³⁵ Congressional Budget Office. "The Effects of Aging on Costs of Operating and Maintaining Military Equipment." August 2001.

³⁶ Humphrey, Watts S. *Managing the Software Process*. Addison-Wesley Publishing Company. 1990.

³⁷ Kunc, Wendy. Naval Cost Analysis Division. "VAMOSC Program Update" Briefing to Third Annual Naval VAMOSC User Conference. 9 July 2003; Bowles, Jennifer. NAVAIR. "Example Uses of VAMOSC Data." Briefing to Third Annual Naval VAMOSC User Conference. 9 July 2003; and Stoll, Lawrence. NAVAIR. "Applications of VAMOSC at NAVAIR: A User Perspective on VAMOSC-MAMSR Databases." Briefing to Third Annual Naval VAMOSC User Conference. 9 July 2003.

³⁸ McNutt, Gary. "Air Force Total Ownership Cost (AFTOC) (FOUO)." Briefing to R-TOC Pilot Programs, 7th Quarterly Forum. 25 July 2001.



JSTARS Cost and Performance System (JCAPS) a database and analysis tool, which is being developed by Northrop Grumman. The Marine Corps AAV is using a system called the O&S Cost Analysis Model (OSCAM) that is also being used by the Navy and Air Force.³⁹

One of the tests for cost databases and analysis tools is their ability to support cost-performance trades at the subsystem or component level. IPTs need to be able to access component cost data that includes procurement cost, O&S cost, and inherent reliability.

G. Activities and Tools that Support CAIV and R-TOC

Leadership interest - Leadership sets the policy and then motivates personnel to meet the requirements set. Workers do best what the boss checks. If leaders vigorously insist on searching out and reducing cost drivers, then the workforce will react to that guidance. By their questions, leaders can change the culture, one opportunity at a time. Focus on cost drivers should achieve a good effect on the relevant warfighting system, but the greater gain is in changing the culture of the acquisition workforce to one of continually searching for and attacking cost drivers—no matter what phase of the program.

Sustainment Through Competitive Sourcing Decisions - As a weapon system develops, there must be a determination made of the support system that will provide the best value. This is an important decision when measured in terms of readiness, military labor expended, and in terms of the resources over the system's life cycle. All the possibilities need to be searched out and then the best value selected that meets the required operational readiness and flexibility at an affordable cost. This is a difficult process, as said elsewhere in this paper, due to the "rice bowls" involved and the concern for operational flexibility, particularly during wartime or contingencies.

³⁹ Griffith, Sean, and Bruce McKinney. "Advance Amphibious Assault Vehicle: Operations and Support



Activity-Based Costing - ABC provides a way to equitably attribute indirect costs to the product or organization that consumed it in a manner that is logical and statistical. ABC clarifies the amount of overhead burden that a product or weapon system is carrying, such that cost-based business decisions can be made more accurately. In development and production, costs may be incorrectly charged, particularly in the case of a shifting business base. An example of this in DoD is the increasing surcharges levied on repair parts, resulting from a shrinking business base. ABC makes clear to managers what their indirect burden rates are, and pressures them to make the necessary adjustments in excess capacity to avoid increasing a customer's burden rate. ABC is applicable to both Government organizations and defense contractors.

In principle, Activity Based Costing ought to provide utility for DoD organizations. However, care must be taken in where to use ABC and where it is unlikely to be successful. Activity drivers that must be used in ABC may not always be simple; in some cases, multiple activity drivers are necessary to provide accuracy. ABC is not likely to be successful in circumstances where the work being done is not repetitive; in such cases, accurate activity drivers are probably not possible to devise. Even if ABC should be found not to provide reliable distribution of overhead burden for a Government organization, it may, nevertheless, provide accurate treatment of indirect costs in contractor facilities. The successful application of ABC would appear to depend on whether or not the work activity is of a repetitive nature and whether accurate activity drivers can be devised.

Earned Value Management - EVM is an accounting mechanism wherein specific activities are assigned along with resources and schedule required. In other words, an individual or group is assigned work to do and provided funding and a schedule for completion. EVM decomposes the work breakdown structure all the way down to the task, referred to as a work package, that might take a week to a month or possibly as

Cost Analysis Model." Briefing to R-TOC Pilot Programs, 15th Quarterly Forum. 5 August 2003.



long as several months to complete. If the organization has a real time or near real time cost accounting system, then managers, Government and contractor, by watching the dollar expenditures can determine which work is taking more resources than planned or time than scheduled. This is a very effective way to control expenditures both in SDD and in production. EVM is not required for fixed price contracts but high quality contractors should carefully manage expenditures; if the RFP spells out tight control of funds in sections L and M of the RFP and also in the performance-based SOW, conscientious contractors may be encouraged to choose EVM, required or not.

Reliability-Centered Maintenance (RCM) - A useful tool for controlling cost is RCM, because one of the goals of RCM is accomplishing only maintenance activity that is value-added. Interestingly, some of the routine maintenance performed on warfighting systems is not only unnecessary but also reduces the reliability of the system. For example, an unnecessary inspection may cause wear due to partial disassembly of components; reassembly may result in a defect such as a cross-threaded fastener. Besides eliminating unnecessary maintenance, another positive outcome of RCM might be the design of a higher reliability component that increases weapon system availability.

The best time to perform RCM is probably early in the developmental cycle.⁴⁰ This might be during Technology Development or early in SDD. However, whatever the life cycle phase of a weapon system, RCM may be beneficially applied, even late in a system's life. The use of RCM is consistent with maintaining system databases. RCM may be accomplished in IPTs. Surprisingly, RCM, although of a detailed nature, is not terribly expensive and should more than pay for itself. Finally, RCM should continue throughout a system's life cycle with short reviews every nine to twelve months.⁴¹

⁴⁰ Moubray, John. Reliability-centered Maintenance. 2nd Edition. Industrial Press Inc. 1997.

⁴¹ Ibid p284-286.



The AAV program embraced RCM in late 1999 and early 2000. Over two small contracts with the modest expenditure of about \$400,000, the program trained about 60 personnel, trained and certified five facilitators, and in less than a year, had an RCM program up and running. This effort occurred during the same period that the AAV program was fabricating Program Definition and Risk Reduction (PDRR) prototypes. Program personnel indicated that AAV actually would have benefited from embarking on RCM even earlier, at the time that the system specification was being written. The AAV leadership team was sufficiently convinced of the benefit of RCM, that they requested the contractor to revise plans for the SDD Phase and to conduct RCM analysis in lieu of the previously planned Failure Modes and Effects Analysis (FMEA) / Failure Modes, Effects, and Criticality Analysis (FMECA).⁴²

Software Estimation - There are numerous software estimation tools designed to assist the materiel developer and the contractor assess the size, development schedule, manage requirements, and estimate software support personnel. All of these factors are significant cost drivers, with the software support personnel impacting O&S costs over the deployed life of a software-intensive system. As our systems continue to become more dependent upon large and complex software programs, software supportability will continue to grow as a driver of TOC and remain in the forefront of TOC reduction efforts.

Lean Manufacturing - Since publication of *The Machine That Changed the World* in 1990, “lean” manufacturing has received increasing recognition as an approach for squeezing waste out of manufacturing processes, useful for prime contractors and vendors alike.⁴³ Radical reengineering (kaikaku) and continuous process improvement (kaizen) both have a place in lean manufacturing. Lean manufacturing is not easy, but

⁴² Garza, Luis. Thesis: “A Case Study of the Application of Reliability Centered Maintenance (RCM) in the Acquisition of the Advanced Amphibious Assault Vehicle (AAV).” Naval Postgraduate School. December 2002.

⁴³ Womack, James P., Daniel T. Jones, and Daniel Roos. *The Machine That Changed The World*. Rawson Associates, a Division of Macmillan Publishing Company. 1990.



in numerous cases and in different industries, it has wrought dramatic improvement, both short- and long-term.⁴⁴

An example of the effectiveness of lean manufacturing is Pratt & Whitney, whose business base dropped precipitously in 1991 as the result of the end of the Cold war and a world recession. Over several tumultuous years (1991-1995), Pratt made major strides by applying lean techniques. Pratt managers, guided by “lean” consultants called *sensei*, were able to reduce their manufacturing throughput time (cycle time) from eighteen months to six. Work-in-process and finished-goods inventories were driven down by 70%; this allowed a large central warehouse to be closed. Quality issues fell by more than half. Unit costs for manufactured parts typically dropped by 20%. All these reductions occurred during a business down-cycle when production volume fell by 50%, which under normal circumstances would have caused unit costs of manufactured parts to increase by 30%.⁴⁵ Although DoD is still learning about lean techniques, Pratt & Whitney experience suggests the potential for large reductions in the cost of defense products through lean production.

Commercial Operations and Support Savings Initiative (COSSI) -

COSSI is a program jointly shared between the U.S. Army, Navy, and Air Force with the Office of Secretary of Defense (Director, Defense Research & Engineering) providing administrative oversight. COSSI's mission is to leverage private sector research and development by inserting leading edge commercial technologies into fielded military systems to reduce operations and support costs.⁴⁶

COSSI, itself, is an adaptation of use of commercial items (CI), an acquisition reform initiative; however, COSSI more specifically develops technology to be inserted

⁴⁴ Womack, James P and Daniel T. Jones. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. Simon and Schuster. 1996.

⁴⁵ Ibid.

⁴⁶ Department of Defense. Office of Technology Transition. Commercial Operations and Support Initiatives website. <http://www.acq.osd.mil/es/dut/index.htm>. n.d.



into existing systems. It is completely consistent with R-TOC, but is funded separately, in accordance with PL 105-85 Sec 203 (g) (FY 98 Authorization Act).⁴⁷ Stage I funding comes from COSSI funding; Stage II funding is budgeted and provided by the program office. Successful COSSI is envisioned to take two to three-years in Stage I, followed by Stage II procurement of modification kits and installation. The opportunities are that funding from outside the program can be used to provide new systems or components that provide improved technology for better performance and/or reduced O&S costs. The apparent risks are in communications, contractor performance, and contracting methods. Poor communication between materiel developer and user may result in loss of customer interest or requirements creep. Poor communication between contractor and materiel developer may result in failure to achieve the desired technical improvement or necessitate a schedule slip.⁴⁸

COSSI may benefit from high performing IPTs and clearly articulated contractual instruments. For Stage II, budgeting actions need to be carefully timed to avoid a schedule slip. Stage II contractual actions appear to require a J&A in most instances to retain the contractor who has previously done the Stage I developmental work.⁴⁹

Like any other acquisition activity, COSSI requires careful planning and close communications among materiel developer, customer, and contractor. In instances where there is commercial application, the contractor may enter into a sharing arrangement that reduces the cost to the DoD.⁵⁰ Share arrangements have been simplified by the use of Other Transaction Authority (OTA). Unfortunately, there are

⁴⁷ Ibid.

⁴⁸ Holland, Charles J. and Donna Richbourg. "Commercial Operations and Support Savings Initiative Handbook." Office of the Under Secretary of Defense. 14 December 2001.

⁴⁹ Ibid.

⁵⁰ Ibid.



regulatory and legal obstacles to the streamlined use of OTAs, part of which necessitates re-competition between Stage I and Stage II.⁵¹

An example of a COSSI success appears to be the USAF MILSTAR Antenna Program Electronic Systems Center. It replaces a high maintenance component, described as “the worst box in the MILSTAR Terminal” that was depleting available funds due to its excessive unscheduled demand for repairs. The mean time between failure (MTBF) for the old component was less than 1000 hours; the new design is predicted at 28,000 hours. Ordinarily, COSSI results in dual-use systems or components, but in this case the result is a unique military product employing commercial technology and commercial practices, manufactured in a commercial vendor’s plant; the original component was manufactured by Raytheon. As with other COSSI projects, this one required significant management attention, requiring experienced managers on both Government and contractor sides to bring in a successful result.⁵²

Performance-Based Logistics (PBL) -

PBL is the output performance parameters to ensure a system-ready capability, the assignment of responsibilities and implementation of incentives for the attainment of the goals associated with these performance parameters, and the overall life-cycle management of system reliability and sustainment, and total ownership cost.⁵³

[PBL is] a strategy for weapon system product support that employs the purchase of support as an integrated, affordable performance package designed to optimize system readiness. It meets performance goals for a

⁵¹ DoD COSSI Independent Assessment Executive Roundtable. “An Evaluation and Assessment of the DoD Commercial Operations and Support Savings Initiative Program.” The National Center for Advanced Technologies Report Number 01-C01A. September 2001.

⁵² Ibid.

⁵³ Defense Acquisition University. “Program Managers Tool Kit.” 12th Edition. December 2002.



weapon system through a support structure based on long-term performance agreements with clear lines of authority and responsibility⁵⁴

PBL begins in Pre-Acquisition as the support concept is first considered. PBL is driven by specific warfighter support requirements; it is accommodated by innovative partnerships between DoD customers of logistics support, the DoD providers of that support, and commercial providers, leveraging the core competencies of each. PBL metrics are consistent with TOC metrics such as maintenance cost per operating hour or ton-mile. PBL suffers from the difficulty in tying databases together to measure support performance; this mirrors problems in obtaining TOC data.

The USMC Medium Tactical Vehicle Replacement is an example of the innovative support envisioned by PBL. The Marine Corps maintains these trucks at the organizational support level. Intermediate and depot level support are provided by Oshkosh Truck Corporation (OTC); this contractor logistics support (CLS) includes both maintenance and supply, peacetime and wartime, and extends worldwide. Wartime operations have already been tested during Operation Iraqi Freedom. The support contract is firm-fixed price (FFP) and indefinite delivery-indefinite quantity (IDIQ); its duration is potentially 10 years, including a 3-year base period with seven option years. During the first three years, the contract dollars are bounded by maximum and minimum amounts in each year. Maintenance can be conducted on-site or at Oshkosh but must meet time windows. Repair parts are a split responsibility with OTC providing about 2500 different parts (again, within tight time guidelines) and Defense Logistics Agency supplying an additional 1000 common parts. The expected TOC reduction for MTRV is \$546.6 million in cost avoidance.⁵⁵

⁵⁴ Kratz, Louis. "Developing a Performance-Based Strategy." Briefing to PEO/SYSCOM Workshop. Spring 2002.

⁵⁵ Lara, Luis F. Thesis: "Analysis of the Medium Tactical Vehicle Replacement (MTRV) Contractor Logistics Support (CLS) Contract." Naval Postgraduate School. December 2001.



PBL is mandated by USD(ATL) memo, and is addressed in Defense Acquisition Guidebook (C.2.8.3) as the preferred approach for product support; FY 03-07 DPG requires PBL implementation planning for ACAT I & II fielded systems by March 2002; the Sep 01 QDR expected PBL to compress the supply chain and improve readiness.

Availability of Cost Driver Data for New Technology - The better the available cost information pertaining to legacy systems, the better cost estimates that may be established for new systems in development. This data needs to be available at the subsystem or component level. In addition to the cost driver associated with past system software, an analysis of the tools, techniques, and software requirements must be accomplished, as the software development effort may be comparable or radically different from the previous like-system. Cost drivers at subsystem or component level for in-service weapon systems suggest the range of TOC for similar components on new weapon systems that are in development. Alternatively, if new technology is being planned for a developing system, then subsystem or component testing must be planned to verify reliability and cost of operation. This testing should be completed not later than Systems Integration phase of SDD in order that cost and RMA are understood and can influence tradeoff decisions.

H. Risk Management

During development, applying Cost As an Independent Variable introduces its own risks. From the outset, CAIV recognizes that there are limits to affordability. A primary risk is that a warfighting system might be cancelled because it becomes too expensive. This risk needs to be addressed as the Capability Development Document is being drafted. The weapon system capability must be synchronized with cost objectives, available resources, and required schedule. Cost objectives refined during pre-acquisition can logically result in a series of cost targets that serve to manage the risk of cost growth.



Even though CAIV offers the possibility of large cost savings or avoidance, the program may increase the cost of analysis during the developmental phases, because of the additional cost tradeoffs that are required and expenditures to provide improved cost modeling. These cost risks should be expected at the outset and planned for.

The principle challenge in applying CAIV is for weapon system cost to be allocated across the entire system in terms of cost metrics, such as average procurement unit cost (APUC), operating and support (O&S) cost, and, possibly, disposal cost. To simultaneously control these costs at the start of system development, DoD and contractor need to refine broad cost objectives into specific cost targets at a level that can be tracked and assessed. The SEAWOLF Class Submarine Combat Systems provided a model for breaking out cost and performance attributes that might still be applied today, as follows. The contractor allocates the specific cost targets through the System Development Work Breakdown Structure (WBS). In that way, every subsystem or component has its own budget for procurement cost and its slice of operating and support cost; these target costs can be managed within subordinate IPTs. This breakdown and allocation of cost objectives is typically part of the warfare system decomposition that is completed early in SDD and includes not only physical attributes and performance functions, but also includes procurement costs and O&S (ownership) costs. For tactical systems, a major driver of design/production and ownership costs is the Operational Availability (A_o) requirement for the system. The A_o requirement drives system redundancy and complexity requirements and therefore cost. Right from the start of SDD, the process of establishing the architecture of a tactical system to meet these Availability requirements should be coupled with the Design to Cost (DTC) and Design to Affordability (DTA) efforts in the allocation of tactical and cost requirements to each subsystem and component. Typically, the opportunity of laying out the tactical weapon system architecture and system design with the DTC/DTA objectives is an opportunity that occurs only at the start of a program. Once the Architecture and System Design are established, the ability to fully redesign the system



is generally too costly. Occasionally a mid-life system upgrade may provide the opportunity to perform DTC/DTA cost engineering a second time at the system level.⁵⁶

Since all of these costs must be managed within CAIV, there is risk of not having cost estimation means that provides sufficient resolution and accuracy, even though estimation models do exist to support this degree of cost management. There is no doubt that this approach is demanding and rigorous, but the DoD routinely expects their contractors to manage this way. The R-TOC Pilot programs such as Advanced Amphibious Assault Program (AAAV), Joint STARS, AH-64 Apache Helicopter, and CH-47 Chinook Helicopter programs are working on various cost modeling initiatives to better portray and understand O&S cost impacts to facilitate better decisions.⁵⁷

Cost modeling requires supporting databases, capable of feeding data from legacy systems; there is risk that such data is not refined enough or may be inaccurate. Cost models presuppose the availability of accurate, representative cost data and, typically, some of this data necessarily comes from legacy systems. If the technology is new, or the design is radical, cost data must come from testing that takes place during development.

The additional cost metrics, mentioned above, create additional complexity in the tradeoff process. Whereas it would be more convenient to use only one cost metric, this does not provide enough cost resolution. Costs must be “sliced and diced,” at least sufficiently to show their contribution to APUC and O&S cost. Then, the subordinate IPTs can use these cost parameters to guide their tradeoff decisions. Cost models have

⁵⁶ Watterson, Ozzie. Interview on development of SEAWOLF Class Submarine Combat Systems (AN/BYS-2). Mr. Watterson held the position of Technical Program Manager during SEAWOLF’s early acquisition milestones and development. Conducted in Middleton, RI. 20 August 2003.

⁵⁷ Institute for Defense Analysis. Website: “Reduction of Total Ownership Costs.” <http://rtoc.ida.org/rtoc/rtoc.html>. n.d.



been recognized as an obstacle as recently as November 2002 by Dr. Spiros Pallas, the OSD R-TOC point-of-contact and by an R-TOC Pilot Program briefer in April 2003.^{58, 59}

Schedule risk is not an especially obvious effect of CAIV but is worth highlighting. TOC analysis, itself, may sometimes put pressure on the program schedule. An example of this might be the should-cost analysis that considers not only procurement cost but also analyzes the O&S effects of production decisions. This would be much more complicated and take longer than the traditional should-cost analysis, which addresses only production-related costs. Schedule may need to be traded off in order to stay within resource constraints demanded by CAIV. Tradeoff analyses that impact the software component may result in significant schedule increase, which should be factored into the cost of the tradeoff being considered. Unfortunately, DoD pays dearly for schedule changes: both schedule compression and stretch-out. Schedule change is a political fact of life, but sometimes, is simply the result of poor planning, which may have been avoidable.

I. Why We May Have Difficulty Seeing and Proving TOC Reduction

A report prepared by the Congressional Budget Office on the cost impacts of aging military equipment, published in 2001 outlined some of the data anomalies within the Department of Defense.⁶⁰ One could reasonably draw from that report that DoD cost reporting is murky and that, even if R-TOC efforts are successful, the department might have difficulty proving it. Without reliable system ownership cost data, any changes in the cost basis are impossible to capture. But there are other aspects that also may influence the results of TOC reduction efforts.

⁵⁸ Pallas, Spiros. "R-TOC in DoD Systems: Status Report." Briefing to PEO/SYSCOM Commanders Conference. 21 Nov 2002.

⁵⁹ Institute for Defense Analysis. Website: "Reduction of Total Ownership Costs." <http://rtoc.ida.org/rtoc/rtoc.html>. n.d.

⁶⁰ Congressional Budget Office. "The Effects of Aging on Costs of Operating and Maintaining Military Equipment." August 2001.



The Pilot TOC reduction efforts began with about ten programs and soon grew to thirty. These programs were at different life-cycle phases, with several programs early in their development phases. For those early programs such as AAV and Comanche Helicopter, the real effects of Total Ownership Cost reduction initiatives will not be demonstrable until well after each system's entry into operational service, which in some cases is still years away. Even with R-TOC applications on deployed systems such as CG-47 Class Aegis Cruisers and CVN-68 Class Aircraft Carriers, many of the cost reduction initiatives are still in development or being scheduled for implementation and the cost savings or avoidance are years away. By the time the funding is "saved," it will be difficult, if not impossible, to recognize the savings and DoD will continue to be consumed by how much the warfighting system still costs to operate, regardless of past R-TOC successes.

For those warfighting systems that are in-service, the demonstration of cost savings or avoidance hinges on cost databases and cost estimating techniques used to calculate the original costs and TOC baselines, along with the ability of the Service's cost accounting systems to track actual costs. A recent study of DD 963 Spruance class ships that compared ship age to operational costs bears witness to some of the difficulties with available cost data.⁶¹ Not only did that study highlight evolutionary changes in the Visibility And Management of Operating and Support Costs (VAMOSC) database, but it also indicated that certain data was suspect, due to decisions regarding the level of maintenance effort that should be expended on aging ships that were about to be retired from active service. Reading "between the lines" of the above-noted CBO report also suggests that command decisions on how to distribute scarce O&S funds may also skew actual weapon system O&S costs.

⁶¹ Stranges, Bill, Coleen Adamson, Andrea Nowicki, and Deanna Ohwevwo. Briefing: "DD-963 Spruance Class Ship Aging Vs Maintenance Expenditures from FY91 to FY00" presented at the SCEA 2002 National Conference. June 2002.



Additionally, shifts in maintenance policies, such as the policy on overhaul intervals or criteria almost certainly will skew O&S cost data.

There are two important meta-messages related to cost databases. The first is that each of the Services in DoD needs accurate cost information for use in identifying cost drivers and estimating the cost savings and avoidance resulting from TOC reduction actions. The second message is that the real world is not an accountant's laboratory where variables can be tightly controlled to run an experiment. DoD operates in a world where policies frequently change, OPTEMPO fluctuates, maintenance actions are postponed or missed completely, data entry is sometimes neglected or done sloppily, and funding is diverted from one priority to another. These two messages, taken together, suggest that sample data collection might be a useful approach, somewhat less ambitious, but more accurate and better understood than other approaches. That is, sample data does not chronicle the whole population; rather, it samples selected slices of the population, accumulated by data collectors whose full-time job is to obtain accurate data.

J. Activity During the Various Life Cycle Phases

Cost As an Independent Variable (CAIV) and Reduction in Total Ownership Cost (R-TOC) comprise a significant number of different initiatives that are applied at appropriate periods within a weapon system's life cycle. Virtually all of these initiatives have been addressed in this chapter, but Chapter V will provide additional perspective and emphasis, against the backdrop of the life-cycle phases.



CHAPTER V: CONSIDERATIONS OF TOTAL OWNERSHIP COST RELATED TO SPECIFIC PHASES

The purpose of this chapter is to focus on Total Ownership Cost initiatives, phase by phase. This intent is to assist the practitioner or stakeholder by suggesting TOC facets relevant to the phase for which they have specific interest. To that end, the chapter is divided into four parts, as follows:

- Part 1. Pre-Acquisition: Concept Refinement and Technology Development Phases
- Part 2. System Development and Demonstration Phase
- Part 3. Production Phase and Deployment to the Field or Fleet
- Part 4. Sustainment Phase



PART 1: PRE-ACQUISITION: CONCEPT REFINEMENT AND TECHNOLOGY DEVELOPMENT

A. Overview of the Two Phases

Concept Refinement and Technology Development have been separated into two separate phases in the DoDI 5000.2, dated 12 May 2003. For the purposes of this discussion, they are being combined, because both phases are “pre-acquisition” and much of the focus is on the evolution of the capability documents, prepared under the direction of the user community during both periods.

CAIV Up-Front and Early - It is an axiom of acquisition management that the essential requirements of a new warfighting system need to be established early in the program. This is part of the underlying foundation of the Systems Engineering Process. It has long been recognized that adding requirements later in a program’s development is expensive and sometimes infeasible. To maximize the success of Reduction in Total Ownership Cost, the effort must “begin at the beginning.” That is, Cost As an Independent Variable (CAIV) begins in the premise that a cost objective or constraint is established at the outset and that weapon system capabilities are developed within the cost constraint.⁶² It is important to note that CAIV is intended as an analysis tool for TOC, but can be inappropriately manipulated to tradeoff activities or system features to meet a procurement cost goal, while improperly failing to address the impacts on long-term operating and support cost.

⁶² Kaye, Michael A., Mark S. Sobota, David R. Graham, and Allen L. Gotwald. “Cost As An Independent Variable: Principles and Implementation.” *Acquisition Review Quarterly*. Fall 2000.



There is a school of thought that successful programs begin by carefully balancing technology, requirements (now capabilities), resources, and schedule.⁶³ This is accomplished through the tradeoff process, beginning with the analysis of alternatives, which will be briefly discussed later.

B. Leadership, Motivation, and Stakeholder Involvement

JROC - The Vice Chairman, Joint Chiefs of Staff chairs the Joint Requirements Oversight Council, referred to as the JROC. It is the JROC that oversees the capabilities development of a new warfighting system on behalf of the Chairman, Joint Chiefs of Staff. It is within the purview of the JROC to reinforce the need for specific affordability constraints on any new program, prior to validation and approval of capability documents. DoDI 5000.2, published 12 May 2003, mandates that affordability be a consideration during preparation for the Initial Capabilities Document (ICD).⁶⁴ However, CJCSI 3170.01C, published 24 June 2003, specifies that preparation of the ICD include an analysis of relative cost, but the instruction does not specify that affordability determinations be performed in conjunction with the Initial Capabilities Document; it does require that affordability determinations be prepared later, during preparation of Capability Development Documents, which occurs during Technology Development Phase. Ignoring the apparent minor disparity between the two regulations, which does need to be rationalized, JROC attention toward affordability clearly would show the way for DoD leadership to speak with one voice on the matter of Total Ownership Cost.

⁶³ U.S. General Accounting Office. "Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes." Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-01-288. March 2001. And, Forsberg, Kevin, Hal Mooz, and Howard Cotterman. *Visualizing Project Management: A Model for Business and Technical Success*. 2nd Edition. John Wiley & Sons, Inc. 2000.

⁶⁴ Department of Defense. "Operation of the Defense Acquisition System." DoD Instruction 5000.2. May 12, 2003. para 3.4.1



Milestone Decision Authority (MDA) - The MDA has the authority to demand affordability information at each milestone decision point, including the Concept Decision, which initiates the Concept Refinement Phase. Insofar as the MDA asks very focused, pointed affordability questions during milestone reviews, it brings attention to ownership costs as the developing weapon system progresses toward its next milestone decision point. This could be an effective way to focus attention on life cycle cost and create a CAIV culture.

Sponsor - The sponsor of a warfighting system has the opportunity and, eventually, the responsibility to establish cost constraints during the development of the ICD and the CDD. The sponsor can be a proactive adherent and reinforce interest in Total Ownership Cost through insistence on weapon system affordability. The sponsor can even make affordability consideration inevitable by designating an O&S cost cap as a key performance parameter (KPP).

The sponsor of a new warfighting system is a vital partner throughout the developmental phases and beyond. There are several periods in the life cycle during which the sponsor could have a major impact on Total Ownership Cost. The first period is as the capabilities are being identified and refined. Insofar as the sponsor specifies a cost envelope to achieve the required capability, this initiates the cost constraint, within which the tradeoff process may then be performed.

Setting Cost as a key performance parameter (KPP) is a leadership issue. A measure of the importance of warfighting system requirements is the manner in which they are described. The term “key performance parameters” is defined as those minimum attributes or characteristics considered most essential for an effective military capability. Reduction in threshold KPP performance requires an assessment of the military utility of the reduced capability and, possibly, a reexamination of the program to



determine if an alternative solution should be adopted.⁶⁵ If system Total Ownership Cost (TOC) or a subset such as operating and support cost (O&S) is designated as a key performance parameter, it sends a clear signal that the O&S cost to achieve a stated level of affordable readiness or reliability is of the utmost importance and must be vigorously pursued. This is the intent of CAIV, but it has not been rigorously enforced to the extent of being a designated KPP.^{66,67} A start point might be to establish the affordability of large acquisition programs in terms of a set percentage of the funding of the applicable aggregate Military Force Program (MFP), or Mission Area, estimated over the new system's expected life cycle.

Matériel Developer - The matériel developer is a participant, but not the lead, during Concept Refinement and Technology Development phases. However, the senior designated matériel developer can influence the interest in TOC by contributing cost data on existing systems along with cost estimates for new technology, and by requesting that the sponsor establish TOC constraints on behalf of the user community.

The matériel developer also contributes to system affordability by holding the contractor to the stated TOC goals, including the often-controversial reliability growth projections that have a major impact on O&S costs if the growth projections are not realized.

Stakeholder Involvement - Putting together the Initial Capabilities Document (ICD) and, later, the Capabilities Development Document (CDD), most of the emphasis has traditionally been placed on the performance capabilities (the warfighting aspects)

⁶⁵ Office of the Joint Chiefs of Staff. "Joint Capabilities Integration and Development System." Chairman of the Joint Chiefs of Staff Instruction 3170.01C. 24 June 2003.

⁶⁶ Kaminski, Paul. Memorandum: "Reducing Life Cycle Costs for New and Fielded Systems (with CAIV Working Group Report attached). Office of the Secretary of Defense. December 4, 1995.

⁶⁷ Department of Defense. "Mandatory Procedures for MDAPS and MAIS Acquisition Programs." DoD 5000.2-R (including Change 4). Part 3.3.4.1. 1999.



with less vigorous attention to O&S costs and sustainment aspects.⁶⁸ To bring attention to cost and support issues, logistics personnel representing using organizations, the materiel developer, sustaining activities, and contractor organizations must be recognized and engaged as full participants in capability integration and development. Without this representation and full participation, the old ways of ignoring TOC are unlikely to change and there would be little reason to expect that O&S costs would avoid the “death spiral.”⁶⁹

Contractor participants are also value-added, and may be able to offer supporting data on technology and sustainment costs for their products or within their commodity areas, especially when offered incentives to do so. They may also offer an avenue for fresh thinking, market awareness, and the potential for commercial logistics solutions that might have utility in military applications. Insofar as they understand an emerging system’s TOC constraints and are invited and incentivized to participate in the early tradeoff processes, they may be major contributors in providing cost-effective solutions to achieve the required operational availability.

C. Documents

The relevant documents during Concept Refinement and Technology Development phases are the Initial Capabilities Document, which is prepared prior to Concept Decision, and the Capability Development Document, completed during Technology Development. An analysis of alternatives supports the CDD. Each of these documents needs to include direction on TOC and readiness or availability.

⁶⁸ Kratz, Louis. “Developing a Performance-Based Strategy.” Briefing to PEO/SYSCOM Workshop. Spring 2002.

⁶⁹ Jacques S. Gansler, “The Revolution in Business Affairs—The Need to Act Now.” *Program Manager*. September-October 1998. Reprinted from a speech given by Dr. Gansler to the Association of the United States Army, Falls Church. VA. September 2, 1998.



At the completion of Technology Development, additional documentation must be developed to support Milestone B decision. Included are the acquisition strategy and Acquisition Program Baseline, and various cost and affordability documents. All of these documents should reflect TOC system readiness targets or objectives.

Other supporting documentation such as the Test and Evaluation Master Plan (TEMP) also need to reflect cost and readiness guidance, because O&S cost should be tested.

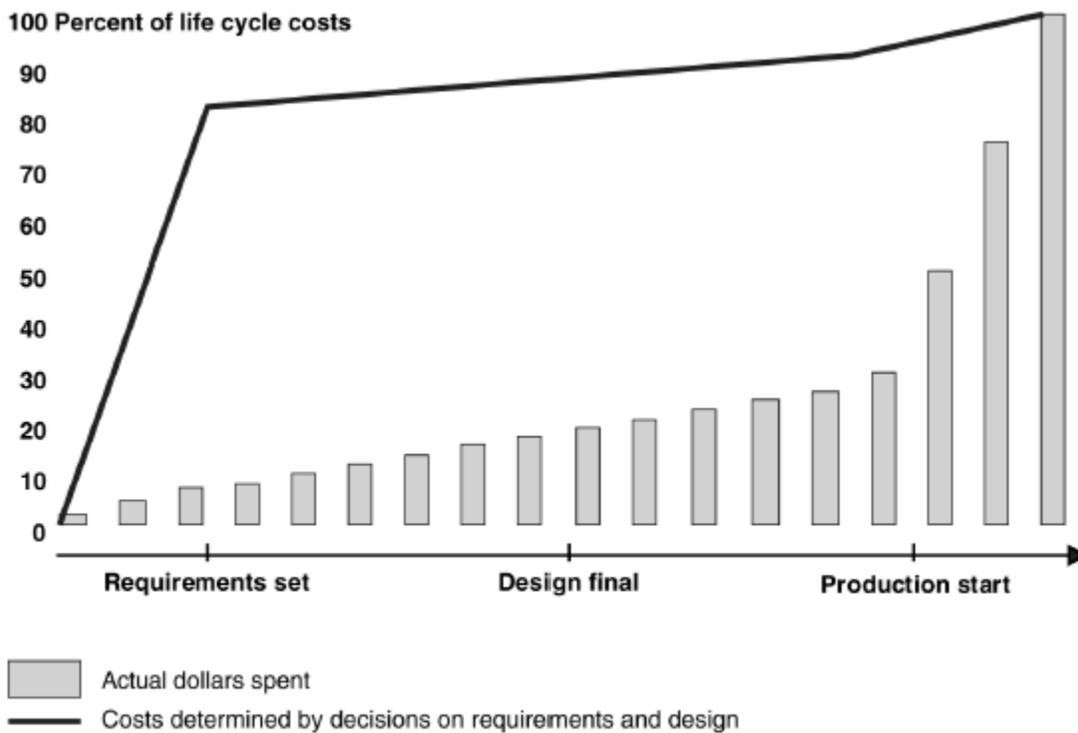
Notionally, the materiel developer puts an RFP out on the street and the contracting activity is brought to the point of contract award. Therefore, the RFP must be consistent with the cost and readiness requirements that are contained in the ICD and CDD.

D. Tradeoff Analysis Through AoAs, CPIPTs and other IPTs

Cost-Performance trades enjoy the greatest impact during these early phases. During the AoA process, which now occurs during the Technology Development Phase, performance capabilities must be determined, eventually culminating in the Capabilities Development Document (CDD). Logistics representatives and cost analysts are valued participants during that tradeoff process for systems seeking effective TOC solutions. This is the best time to establish the parameters that will govern the weapon system development. If logistics support and TOC metrics are not established during the AoA that leads to the CDD, achieving the same effect later will be more expensive, less efficient, and sometimes might not get done at all.

Figure 4, below, is taken from the GAO report on best practices in ownership cost reduction. GAO attributes the chart to DAU, and clearly, it reflects the widely held view within DoD that about 90% of the Total Ownership Cost is locked-in by the time that the requirements are set. In the revised CJCSI 3170.01C and DoDI 5000.2 guidance, this would occur by completion of the Capability Development Document (CDD).





Source: Defense Acquisition University.

Figure 4. Design Decisions vs. Expenditure of Funds⁷⁰

Analysis of alternatives is conducted by the sponsor as the CDD is developed. Cost and affordability are integral to the AoA and attention to total ownership cost should be clearly articulated in the AoA plan.

Two reasonable premises to use as a start point for tradeoff analyses are that (1) costs are constrained and (2) that tradeoff analysis is a good way of finding the best solution.⁷¹ This hardly requires a leap of faith and both premises are addressed in CJCSI 3170.01C, at least implicitly. Constrained budgets are a fact of life. CAIV and R-

⁷⁰ U.S. General Accounting Office. "Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs." Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-03-57. February 2003.

⁷¹ Kaye, Michael A., Mark S. Sobota, David R. Graham, and Allen L. Gotwald. "Cost As An Independent Variable: Principles and Implementation." *Acquisition Review Quarterly*. Fall 2000.



TOC initiatives recognize that costs must be controlled, to stay within constraints. In preparation of the ICD, the Director, PA&E may provide specific guidance, which would likely address issues of cost and affordability.⁷² Additionally, the sponsor is expected to perform cost analysis that is sufficient to make an affordability determination. The strength and clarity of the sponsor's cost guidance during the Concept Refinement and Technology Development phases may have a dramatic impact on the TOC in the tradeoff process, as will be discussed later.

Tradeoff analysis is deeply ingrained in Concept Refinement, formerly called Concept Exploration. Prior to Acquisition Reform, the tradeoff analysis in Concept Exploration was called cost and operational effectiveness analysis (COEA), and with the DoD 5000 series revisions of the mid- and late-1990s became analysis of alternatives (AoA). Both COEA and AoA (which is now accomplished during Technology Development phase) recognize the importance of getting the best “bang for the buck.” However, even though a worthy objective, the “bang for the buck” mantra is not sufficient to ensure the proper management and control of costs. Rather, weapon system affordability requires rigorous cost and system availability metrics, which should take shape during preparation of the CDD.

E. Metrics

Weapon system metrics are described in the CDD. Cost and readiness metrics belong in those documents, possibly even shown as KPP. As the process nears Milestone B, the most important metrics, KPP, automatically become part of the APB. TOC and readiness metrics should be prominent in the APB, whether or not they are KPP.

Best Commercial Practice is that TOC metrics are tightly defined very early in development. This practice corresponds to early phase documentation that is discussed

⁷² Office of the Joint Chiefs of Staff. “Joint Capabilities Integration and Development System.” Chairman



above. Yet, historically and even currently, DoD does not do this with the same rigor as commercial exemplars, such as United Airlines, FED-EX, and Polar Tanker (a subsidiary of ConocoPhillips Marine). A recent GAO report has cited those companies as clearly establishing metrics that would influence LCC during development of their systems. GAO specifically identified the United 777 aircraft, developed by Boeing; the FED-EX 70-cubic foot van, developed by Freightliner; and Polar double-hulled tanker ships, developed by Litton Avondale. In all three cases, each a proven success, the customer worked with the developer to establish specific O&S cost metrics that would control design decisions for those systems. They were able to establish metrics in part because they had cost, reliability, and maintenance records to guide them.⁷³

Since the advent of CAIV in 1995, DoD has clearly recognized the constraint on TOC funds and said that cost will be the independent variable, constraining the amount of military capability that is acquired. The question then becomes what cost metric to choose. In the past, the preference for acquisition cost metrics has been that they be relatively near-term, because the near-term can be estimated more accurately than longer-term costs, and were more palatable than TOC (considering the possible negative aspects of TOC discussed in Chapter I of this paper). However, this has been found to be shortsighted; life cycle cost (LCC), also referred to as system Total Ownership Cost (TOC), is a more inclusive metric, even though it comprises costs that stretch over the life of the weapon system. Although somewhat difficult to determine initially, life cycle cost metrics are useful and provide a means for managers to balance and control the constituent parts of TOC.

One difficulty with using TOC as a metric is that one constituent portion, operating and support (O&S), occurs many years in the future and, therefore, may not

of the Joint Chiefs of Staff Instruction 3170.01C. 24 June 2003. p. A-8.

⁷³ U.S. General Accounting Office. "Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs." Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-03-57. February 2003.



be estimated very accurately during pre-acquisition and developmental phases. Whereas this is a problem, it should not be permitted to become an overwhelming obstacle to establishing cost constraints. One of the challenges, then, is to develop TOC metrics (i.e., affordability metrics) that represent both near- and long-term system costs, which would be useful during analysis of alternatives.

F. Database & Data Collection

During pre-acquisition, a complete cost database is not available, unless the system being acquired is a commercial or non-developmental item. Less complete databases might include predecessor systems, from which preliminary costs can be estimated, realizing, however, that the past software effort may not be a good basis of estimate for a new system. When new technology is being developed in support of a new weapon system, production and O&S costs should be obtained as part of the developmental process. O&S costs can be gathered during testing, if such information is recognized as being important.

G. Activities and Tools that Support CAIV and R-TOC

Matching capabilities (requirements), technologies, schedules, costs, and acceptable risk is a rational approach during pre-acquisition. It is consistent with management of TOC and the practice of IPPD; it fits the new DoD 5000 developmental phases.

PBL begins in Pre-Acquisition as the support concepts are first considered. PBL is driven by specific warfighter support requirements. Once PBL is recognized as a requirement during pre-acquisition, provisions can be made for it. Of particular help are logisticians at various levels and in different organizations who should be encouraged to work innovatively to forge partnerships between DoD support providers and commercial providers, leveraging the core competencies of each. PBL metrics are consistent with TOC metrics, such as maintenance cost per operating hour or ton-mile.



H. Risk Management

Risk and Trade Space - The use of CAIV clearly adds risk to Concept Refinement and also to later developmental phases. First, there is increased risk in the user selection of technologies that will go into new weapon systems. If a technology is immature, unexpected R&D costs and additional schedule may be necessary to bring the technology to the point where it can be used in the new system. Component or subsystem testing may be needed to be sure that the item performs properly and to quantify its reliability. Analysis of Technology Readiness Levels may be very helpful in guiding the selection of subsystems or components. A significant task during Concept Refinement is preparation of the Technology Development Strategy, which addresses technology risk for a new weapon system. If there is a misstep or hiccup in Technology Development, the approval of a program new start can be delayed, along with attendant risk that program funding may come apart and the funding stream diverted to other programs.

The figure below depicts cost versus performance of a new technology. Risk is included in two ways. As shown in the figure, the risk dimension actually “discounts” the anticipated performance, and cost, options; in other words, it lessens the trade space to ensure a decision-maker does not trade away something that may not be attainable or affordable. Risk also may include dimensions of the trade space that are not depicted in the figure, and critical decisions may be driven by the particular risks of certain alternatives. Examples might be risk to schedule or manufacturability, for example, which are not facets of the cost- performance trade but are, nevertheless, components of trade space.



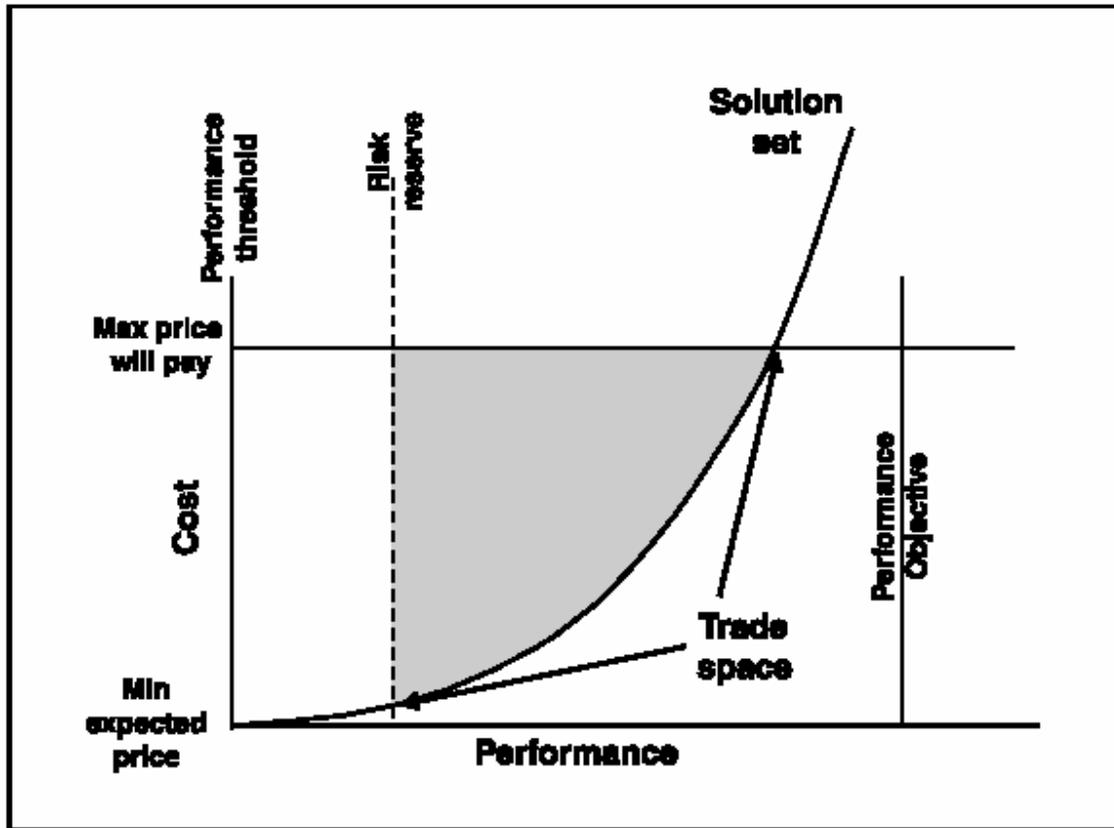


Figure 5. Cost-Performance Trade Space⁷⁴

I. Summary of the Focus for Concept Refinement and Technology Development

During these pre-acquisition phases, it is possible to get control of TOC by doing the following.

- Match requirements, technologies, schedules, resources, and acceptable risk during this pre-acquisition timeframe. If a program gets into trouble during its development, there is a high likelihood of an imbalance; i.e., one of these components that is not congruent with the others, such as use of a high-risk technology without enough time scheduled to bring it maturity.

⁷⁴ Kaye, Michael A., Mark S. Sobota, David R. Graham, and Allen L. Gotwald. "Cost As An Independent Variable: Principles and Implementation." *Acquisition Review Quarterly*. Fall 2000.



- Assemble a team that includes cost analysts and logisticians along with the usual cast of warfighters and engineers.
- Establish LCC as a key performance parameter to emphasize the importance of cost. KPP automatically will roll into the Acquisition Program Baseline, even though cost goals may need to be refined as better cost information becomes available.
- Include reliability testing and O&S cost in Technology Development.

Solicit leadership involvement in discussions of TOC in milestone decision reviews and other venues to influence the outcome, i.e., the culture of acquisition.



PART 2: SYSTEM DEVELOPMENT AND DEMONSTRATION

A. Overview of the Phase

During System Development and System Integration, which in the aggregate comprise System Development and Demonstration (SDD) phase, the primary effort is handed off from the user community to the materiel developer. Although the materiel developer takes on major responsibilities and a heavy workload, the preponderance of effort shifts to the contractor during SDD. Since the mid-1990s, much of the effort has been accomplished through the use of multi-functional teams comprised of various Government and contractor stakeholders.

The materiel developer takes much of his direction from the ICD, CDD, the approved acquisition strategy, the APB, and guidance from the milestone decision authority (MDA). PMs have strong motivation to stay within the constraints formed by those documents; the PM's performance is graded, in large measure, by the degree to which he supports or meets the objectives in those documents.

B. Leadership, Motivation, and Stakeholder Involvement

Influencing outcomes and culture continue to be the principal domain of senior leaders. If leaders set the right standards and ask the right questions, they can help to shape the acquisition system outcomes and culture.

Milestone Decision Authority - The MDA makes the decision whether or not to delay entry into SDD, if the technology is immature. He also determines whether to allow a program to advance to the next phase if the risk of failure is high, and may choose to delay unless there are overarching reasons and taking the risk is in the national interest. Both of these possibilities of delay seem, at first glance, unrelated to Total Ownership Cost. However, pushing the program ahead before it is ready may be a very expensive error that contributes to TOC. PMs are optimists as evidenced by the



preponderance of weapon programs that are over budget and behind schedule.⁷⁵ The MDA needs to be a realist.

Leaders within the sponsor and user communities need to minimize requirements and set cost goals or targets in balance with life-cycle resources. Cost goals or targets that have been identified as key performance parameters provide unambiguous direction. Clear cost constraints help to steady a program during the SDD Phase, when there is a normal user tendency to add to the requirements of the system. This phenomenon is called “requirements creep.” Strong leadership provides a counterbalance to control requirements creep.

Program Executive Officers (PEOs) and Program Managers - PEOs and PMs need to set metrics that will keep the program in balance and then manage to those metrics. The PM must work with the sponsor to achieve an equilibrium point where the weapon system capabilities are achievable within the available resources and within reasonable risk. The resources include all the funding for the weapon system over its expected life. This is system Total Ownership Cost matched against total expected resources.

PMs and Contracting Officers need to ensure that contract requirements cost and reliability / operational availability metrics are clearly stated and that contractors are incentivized to accomplish high quality, thorough TOC analysis and meet TOC goals and targets.

IPT leads (whether contractor or Government) must manage in accordance with TOC targets as well as meet performance requirements.

⁷⁵ Fleming, Quentin W., and Joel M. Koppelman, *Earned Value Project Management*, 2nd Edition. Program Management Institute, Inc. 2000.



Producibility and Logistics Stakeholders - One of the GAO criticisms of our former and current acquisition systems is the multiplicity (linearity) of stakeholders.⁷⁶ There are many interested parties and participants, representing different organizations, who need to be involved in the development, production, and logistics support of our new systems; each plays an indispensable role and contributes to the success of the program by providing his unique perspective.

Producing organizations, including prime contractor and subcontractors need to be involved in producibility issues during SDD. The producibility effort during SDD pays off on the manufacturing floor, during the production and fielding phase. Producibility is accomplished component-by-component. The Government may contribute to producibility engineering by including it in the RFP and contract; producibility questions during engineering reviews reinforce interest and encourage the contractor's efforts.

User Juries - During System Development and Demonstration, users need to be involved as the system design evolves. This includes the system sponsor and the designated user representative, but that is not enough. Uniformed personnel who will operate the equipment, along with maintenance technicians who will fix it when it breaks, are stakeholders and need to be participants in development. User reviews must be structured within the developmental phases. There are creative opportunities for participation and may include contractor technical personnel visiting and observing operations or maintenance of existing systems in the field or fleet; similarly, operator and maintenance personnel benefit from visiting developmental facilities to interact with mockups, prototypes, or Engineering Development Models (EDM). Simulators, 3-D solid models, and virtual environments offer possible venues for displaying new designs and getting user / maintainer feedback. User juries offer the potential to recognize the

⁷⁶ U.S. General Accounting Office. "Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs." Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-03-57. February 2003.



need for changes prior to production and also provide a useful forum for information about O&S cost drivers on the legacy systems.

Support organizations - User juries answer part of the need, but are unlikely to embrace all of the operations and support issues. Supporting organizations—those that supply the parts; store the parts, components or even the weapon system, itself; perform the various levels of maintenance; provide the in-service engineering; conduct the operational planning, plan and conduct training; and, doubtless, many other sustaining functions—need to participate in SDD at selected times and be given the opportunity for buy-in to the developmental process.

Producibility and logistics design considerations are not necessarily congruent. Sometimes, producibility improvements interfere with system supportability. Part of the work of minimizing TOC is de-conflicting producibility and supportability. Subordinate IPTs working at the subsystem or component level may be chartered to de-conflict producibility and logistics facets. Building prototypes or Engineering Development Models and then operating and maintaining them presents very concretely the conflicts between producibility and supportability. The metrics by which the de-conflicted design solution must be measured include total ownership cost (TOC), reliability, and maintainability.

C. Documents

The following documents are relevant during this phase.

- CDD is considered a living document during the SDD phase. This may present an opportunity to sharpen the procurement (APUC) and O&S cost goals.
- The Capability Production Document (CPD) is prepared during SDD and finalized after the critical design review (Design Readiness Review). Any reduction in a key performance parameter (KPP) “requires an assessment of the military utility of the



reduced capability and, possibly, a reexamination of the program to determine if an alternative materiel or nonmateriel solution should be adopted.”⁷⁷

- Acquisition Strategy. This document needs to be updated to reflect changes to the strategy for achieving readiness or affordability.
- RFP—Statement of Work, Instructions to Offerors, and Source Selection Criteria. The RFP establishes a formal dialog with the contractor to clarify what the Government expects the contractor to accomplish.

D. Tradeoff Analysis through CPIPTs and SUB-IPTs

Cost-Performance IPTs are a well-recognized approach to tradeoff analysis. CPIPTs have been part of the IPT landscape since the mid 1990s for the purpose of conducting cost-benefit analyses. These IPTs need to be supported by good cost data and analysis, and the strong voices of the user and the logistician. CPIPT decisions need to be “best value,” achieving acceptable performance metrics (including RMA) while staying within TOC goals. During SDD Phase, the CPIPT make-up should include the strong participation of the contractor. Besides the technical information that the contractor can provide, he may benefit from the exchange by learning where the customer’s values really lie; additionally, the CPIPT provides a forum to achieve contractor and customer buy-in.

The materiel developer and contractor continues to balance capabilities, resources, and schedule throughout the developmental and production phases in the following ways. Preparation for each milestone requires an affordability assessment that is required at both milestones B (entry into SDD) and C (entry into Low Rate Initial Production). Additionally, the practice of IPPD and/or EVM calls for breakdown of work effort for management and control purposes. The materiel developer begins the process by establishing the first three levels of the WBS as part of the RFP. The

⁷⁷ Office of the Joint Chiefs of Staff. “Joint Capabilities Integration and Development System.” Chairman of the Joint Chiefs of Staff Instruction 3170.01C. 24 June 2003. p. A-10.



contractor is then required to respond to the RFP with information several levels below the three provided. As the work effort begins, the contractor will need to divide the effort to the work package level, assuming that EVM is a requirement of the contract. Work packages are then assigned resources, schedule, and managers or work teams assume responsibility. In the same way that work effort and cost are divided all the way to the work package level, reliability and TOC objectives are set, as described in the metrics section, below.

Performance-Based Logistics includes different mixes of Government-contractor involvement. At one end of the logistics pipeline is contractors and vendors, while at the other end is the operator. All the support “in-between” can be set up in the way that best serves the taxpayer and responds to the needs of the warfighter. The R-TOC Pilots Programs provide varied examples of support arrangements that include different stakeholders in partnership. Prime Vendor Delivery and Direct Vendor Delivery are both being used, as are contractor-Government partnerships. PBL should be a major tradeoff activity during SDD.

E. Metrics

Cost and Reliability Targets - Costs and reliability must be controlled down to the subsystem and component level. The Work Breakdown Structure provides a suitable framework. Every system component should be described by WBS element(s), including design cost, testing cost, procurement cost, O&S cost, and such other metrics as reliability and maintainability. These targets or objectives are set, then progress toward achieving them is monitored and management action taken consistent with the progress being shown. It is obvious that management at the level of each component is a daunting task, but it is a task that should be expected of subordinate IPTs that are responsible for the various components. Report roll-ups can be accomplished as necessary to satisfy the leadership levels—both Government and contractor. Subsystem or component development must be individually managed consistent with whether it is meeting its performance (including reliability & maintainability) and TOC



metrics. The aggregated component reliabilities must achieve the warfighting system readiness or operational availability goals within the Total Ownership Cost of the weapon system.

In the area of software, development and supportability metrics are critical in controlling costs in software-intensive systems. An uncontrolled software development process that is not keyed to supportability will prove disastrous in the acquisition phase, impacting cost, schedule and performance, and will be either extremely costly to support or totally unsupportable during the O&S phase.

F. Database & Data Collection

One of the impediments to effective TOC management may be that cost information on existing systems is inaccurate, incomplete, or difficult to obtain. Each of the Services has weapon system cost information, Visibility And Maintenance of Operating and Support Costs (VAMOSC),⁷⁸ but each has experienced difficulty in providing complete and accurate cost information on legacy systems. Within the past several years, the available literature on the R-TOC Pilots and VAMOSC websites indicates that the all the Services have expended great effort in cleaning up their cost databases, so as to provide better historical cost information, more easily.

Approach To Collecting Cost Metrics - There are different approaches to gathering cost and RMA data, in terms of sample data or continuous, contractor-gathered or Service-gathered, choice of maintenance level for data collection, and the number of components that should be tracked. Data at the subsystem or component level should include such information as item cost, estimated inherent reliability, number of failures, modes of failure, actual MTBF, MTTR, and cost of repair. Whatever the choices related to data collection, the information is necessary for early CAIV decisions, as well as later R-TOC decisions.



G. Activities and Tools that Support CAIV and R-TOC

Reliability Testing Not Later Than System Integration (SI) Phase - The General Accounting Office, in comparing DoD developmental techniques to commercial best practices, points out that DoD systems often embrace cutting-edge technologies.⁷⁹ Good risk management practice suggests that subsystems and components need to demonstrate their required reliability not later than the SI phase.⁸⁰ If technological maturity, including reliability, cannot be demonstrated by that time, then a lower risk alternative would be to categorize the subsystem or component as a candidate for evolutionary upgrade, and use a more mature subsystem or component instead. If the new component is necessary to achieve a key performance parameter, then the whole development may need to be delayed. In the past, the program would likely move ahead, in hopes that an immature subsystem or component could catch up. However the newly released DoD 5000 series appears to have broken with past practice, as described below.

The completion of System Integration is now formalized by a Design Readiness Review. As described in DODI 5000.2, this review provides an opportunity for the MDA to conduct a mid-phase assessment of design maturity and specifically includes "...system reliability based on demonstrated reliability rates." The MDA determines the form and content of the review.

Modeling and Simulation - During System Demonstration, modeling and simulation play a key role related to TOC. It is through these means that system O&S costs are estimated. Additionally, modeling and simulation help contractor and materiel

⁷⁸ Assistant Secretary of Defense (Program Analysis and Evaluation). "Cost Analysis Guidance and Procedures." Department of Defense. DoD 5000.4-M. December 1992.

⁷⁹ U.S. General Accounting Office. "Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs." Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-03-57. February 2003.

⁸⁰ Ibid.



developer to better understand system reliability. Often, modeling and simulation provide early indication of system reliability anomalies that will affect TOC.

Intensive Management of the Cost drivers - As Engineering Development Models (EDMs) or prototypes go through testing, test data is generated that should be thoroughly scrubbed in search of cost drivers. These cost drivers may take different forms, such as high repair parts usage, immature diagnostic routines, extensive maintenance man-hours, slow repair cycle or turnaround times, high-cost repair part stocks, and large logistics footprint. Typically, program offices are focused on technical performance, and staying on schedule, and continuing on the glide path toward successful entry into production during this period. However, testing provides signals that require program attention to avert costly mistakes in production and sustainment phases.

H. Risk Management

A well-crafted and well-run risk management program continually searches out the program uncertainties, and can be tuned to recognize and respond to issues that impact procurement cost and O&S cost. Several risks that attend TOC are as follows. First, developmental costs may exceed plans, due to the requirement for increased front-end analysis. Similar to the early development costs related to the use of IPTs, TOC analysis may increase the cost of early development. However, those costs should be recouped in cost savings or avoidance later. Second, there is always a temptation to make design decisions that reduce procurement costs, but increase O&S costs and aggregate system TOC. That is why cost decisions need always to consider reliability impact. Third, improvements in performance, including RMA, must be accompanied by affordability calculations. In sum, TOC and performance must always be kept in balance.



PART 3: PRODUCTION PHASE AND DEPLOYMENT TO THE FIELD OR FLEET

A. Overview of the Phase

This is the point at which the efforts of designers, manufacturers, materiel developers, sustainers, testers, and users all come together. The design is actually manufactured, tested, issued to the warfighter, and then supported. All of the planning and coordination, literally over years, is focused on making production, deployment, and sustainment a success. However, the success or failure of a weapon system is not instantly determined and there are no perfect systems. For example, the M1 Abrams Tank system, more than 20 years after the first production in 1980, is recognized for its battlefield dominance during Operations Desert Storm and Iraqi Freedom, its agility over rough terrain, its ability to fire accurately “on the move,” and especially its armored protection of crewmembers. However, the M1 is also recognized for its poor engine reliability, limited strategic deployability, burdensome software support requirements, and enormous fuel cost. This warfighting system provides a wonderful example of where tradeoff analysis can leave a system, i.e., a great warfighting system that has difficulty getting to the battle and costs too much to operate.

It is interesting to note that the M1 Tank had a cost constraint during its development: design to unit production cost (DTUPC), mandated by Congress. And, M1 stayed within that constraint. DTUPC was an important metric but not the best choice of metric. Better metrics would have more completely addressed TOC (to include DTUPC along with O&S cost) and operational availability. Observation of cost and availability statistics during testing told the stakeholders that M1 was a very expensive warfighting system to operate, but during the height of the Cold War, the present-day CAIV approach would have been considered reckless within DoD.

The message in the M1 Tank story is that stakeholders need to pay attention to the lessons that come out of testing. Logistics lessons from testing include inherent



reliability of components, diagnostic and repair procedures, logistics footprint, and stockage levels, and the O&S costs that are required to meet required availability. The day-to-day workload for acquisition logisticians during this period and the inertia of the logistics systems provide a ready-made excuse to ignore the logistics lessons that show up in testing or postpone implementation of the necessary corrective actions. However, taking aggressive action on the logistics lessons learned serves the user and maintainer better.

Accomplishing logistics support through a contract can result in the capture of better information and also provide a more flexible logistics response than would be attained by a Government-only logistics system. Especially during the transition period when DoD is just learning to operate and support a new warfighting system, buying support from the contractor can help smooth the transitional rough spots; however, use of contractor personnel needs to be synchronized with Service practices. For example, establishing a worldwide help desk to provide expert contractor assistance on diagnostics for a particular ship system might be preferable to having contractor personnel physically aboard ship.

B. Leadership, Motivation, and Stakeholder Involvement

Continual Leadership Attention - The leadership can help out by asking for feedback related to Operating and Support cost and readiness. Leadership interest is particularly important during the Production and Deployment Phase, because early problems may cross organizational boundaries and involve personnel from different functional areas who are not familiar with and do not understand one another. Leadership involvement in readiness reviews and problem-solving meetings can help set the right tone.

Customer Feedback - Rapid response to customer problems encourages crisp solutions, minimizing the cost of failures and impact on readiness. Rapid response can



be encouraged by well-constructed contractor incentives and is further addressed below.

Value Engineering - Value engineering may be written into a contract as an incentive to the contractor to share cost savings or it can be contracted as a work effort that is directed by the Government. Good results from the VE program would seem to result from a highly motivated contractor; recent FAR changes that increase the contractor's share of savings ought to encourage the contractor to look for production or O&S cost drivers and offer corrections for poorly performing subsystems or components.

Contractor Incentives Tied to Reliability or Operating & Support Costs - In addition to the incentives that attend Value Engineering, the contractor can also be motivated by carefully constructed warranty clauses. For example, Reliability Improvement Warranties offer incentive to the contractor to improve system reliability and thereby pocket savings on the extant contract. Availability guarantees or mean time between failure guarantees may also encourage the contractor to offer expeditious corrective action to fix poor performing components. Possibly, warranty can be combined with prime vendor support in such a way that it is cost-effective, responsive to the user, and at the same time minimally invasive to the end-user.

The materiel developer, the user / sponsor, sustaining organizations, field or fleet representatives, and contractor representatives should meet regularly during deployment of a new warfighting system into service. Team play does not diminish in importance during the Production and Deployment phase; it only gets more intense. At the same time, the center of gravity shifts from the design effort, to testing, to production, to the operator and maintainer. Especially at this stage, aggressive team response to the inevitable problems will work much better than individuals or organizations casting blame on one another.



C. Documents

The following documents are relevant during this phase.

- Capability Development Documents (CDD) and Capability Production Documents (CPD) continue to be updated in the case of evolutionary or spiral development. This presents an opportunity for the sponsor to refine cost and readiness goals.
- Acquisition strategies for evolutionary acquisitions should describe plans for improving TOC.
- RFP (including the Statement of Work, Instructions to Offerors, and Source Selection Criteria) can be written to focus the contractor's efforts toward meeting performance goals within Total Ownership Cost parameters. Follow-on support agreements can be competitively awarded, with the clear understanding that future work is tied to performance (whether contractor or Government). One technique that maintains competitive interest of the winning support contractor is the contract awarded for one or two years of support, but including a number of one-year options. With this form of contract, the support contractor knows that his future business is tied to his performance on the current contract.

D. Tradeoff Analysis through CPIPTS and other IPTS

During production and deployment, tradeoff analysis takes the form of detecting the cost drivers and determining the best ways to reduce them. The presentation of the trades begins to take the form of business case analyses (BCA). During this phase, seeking funding outside of the program is a competitive adventure, where the best business case analyses compete to attract the limited funds available.

E. Metrics

During this phase, average procurement unit costs evolve into "from actuals." At first glance, it would seem that procurement costs would become locked-in over time. Yet, competition may help overcome the inertia: sometimes at the level of the prime contractor and sometimes with subcontractors and vendors.



Average procurement unit cost (APUC) computed by lot is of historical interest because of trend information. However, manufacturing process improvement is probably better measured by the contractor's improvement in man-hours per unit produced and reduction in the cost of work-in-process inventory.

O&S costs can be refined during the phase, depending on the capability of the cost analysis system being used. Some of the R-TOC Pilot programs appear to be obtaining their cost analysis through their contractors.

Initially, it is important to look for "bad actors," cost-drivers that may need corrective action. At the component level, emerging failure information may suggest a cost-driver. One of the operative questions is whether a component is meeting its reliability predictions.

The contractor needs to be looking for cost-drivers, too, and depending on incentives in the contract will be more or less responsive to the need for failure analysis and corrective action. To the Service, the main issues are cost versus readiness. For the contractor, the key issues are profit and future business. Continuing dialog amongst the stakeholders is important to keep stakeholder objectives aligned and ensures continued cooperation.

Operational Availability or readiness is routinely tracked and a useful additional computation may be the cost per mile (or hour or round) at the required A_0 . This would be a good statistic to show trend against the original baseline.

F. Database & Data Collection

Databases and data analysis have been discussed in the body of this paper. Service databases are providing input to analytical models that calculate O&S costs; however, the use of different databases presents some anomalies that may be corrected over time. In some cases this analytical effort is being contracted out. Sample data collection offers an alternative source of information that can be used



selectively; sample data collection is expensive, however, it may provide more accurate information in focused areas.

G. Activities and Tools that Support CAIV and R-TOC

Analysis of Emerging Data in Search of Cost drivers - is discussed above.

Reliability-Centered Maintenance - Whether or not RCM was used in earlier phases of a program, it provides an orderly approach to maximize readiness and avoid wasteful maintenance efforts. This could be used selectively to analyze potential cost-drivers.

Purchase of Spares in Conjunction with the Production Contract - Initial spares are ordinarily part of the production contract, paid out of procurement funds. Follow-on spares are paid by Operating and Support funds and are usually contracted separately. Purchase of follow-on spares through ongoing production contracts offers the possibility of reduced prices if economic order quantities can be achieved.⁸¹

Earned Value Management - If the production contract is a cost type, earned value management is normally required. Often Government buying organizations do not understand EVM and do not recognize when cost or schedule goals are unrecoverable.⁸² If a fixed price contract is in force, then EVM is not required, but should still be encouraged as a method by which the conscientious contractor can manage more tightly.

Aggressive Quality Management, Particularly Root Cause Analysis and Corrective Action - If the contractor reacts aggressively to quality defects and vigorously

⁸¹ Bogner, Michael, Chuck Wong, and Bernie Price. "Quantity Discounts/Economic Order Quantity: New Quantity Discount Analysis Tool Lets DoD Buyers Save on Total Cost and Receive More Goods." *Program Manager*. September-October 2002.

⁸² Fleming, Quentin W., and Joel M. Koppelman, *Earned Value Project Management*, 2nd Edition. Program Management Institute, Inc. 2000.



seeks corrective action, the result should be reduced cost to the Government. Incentives to achieve this kind of contractor behavior have already been discussed briefly. Additionally, the corrective solutions should routinely be reviewed for both production and logistics cost impacts. Good contractor review processes should be the “first line of defense” against production or O&S cost growth.

Lean Manufacturing - In 1993 the Lean Aerospace Initiative was launched, as a partnership between the United States Air Force, Massachusetts Institute of Technology (MIT), and aerospace businesses. Within the past two years, the Army Materiel Command has attempted to apply lean techniques in Army logistics depots, through cooperation with defense contractors. The Defense Acquisition University now offers an on-line continuous learning tutorial on lean concepts, “Introduction to Lean Enterprise Concepts.”⁸³ This movement toward use of lean techniques suggests possible reductions in TOC across development, production, and sustainment.

Lessons Learned from Testing - Testing may provide important lessons learned that might be used to reduce O&S costs. Besides the discovery of subsystems or components that exhibit poor reliability, other lessons appear. For example, faulty diagnostic or repair activities may show up in testing. Lessons learned may reflect in recalculation of stockage levels, improved diagnostic routines that reduce findings of “no fault evident (NFE),” and reduced secondary damage attributable to maintenance work.

Relentless Updating of Technical Manuals - During the period when a new warfighting system is introduced into the fleet or the field, the user community looks at that system with a fresh “set of eyes,” possibly awed by the system’s performance attributes. As the “newness” wears off, and users and maintenance personnel become more familiar with the equipment, they may inadvertently begin to overlook those aspects of the technical publications that are in need of correction.

⁸³ Defense Acquisition University Homepage, <http://www.dau.mil/>. n.d.



Implementation of Performance-Based Logistics - The logistics support planning accomplished during the developmental phases culminates in logistics structures that are set up during this production and deployment time frame. In some instances, creative contracting approaches must be used, particularly to launch public-private partnerships. The contractual arrangements must be fair, flexible, and innovative. Arriving at the best results depends on good dialogue between the uniformed user, the materiel developer who planned the support structure in the first place, and the organizations (DoD and contractor) that provide logistics support. The number of stakeholders is well recognized as an obstacle to Total Ownership Cost reduction.

H. Risk Management

A warfighting system risk management program continues to offer benefit during production and deployment. If it is conducted by sub-IPTs that are focused at the subsystem or component level, solutions can be balanced to address both logistics and production concerns. Risk management certainly can be made to include root cause analysis and corrective action programs for product defects that show up in production, in the training base, or in operational service. Although most of the risk management effort is likely to occur within contractor organizations, it is best managed centrally, with roll-up reports for higher-level program IPTs that include contractor, materiel developer and user. An integrating IPT should meet regularly and include Government PM and senior contractor personnel who can both energize the workforce and support efforts that take place at the sub-tier IPT levels.



PART 4: SUSTAINMENT PHASE

A. Overview of the Phase

This phase represents a major transition of responsibility from the acquiring organization to the sustaining organization. Depending on Service and type of warfighting system, the program management office may be terminated, or greatly reduced in size. Ordinarily, there is little funding for in-service engineering. There may not be a prime contractor in this phase, depending on how logistics support is structured.

B. Leadership, Motivation, and Stakeholder Involvement

Leadership emphasis comes from the user and the sustaining command. Active dialogue usually addresses supply and maintenance issues. Total Ownership Cost issues need to be placed in the spotlight by the users.

Sustaining commanders need to continue to emphasize identification of cost-drivers. Current best practices have achieved some of the largest cost savings through partnering. For example, Common Ship Systems has found major R-TOC initiatives in reducing crew labor (sailor man-year savings). H-60 Series Helicopters have identified RMS improvements that have led to combined models and simplified fleet management.

There continues to be a need for communications among the stakeholders and a forum for ongoing discussion that includes sponsor, user, and sustaining organization.

C. Documents

Generic documentation that the sustaining organization needs includes a prioritized plan and detailed supporting information, to include business case analyses.



D. Tradeoff Analysis through Teams

Even though standing teams probably do not exist in the same way as with programs that are being actively developed or produced, there is still value in putting together *ad hoc* teams that include sponsor, user, sustaining organization, maintainer, and in-service engineering.

Business case analysis (BCA) to support an R-TOC initiative competes against other R-TOC BCAs for limited funding. Competitive success is primarily based on the best return on investment (ROI), as presented in a BCA, which has been independently validated.

E. Metrics

The principal determinant that decides “winners and losers” is ROI. Obviously, the size of the investment is also a factor; an R-TOC initiative that has the flexibility to adjust the scope may be able to improve its chances for selection. Additionally, the shorter the payback, the more competitive is the initiative.

Underlying the competitive selection of R-TOC initiatives are two factors: the reduction in ownership cost and the associated improvement in performance. Not surprisingly, lower cost usually brings better performance, such as higher availability, higher reliability, or improved maintainability. Sometimes there are other improvements in warfighting performance, as well.

F. Database & Data Collection

Funding to support systems in the sustainment phase is normally minimal; therefore, available data would come from existing Service databases. However, in some instances, logistics contractors may keep data as part of ongoing logistics contracts. Where commercial items or components are being used, the commercial contractor may maintain a database.



Funding Software Support. The software annual change traffic (ACT) provides an indicator for the number of software professionals that will be needed to adequately support the system throughout its life cycle. This software support is a major O&S cost driver for software-intensive systems and must be accurately estimated to ensure that the software does not cause the system to lose its effectiveness due to loss of software functionality or lack of upgrades.

G. Activities and Tools that Support CAIV and R-TOC

Available tools include the following:

- Commercial Operating and Support System Initiatives (COSSI).⁸⁴ Brief discussion of this subject is located in Chapter IV, paragraph G, and may be found on pages 39-41.
- Reliability-Centered Maintenance. As stated previously, whether or not RCM was used in earlier phases, it provides an orderly approach to maximize readiness and avoid wasteful maintenance efforts. RCM could be used selectively to analyze potential cost-drivers.

H. Risk Management

Due to the reduced management during this phase, risk management might be expected to be performed as part of other activities, such as postproduction support, DMSMS, and RCM reviews.

⁸⁴ Holland, Charles J. and Donna Richbourg. "Commercial Operations and Support Savings Initiative Handbook." Office of the Under Secretary of Defense. 14 December 2001.



CHAPTER VI: FINDINGS AND CONCLUSIONS

As a system progresses from early concept, through prototyping, into production, and finally reaches the sustainment phase, the opportunities to significantly reduce Total Ownership Cost diminish. This clearly indicates that R-TOC efforts are most effective early in the developmental cycle where changes are least expensive and easiest to implement. The possible effect of a balance between capabilities and affordability is that *more warfighting assets are available to the warfighter*. To that end, the TOC stakeholders outlined earlier have a vested interest in influencing the system design and development, especially early in the process, to yield a suitable, effective, and *affordable* solution. The challenge is how to accomplish this goal.

An answer to this challenge has been postulated earlier – make TOC goals part of the system key performance parameters (KPP). One of the only methods of keeping the TOC goals from being in the “trade-space” for CAIV or other tradeoff analyses is to designate those goals as KPP. As with other KPP, the TOC KPP would be considered as a mandatory threshold and the use of other tools and techniques would then serve to reinforce the importance of TOC. As KPP are also part of the Acquisition Program Baseline, TOC would receive attention from decision-makers at every level, throughout the developmental process.

Tools, Techniques and Concepts Supporting Efficient TOC Solutions

CAIV and Other Tradeoff Analyses - With a firm understanding of those performance characteristics (hopefully, including TOC) that the warfighter deems critical to the system effectiveness and suitability via the KPP, CAIV analysis techniques can be used to effect TOC reduction on subsystems, features, and capabilities in the “trade-space” – items not identified as KPP. These analyses serve the materiel developer in balancing system capabilities, technologies, schedules, and costs within the parameters set by the sponsor. Proper identification of performance parameters and closer



connectivity between materiel developer and sponsor will help ensure that the developed system is effective, suitable, and affordable.

In addition to cost tradeoffs, other tradeoff analyses may reduce system TOC. A high maintenance, low availability, cutting-edge system that is not a KPP requirement might be traded-off or deferred to a future block upgrade, allowing the technology to mature, reliability to improve, and life cycle cost to decline. Schedule tradeoffs, while always undesirable, may allow software engineers to more fully test and integrate a critical software function, eliminating frustrating downtime and costly diagnostics. Both of these tradeoffs would reflect reduced TOC.

Integrated Product Teams - Cost-Performance IPTs play a key role in tradeoff analyses that impact TOC and other IPTs can, and should, participate in reducing costs, as well. By their nature, IPTs solve problems and make recommendations based on their research of a particular program aspect in accordance with their charter. If each IPT charter includes the goal for reducing TOC within their area of concentration, significant opportunities for TOC reduction could be captured.

Ownership Cost Databases - We currently are limited in our understanding of life cycle costs for the systems we support now, due to the lack of reliable information databases. Without that knowledge, we are limited in estimating the impact of TOC reduction efforts on those life cycle costs. Asking a program how much they will save by a R-TOC effort is rather like asking a person the distance of the path he *didn't* take and comparing it to the one he did. Someone else certainly has traveled the other path, but there is simply no record of it. Establishing RMS cost databases may seem an expensive initiative, but the knowledge gained from capturing sustainment costs would help focus R-TOC efforts and influence the design of future systems, bringing about a better balance of capabilities and affordability.

Contractor and Government R-TOC Incentives - The profit incentive present in the commercial marketplace provides DoD with a powerful tool for reducing TOC.



Contract incentives (e.g., reliability improvements, increase in MTBF, and reduced maintenance cycle time.), Value Engineering Change Proposals (VECPs), shared savings from cost reduction initiatives, and other incentives motivate the contractor to perform in a manner that enhances their profit and reduces TOC of the weapon system – a true “win-win” situation.

Source selection criteria shape how contractors compete for development, production and Contractor Logistics Support (CLS) contracts and, therefore, TOC elements in the Source Selection Plan impact in a positive way the proposals that contractors submit. In the case of Public-Private competition or partnerships for Logistics Support contracts, the same concept applies – the winning bidder must present the most advantageous proposal and the source selection criteria define those parameters. Selecting key TOC elements as source selection criteria ensures that the competing entities focus on methods of achieving TOC efficiencies to gain advantage over other bidders.

TOC incentives for Government sponsors⁸⁵ and materiel developers have been less effective than desired. While TOC is obviously important to the Combat Developer and user community, more emphasis has been placed on emerging warfighting capabilities and modernization efforts than on TOC performance in the early stages of development – stakeholders are more interested in “what the weapon system will do” than “what it will cost to do it.” After introduction to the field or fleet, typically, TOC has become an issue and R-TOC efforts initiated in response – precisely at the point in development where such efforts are most costly and least effective.

Following suit, the materiel developer communities focus on those APB elements, including KPP specified by the sponsor in the capability documents. With little TOC emphasis passed from the sponsor in the defining capability documents,

⁸⁵ The term, “sponsor,” is consistent with CJCSI 3170.01C. Sponsor supercedes the term, “combat developer,” which may still be used in some DoD communities.



materiel developers have the incentive to manage to the *acquisition cost*, program schedule, and specified performance. The reason materiel developers are focused on the acquisition costs is that, typically, the program and budget elements they manage are RDT&E and Procurement funding, which relate primarily to the acquisition cycle, but only represent about 20 percent of TOC. Except for TOC-related KPP, TOC elements inevitably drop into the “trade-space” for managing to the acquisition cost, program schedule, and performance identified by the Combat Developer. This often sub-optimizes TOC by trading-off features / functions (resulting in higher O&S costs) in favor of lower acquisition cost, even though O&S costs consume about 80 percent of TOC.

Reduction in Total Ownership Cost (R-TOC) - Although R- TOC initiatives are more effective and less costly when performed early in the development cycle, TOC reduction can be effective throughout the system’s life cycle. Confirming, through cost-benefit analyses, that R- TOC initiatives will reduce cost, these initiatives will likely result in increasing capability for the warfighter. More funding available in the acquisition phase or in the O&S phase, either provides more assets directly (acquisition phase) or frees funding to improve readiness rates (O&S phase). Therefore, R- TOC initiatives are effective when evaluated on their own merits and not coupled to other interests such as increased system capability.



APPENDIX 1: ACRONYM LIST

3-D	Three-dimensional
AAAV	Advanced Amphibious Assault Vehicle
ABC	Activity-Based Costing
ACAT I	Acquisition Category I
ACAT II	Acquisition Category II
AFTOC	Air Force Total Ownership Cost
AH-64	Apache Attack Helicopter
A _o	Operational Availability
AoA	Analysis of Alternatives
APB	Acquisition Program Baseline
AT&L	Acquisition, Technology and Logistics
APUC	Average Procurement Unit Cost
BCA	Business Case Analysis
CAIG	Cost Analysis Improvement Group
CAIV	Cost as an Independent Variable
CBO	Congressional Budget Office
CDD	Capability Development Document
CFA	Crossed-Field Amplifier
CG-47	Aegis Class Cruiser
CH-47	Chinook Cargo Helicopter
CI	Commercial Item
CJCSI	Chairman, Joint Chiefs of Staff Instruction
CLS	Contractor Logistics Support
COEA	Cost and Operational Effectiveness Analysis
COSSI	Commercial Operations and Support Savings Initiative
CPD	Capability Production Document
CPI	Communications and Power Industries
CPIPT	Cost-Performance Integrated Product Team
CVN	Aircraft Carrier



DAU	Defense Acquisition University
DMSMS	Diminishing Manufacturing Sources and Material Shortages
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DR	Decision Review
DRMO	Defense Reutilization Management Office
DRR	Design Readiness Review
DTUPC	Design to Unit Production Cost
DVD	Direct Vendor Delivery
EA-6B	Prowler Electronic Warfare Aircraft
EDM	Engineering Development Model
EUL	Economic Useful Life
EVM	Earned Value Management
EVMS	Earned Value Management System
FAR	Federal Acquisition Regulation
FED-EX	Federal Express
FMC	Fully Mission Capable
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects, and Criticality Analysis
FMS	Foreign Military Sales
FY	Fiscal Year
GAO	General Accounting Office
ICD	Initial Capabilities Document
ICE	Independent Cost Estimate
IDA	Institute for Defense Analysis
IPPD	Integrated Product and Process Development
IPT	Integrated Product Team
ITAS	TOW [Missile] Improved Target Acquisition System
J&A	Justification and Approval
JCAPS	JSTARS Cost and Performance System



JROC	Joint Requirements Oversight Council
JSF	Joint Strike Fighter
JSTARS	Joint Surveillance Target Acquisition Radar System [Aircraft]
KPP	Key Performance Parameter
LCC	Life Cycle Cost
LPD-17	Amphibious Transport Dock Ship
LRIP	Low Rate Initial Production
HAZMAT	Hazardous Material
HEMTT	Heavy Expanded Mobility Tactical Truck
MA	Mission Area
MAP	Military Assistance Program
MBO	Management By Objectives
MC	Mission Capable
MDA	Milestone Decision Authority
MFP	Military Force Program
MIL	Military
MIT	Massachusetts Institute of Technology
MRSP	Mobility Readiness Spares Package
MTBF	Mean Time Between Failure
MTBHMf	Mean Time Between Hardware Mission Failure
MTTR	Mean Time To Repair
MTVR	Medium Tactical Vehicle Replacement
NFE	No Fault Evident
NMC	Not Mission Capable
O&M	Operations and Maintenance
O&S	Operating and Support
OPTEMPO	Operational Tempo
OSCAM	Operating and Support Cost Analysis Model [Trade Name]
OSD	Office of the Secretary of Defense
OTA	Other Transaction Authority
OTC	Oshkosh Truck Corporation



PA&E	Program Analysis and Evaluation
PBL	Performance-Based Logistics
PDRR	Program Definition and Risk Reduction
PL	Public Law
PEO	Program Executive Officer
PM	Program Manager, Project Manager, or Product Manager
PMO	Program Management Office
PROSE	Partnership to Reduce Operating & Support Cost Engine
PV	Prime Vendor
PPSP	Postproduction Support Plan
RAM	Reliability, Availability, Maintainability
RCM	Reliability-Centered Maintenance
RDT&E	Research, Development, Test & Evaluation
RFP	Request For Proposal
RMA	Reliability, Maintainability, Availability
RMS	Reliability, Maintainability, Supportability (or Sustainability)
ROI	Return On Investment
R-TOC	Reduction in Total Ownership Cost
SA	Supportability Analysis (or Analyses)
SAR	Selected Acquisition Report
SDD	System Development and Demonstration
SH-60	Multi-Mission Helicopter
SI	System Integration
SLAM-ER	Standoff Land Attack Missile Expanded Response
Sub-IPT	Subordinate Integrated Product Team
TEMP	Test and Evaluation Master Plan
TOC	Total Ownership Cost
TOW	Tube-Launched, Optically-tracked, Wire-guided Missile
US	United States
USD(A&T)	Under Secretary of Defense (Acquisition & Technology) (now USD(AT&L))



USD(AT&L)	Under Secretary of Defense (Acquisition, Technology & Logistics) (formerly USD(A&T))
VAMOSOC	Visibility and Management of Operations and Support Costs
VE	Value Engineering
VECP	Value Engineering Change Proposal
WBS	Work Breakdown Structure



APPENDIX 2: CROSSWALK BETWEEN CJCSI 3170.01C AND CJCSI 3170.01B

Much of the activity that takes place during Concept Refinement (formerly Concept Exploration) is described in CJCS Instruction 3170.01C, “Joint Capabilities Integration and Development System,” published 24 June 2003. Here is a short review to assist the reader to crosswalk between this new policy and previously published guidance. CJCSI 3170.01C supercedes CJCSI 3170.01B, “Requirements Generation System,” 15 April 2001. The earlier document referred to Mission Need Statements (MNS), Operational Requirements Documents (ORD), and the requirements generation process. The new terminology describes Initial Capabilities Document (ICD), which replaces the MNS; Capability Development Document (CDD) replaces the ORD; Capability Production Document (CPD) is a reissue of the CDD to support the Milestone C Decision Review, which leads to the Production and Deployment phase. The new process is called the Joint Capabilities Integration and Development System (JCIDS) and replaces Requirements Generation.⁸⁶

It would be value-added if the ICD for a weapon system was required to include a ceiling cost that the Service could afford to pay for the specified capabilities over the life cycle: that is, the weapon system TOC. However, Service sponsors are not required to include TOC constraints in the Initial Capability Document. The CJCSI 3170.01C guidance regarding preparation of the ICD is that relative cost and sustainability are considered for the approaches under consideration and, additionally, that the D, PA&E may provide specific guidance, as approved by the MDA. The intent of the instruction appears to leave the door open for inclusion of a TOC constraint but does not mandate its inclusion.

⁸⁶ Office of the Joint Chiefs of Staff. “Joint Capabilities Integration and Development System.” Chairman of the Joint Chiefs of Staff Instruction 3170.01C. 24 June 2003.



CJCSI 3170.01C directs increasing focus on supportability and affordability at such time as the Service prepares the Capability Development Document (CDD). The instruction states that the CDD “provides operational performance attributes, including supportability, necessary for the acquisition community to design the proposed system, including key performance parameters that will guide the development, demonstration and testing of the current increment....” The Instruction further states that the sponsor is “...expected...to make affordability determinations in the evaluation of various approaches to delivering capabilities to the warfighter.”



APPENDIX 3: DODI 5000.2 SPECIFIC GUIDANCE RELATED TO OWNERSHIP COST

DoDI 5000.2 describes the exit criteria for Technology Development as follows: “...when an affordable increment of militarily-useful capability has been identified, the technology for that increment has been demonstrated in a relevant environment, and a system can be developed for production within a short timeframe (normally less than five years)...” Affordability must be described in an “affordability assessment.”

Affordability Determination - DoDI 5000.2 provides the following description: “3.7.2.6. An affordability determination results from the process of addressing cost during the requirements process and is included in each CDD using life-cycle cost or, if available, total ownership cost.”



REFERENCE LIST

1. Assistant Secretary of Defense (Program Analysis and Evaluation). "Cost Analysis Guidance and Procedures." Department of Defense. DoD 5000.4-M. December 1992.
2. Blanchard, Benjamin S. *Logistics Engineering and Management*, 5th ed. Prentice Hall. 1998.
3. Bogner, Michael, Chuck Wong, and Bernie Price. "Quantity Discounts/Economic Order Quantity: New Quantity Discount Analysis Tool Lets DoD Buyers Save on Total Cost and Receive More Goods." *Program Manager*. September-October 2002.
4. Bowles, Jennifer. "Example Uses of VAMOSOC Data." Briefing to Third Annual Naval VAMOSOC User Conference. 9 July 2003.
5. Congressional Budget Office. "The Effects of Aging on Costs of Operating and Maintaining Military Equipment." August 2001.
6. Defense Acquisition University Homepage, <http://www.dau.mil/>. n.d.
7. Defense Acquisition University Website. "AT&L Knowledge Sharing System." <http://deskbook.dau.mil/jsp/default.jsp>. n.d.
8. _____. "Community of Practice for Cost as Independent Variable and Reduction of Total Ownership Cost Best Practices." http://pmcop.dau.mil/simplify/ev.php?URL_ID=1205&URL_DO=DO_Topic&URL_SECTION=201&reload=1034872330. n.d.
9. _____. "Defense Acquisition Deskbook." <http://legacydeskbook.dau.mil>. 2002. n.d.
10. _____. "Program Managers Tool Kit." 12th Edition. December 2002.
11. Department of the Air Force. Software Technology Support Center. "Guidelines for Successful Acquisition and Management of Software-Intensive Systems: Weapon Systems, Command and Control Systems, Management Information Systems." Version 3.0. May 2000.
12. Department of Defense. "The Defense Acquisition System." DoD Directive 5000.1. May 12, 2003.



13. _____. "Operation of the Defense Acquisition System." DoD Instruction 5000.2. May 12, 2003.
14. _____. "Mandatory Procedures for MDAPS and MAIS Acquisition Programs." DoD 5000.2-R (including Change 4). Part 3.3.4.1. 1999.
15. _____. Office of Technology Transition. Commercial Operations and Support Initiatives website. <http://www.acq.osd.mil/es/dut/index.htm>. n.d.
16. DoD COSSI Independent Assessment Executive Roundtable. "An Evaluation and Assessment of the DoD Commercial Operations and Support Savings Initiative Program." The National Center for Advanced Technologies Report Number 01-C01A. September 2001.
17. Fleming, Quentin W., and Joel M. Koppelman, *Earned Value Project Management*, 2nd Edition. Program Management Institute, Inc. 2000.
18. Forsberg, Kevin, Hal Mooz, and Howard Cotterman. *Visualizing Project Management: A Model for Business and Technical Success*. 2nd Edition. John Wiley & Sons, Inc. 2000.
19. Hoffer, Kip. E-mail and telephonic correspondence. Crane Naval Surface Warfare Center, In-Service Agent for AEGIS Microwave Tubes. November 17-19, 2003.
20. Holland, Charles J. and Donna Richbourg. "Commercial Operations and Support Savings Initiative Handbook." Office of the Under Secretary of Defense. 14 December 2001.
21. Hudson, Jack (Major General, USAF). Briefing: "JSF Program Update." Program Executive Officer, Joint Strike Fighter. October 2003.
22. Humphrey, Watts S. *Managing the Software Process*. Addison-Wesley Publishing Company. 1990.
23. Kratz, Louis. "Developing a Performance-Based Strategy." Briefing to PEO/SYSCOM Workshop. Spring 2002.
24. Gansler, Jacques S. Memorandum: Definition of Total Ownership Cost (TOC), Life Cycle Cost, and the Responsibilities of Program Managers. Office of the Secretary of Defense. 13 November 1998.



25. _____. "The Revolution in Business Affairs—The Need to Act Now." *Program Manager*. September-October 1998. Reprinted from a speech given by Dr. Gansler to the Association of the United States Army, Falls Church, VA. September 2, 1998.
26. _____. "Moving Toward a Market-Based Government: The Changing Role of Government as the Provider." IBM Endowment for The Business of Government. University of Maryland. 2003.
27. Garza, Luis. Thesis: "A Case Study of the Application of Reliability Centered Maintenance (RCM) in the Acquisition of the Advanced Amphibious Assault Vehicle (AAAV). Naval Postgraduate School, December 2002.
28. Griffith, Sean, and Bruce McKinney. "Advance Amphibious Assault Vehicle: Operations and Support Cost Analysis Model." Briefing to R-TOC Pilot Programs, 15th Quarterly Forum. 5 August 2003.
29. Institute for Defense Analysis. Website: "Reduction of Total Ownership Costs." <http://rtoc.ida.org/rtoc/rtoc.html>. n.d.
30. Kaminski, Paul. Memorandum: "Reducing Life Cycle Costs for New and Fielded Systems (with CAIV Working Group Report attached). Office of the Secretary of Defense. December 4, 1995.
31. Kaye, Michael A., Mark S. Sobota, David R. Graham, and Allen L. Gotwald. "Cost As An Independent Variable: Principles and Implementation." *Acquisition Review Quarterly*. Fall 2000.
32. Kunc, Wendy. Naval Cost Analysis Division. "VAMOSOC Program Update" Briefing to Third Annual Naval VAMOSOC User Conference. 9 July 2003.
33. Lara, Luis F. Thesis: "Analysis of the Medium Tactical Vehicle Replacement (MTVR) Contractor Logistics Support (CLS) Contract." Naval Postgraduate School. December 2001.
34. McNutt, Gary. "Air Force Total Ownership Cost (AFTOC) (FOUO)." Briefing to R-TOC Pilot Programs, 7th Quarterly Forum. 25 July 2001.
35. Moubray, John. Reliability-centered Maintenance. 2nd Edition. Industrial Press Inc. 1997.
36. Office of the Joint Chiefs of Staff. "Joint Capabilities Integration and Development System." Chairman of the Joint Chiefs of Staff Instruction 3170.01C. 24 June 2003.



37. Pallas, Spiros. "R-TOC in DoD Systems: Status Report." Briefing to PEO/SYSCOM Commanders Conference. 21 Nov 2002.
38. Rush, Benjamin C. "Cost as an Independent Variable: Concepts and Risks." *Acquisition Review Quarterly*. Spring 1997.
39. Stoll, Lawrence W. "Applications of VAMOSC at NAVAIR: A User Perspective on VAMOSC-MAMSR Databases." Briefing to Third Annual Naval VAMOSC User Conference. 9 July 2003.
40. Stranges, Bill, Coleen Adamson, Andrea Nowicki, and Deanna Ohwevwo. Briefing: "DD-963 Spruance Class Ship Aging Vs Maintenance Expenditures from FY91 to FY00" presented at the SCEA 2002 National Conference. June 2002.
41. Sullivan, Robert. "Precision Fires Rocket and Missile System Pilot Update (FOUO)." Briefing to 14th R-TOC Quarterly Pilot Program Forum. 29-30 April 2003.
42. U.S. General Accounting Office. "Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes." Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-01-288. March 2001.
43. U.S. General Accounting Office. "Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs." Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate. GAO-03-57. February 2003.
44. Watterson, Ozzie. Interview on development of SEAWOLF Class Submarine Combat Systems (AN/BYS-2). Mr. Watterson held the position of Technical Program Manager during SEAWOLF's early acquisition milestones and development. Conducted in Middleton, RI. 20 August 2003.
45. Womack, James P., Daniel T. Jones, and Daniel Roos. *The Machine That Changed The World*. Rawson Associates, a Division of Macmillan Publishing Company. 1990.
46. _____, and Daniel T. Jones. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. Simon and Schuster. 1996.



INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center 2
8725 John J. Kingman Rd., STE 0944
Ft. Belvoir, VA 22060-6218
2. Dudley Knox Library, Code 013 2
Naval Postgraduate School
Monterey, CA 93943-5100
3. Research Office, Code 09 1
Naval Postgraduate School
Monterey, CA 93943-5138
4. Douglas A. Brook 1
Dean, GSBPP
555 Dyer Road
Naval Postgraduate School
Monterey, CA 93943-5000
5. David Lamm 1
GSBPP
555 Dyer Road
Naval Postgraduate School
Monterey, CA 93943-5000
6. Jim Greene 1
GSBPP
555 Dyer Road
Naval Postgraduate School
Monterey, CA 93943-5000
7. Bill Gates 1
GSBPP Associate Dean for Research
555 Dyer Road
Naval Postgraduate School
Monterey, CA 93943-5000
8. Michael Boudreau 1
GSBPP
555 Dyer Road
Naval Postgraduate School
Monterey, CA 93943-5000



9. Brad Naegle 1
GSBPP
555 Dyer Road
Naval Postgraduate School
Monterey, CA 93943-5000
10. Karey Shaffer 1
GSBPP
555 Dyer Road
Naval Postgraduate School
Monterey, CA 93943-5000



FY 2003 Sponsored Acquisition Research Products

Sponsored Report Series

[NPS-AM-03-003](#) Centralized Control of Defense Acquisition Programs:
A Comparative Review of the Framework from 1987 – 2003
September 2003

[NPS-AM-03-004](#) Reduction of Total Ownership Cost
September 2003

Working Paper Series

[NPS-CM-03-002](#) Transformation in DOD Contract Closeout
June 2003

Acquisition Case Series

[NPS-CM-03-005](#) Contract Closeout (A)
September 2003

Other Sponsored Research

[NPS-CM-03-001](#) Transformation in DOD Contract Closeout
MBA Professional Report
June 2003

Copies of the Acquisition Sponsored Research Reports may be printed from our website www.nps.navy.mil/gsbpp/acqn/publications/index.htm



ACQUISITION RESEARCH
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL



ACQUISITION RESEARCH
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CALIFORNIA 93943

www.nps.navy.mil/gsbpp/acqn