NPS-CM-09-141

ACQUISITION RESEARCH SPONSORED REPORT SERIES

Performance, Award Fee and Cost Incentives during System Design and Development

03 March 2010

by

Gregory G. Hildebrandt, Visiting Associate Professor

Graduate School of Business & Public Policy

Naval Postgraduate School

Prepared for: Naval Postgraduate School, Monterey, California 93943

The research presented in this report was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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

NPS Acquisition Research Program
Attn: James B. Greene, RADM, 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
Fax: (831) 656-2253
e-mail: jbgreene@nps.edu

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

Abstract

The analysis addresses the use of Performance Incentives and Award Fees in DoD contracting during System Development and Demonstration (SDD). There is discussion of the F/A-18E/F contract that included cost-sharing, Performance Incentives and Award Fees. However, we first discuss recent GAO criticism of profits received on Award Fee contracts and the response by DoD and other organizations. Next, the general policy guidelines established in 1969 by DoD and NASA that are still in effect are reviewed, as are the recommendations made by academic economists beginning in the 1970s. We also discuss the recent introduction of System Design Specifications. While these specifications contain a great deal of information that can be used when developing Performance Incentives and Award Fees, this new policy represents a movement away from performance specifications and may constrain a contractor's ability to make trade-off decisions. The broad conclusion of this analysis is that the intuition obtained from the 1969 DoD and NASA Guide might be combined with that of economists when properly structuring incentive contracts. This may help achieve the objectives of the government when there is pervasive cost uncertainty, challenging performance characteristics, and certain contractor actions not easily observable by the government.

Keywords: General Accounting Office (GAO), System Development and Demonstration (SDD), Cost-Sharing Ratio, Performance Incentives, Award Fee, Accounting Profit, Economic Profit, Cost Uncertainty, Moral Hazard, Cost-plus-award fee/incentive fee (CPIF/AF), F/A-18E/F CPIF/AF Contract, System Design Specification

THIS PAGE INTENTIONALLY LEFT BLANK

Acknowledgments

This research was sponsored by the Naval Postgraduate School's Acquisition Research Program with support provided by DASN(A&LM).

THIS PAGE INTENTIONALLY LEFT BLANK

About the Author

Gregory G. Hildebrandt is a Visiting Associate Professor of Economics at the Naval Postgraduate School. He has been a Senior Economist at the RAND Corporation, and as an Air Force officer was assigned as a procurement officer at the Ballistic Systems Division. He also served as an operations analyst at Hq 7th AF in the Republic of Vietnam, and later taught at the Air Force Academy where he was Director of the Procurement Research Office, and Director of Advanced Economics. Subsequently, he held military assignments at the Central Intelligence Agency, focusing on Soviet-military economics, and the Office of the Secretary of Defense, Program Analysis and Evaluation, focusing on the military balance between NATO and the Warsaw Pact. Dr. Hildebrandt is a graduate of the Air Force Academy, received a Master of Science in Operations Research from USC and a PhD in Economics from Princeton.

Gregory G. Hildebrandt
Visiting Associate Professor of Economics
Graduate School of Business and Public Policy
Naval Postgraduate School
Monterey, CA 93943-5000
Tel: 818-707-7078
Fax: (831) 656-3407
E-mail: gghildeb@nps.edu

THIS PAGE INTENTIONALLY LEFT BLANK

NPS-CM-09-141

ACQUISITION RESEARCH
SPONSORED REPORT SERIES

Performance, Award Fee and Cost Incentives during System Design and Development

28 September 2009

by

Gregory G. Hildebrandt, Visiting Associate Professor

Graduate School of Business & Public Policy

Naval Postgraduate School

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

THIS PAGE INTENTIONALLY LEFT BLANK

I. Introduction

The Department of Defense has an extensive history in the use of both objectively measurable Performance Incentives and subjectively measurable Award Fees. One can trace the use of Performance Incentives to the Wright Brothers' contract to produce an aircraft for the Army Signal Corps. Later, Performance Incentives were extremely popular with the DoD from the early 1960s to the early 1970s. Subsequently, subjectively based Award Fees gained popularity and continue to be used.

In this analysis, we start with the recent General Accounting Office 2005 critique of the DoD's use of Award Fee contracts. Following this critique, several memoranda were prepared by the OSD, the Navy, and the Office and Management and Budget, and we briefly mention some of the highlights of these memos. At least one of the memos encouraged more extensive use of objectively measurable performance characteristics in contracts. Significant attention, therefore, will be paid to incentive contracts with objectively measurable performance characteristics.

We turn next to the history of incentive contracting, beginning with the contract awarded to the Wright Brothers in 1907. From the early 1960s to the 1970s, there was significant use of contracts with both cost-sharing arrangements and performance incentives. This study highlights several of the major events during this period.

Around 1980, there was a shift in emphasis to Award Fee contracts. However, in the 1990s, the F/A-18 E/F Engineering and Manufacturing Development contract employed a contract with cost sharing, objectively measurable performance characteristics, and Award Fees. Such contracts are called cost-plus-award-fee/incentive fee (CPAF/IF) contracts with multiple incentives.

In the future of defense contracting, the pendulum may be swinging back to the use of objectively measurable performance characteristics; thus, we review the

DoD cost-effectiveness model, which constituted a significant part of the intellectual basis for the structuring of multiple-incentive contracts. We also examine the best-value model and include a theoretical discussion of the optimal sharing ratio that applies when a Program Manager (PM) knows the value to the government of additional performance and the risk adversity of both the government and the contractor.

In addition to this theoretical analysis of the cost-sharing ratio, there has been a significant amount of research conducted primarily by academic economists who are striving to develop a complete theory of contracts.

One model of particular relevance to our analysis develops the incentive contract appropriate when there is asymmetric information with moral hazard. In this case, there are actions taken by the contractor that are not observable by the government. These actions, which characterize a situation with moral hazard, result in an implicit cost borne by the contractor that would not be included in the allowable accounting costs by the government. The model is typically formulated under the assumption that the character of the initial cost uncertainty applies throughout the contract.

Compared with the DoD cost-effectiveness and best-value models, we show that the information requirements to structure these moral-hazard-based contracts is very demanding. We also believe that the government possesses both a great deal of information about these contractor actions, as well as a sense of the contractor's implicit cost. As a result, these types of actions (which can also impact both cost and objectively measurable performance) may be amenable to Award Fee contracting, and, therefore, to the potential use of CPAF/IF multiple-incentive contracts. Because of the effective use of this type of contract on the F/A-18E/F program, we summarize some of the features of this incentive contract.

There is a new acquisition requirement that may impact incentive- and Award Fee contracting. Major programs are now required to construct System Design

Specifications. In simple terms, these specifications lie somewhere between performance specifications and detail-design specification. With performance specifications, there would likely be both threshold (minimum required) and objective (maximum) performance values. This range of acceptable performance values eases the process of developing objectively measurable performance incentives. In contrast, if detailed design specifications apply during engineering development, then there would be limited opportunity for contractors to make trade-offs among the Key Performance Parameters (KPPs). These are the key, performance variables during development of particular interest to the government.

We will see that System Design Specifications typically constitute a hierarchy of specifications. A question might be raised concerning the extent to which the lower-level specifications might constrain the ability of the contractor to make trade-offs among the higher-level specifications. This will only be possible if the use of threshold and objective performance values continues to be appropriate. If so, there seems to be a role for the use of CPAF/IF multiple-incentive contracts—in which the relevant KPPs are incentivized using traditional objectively measurable performance measures, and Award Fees are used to incentivize the lower levels of the specification hierarchy.

THIS PAGE INTENTIONALLY LEFT BLANK

II. GAO Analysis and Response

In 2005, the DoD was criticized by the General Accounting Office for excessive award and incentive fees awarded to the contractors (GAO, 2005, December). Interestingly, a significant part of the discussion indicated that the fees earned on contracts within a program were based on program performance. As is well known, a significant portion of cost growth is associated with changes in requirements. Much of these changes are a direct result of changes in requirements initiated by the DoD and should not have a bearing on the fee received by a contractor. In fact, a 2008 RAND analysis indicated that approximately 2/3 of cost growth can be attributed to government decisions (Bolton, Leonard, Arena, Younossi & Sollinger, 2008).

The GAO report also notes the inflated performance evaluations on contracts. High-end awards are frequently given. However, there are pervasive institutional problems associated with “performance” inflation in many different settings. In one reported study of personnel evaluations (in which a scale of 1 to 5 was used, and 1 is the highest performance level), about 27% of the employees received a 1; 50% received a 2; approximately 21% received a 3, and about 2% of the employees received a 4 or 5 (Lazear & Gibbs, 2009, p. 248). Perhaps the joint-venture aspect of a government contract is a factor that affects Award Fee profit inflation.

Another issue addressed by the GAO is the “rolling over” of Award Fee incentives. In certain situations in which the entire fee pool planned for a milestone evaluation is not used, the funds not awarded are made available for use during a subsequent milestone on the contract.

There were several memoranda prepared in response to this GAO analysis. Some of this discussion follows:

Under Secretary of Defense (Acquisition, Technology & Logistics) (2006, March 29): “it is imperative that Award Fees be tied to identifiable interim outcomes, discrete events or milestones, as much as possible” (p. 1).

Department of the Navy, Office of the Assistant Secretary (Research Development & Acquisition) (Jaggard, 2006, April 6): The DoN supports the 29 March 2006 recommendation that “rollover” should be the exception rather than the rule. [1]

Under Secretary of Defense (Acquisition, Technology & Logistics) (Assad, 2007, April 24): “It is the policy of the Department of Defense that objective criteria will be utilized whenever possible, to measure contract performance” (p. 1).

Under Secretary of Defense (Acquisition, Technology & Logistics) (Assad, 2007, April 24, pp. 2, 3).

[1] “Rollovers” will typically require special approval in the new Award Fee contracts. However, this issue will not be addressed in this study.

Table 1. Award Fee Provisions

The following shall apply to all award fee provisions:

Award fee may be earned in accordance with the following:

Rating	Award Fee Pool Earned
Unsatisfactory	0%
Satisfactory	No Greater Than 50%
Good	50%-75%
Excellent	75%-90%
Outstanding	90%-100%

Definitions of Ratings

Unsatisfactory	Contractor has failed to meet the basic (minimum essential) requirements of the contract.
Satisfactory	Contractor has met the basic (minimum essential) requirements of the contract.
Good	Contractor has met the basic (minimum essential) requirements of the contract, and has met at least 50% of the award fee criteria established in the award fee plan.
Excellent	Contractor has met the basic (minimum essential) requirements of the contract, and has met at least 75% of the award fee criteria established in the award fee plan.

Office of Management and Budget, Executive Office of the President (Dennett, 2007, December 4): "Awards should be tied to demonstrated results, as opposed to effort, in meeting or exceeding specified performance" (p. 1).

Department of the Navy, Deputy Assistant Secretary of Navy (Acquisition & Logistics Management) (Jaggard, 2008, January 22): "If objective criteria do not exist, and a cost-plus-award-fee (CPAF) contract is considered appropriate, […] the Head of the Contract Agency (HCA) must approve a written determinations and findings (D&F) before using this contract type" (p. 1).

These memoranda clearly illustrate that procurement emphasis has shifted to the use of objectively measureable performance criteria. This is a return to the previous DoD orientation toward such incentive structures. Furthermore, when a CPAF contract is judged appropriate by the appropriate decision-making authority, identifiable outcomes, events or milestones are considered appropriate. Importantly, contractor effort is not considered an appropriate dimension of an Award Fee component. Perhaps most importantly, the implementation of more appropriate awards is being implemented. The guidelines associated with the April 4, 2007, memorandum from the Under Secretary of Defense (Acquisition, Technology & Logistics) should significantly aid this process.

A. History of Incentive Contracting

A brief discussion of some of the important events in the use of incentive contracts can help establish the context within which there is a shift back to the use of objectively measurable performance characteristics. Such contracts have been called multiple-incentive contracts. We argue below that there remains a role for Award Fees; indeed, the DoD and the Navy have experience in the use of cost-plus-award-fee/incentive fee (CPAF/IF) contracts, which are measured objectively by multiple incentives.

B. 1908, Wright Brothers' Incentive Contract

It is appropriate to begin the historical discussion of incentive contracting with the contract awarded to the Wright Brothers for building an aircraft. The contract stipulated that the aircraft should be capable of carrying two persons (having a combined weight of (about) 350 pounds) and sufficient fuel for a flight of 1.25 miles. Cost and airspeed constituted the incentive dimensions of the contract. A target price equal to $25,000 and a target speed of 40 miles per hour (mph) was contained in the contract. However, the contractor was to gain/lose $2,500 for every mph over/under target.

The actual speed obtained on this contract was 42 mph, so the Wright Brothers received $30,000. The reward, therefore, was $5,000 (US Army, 1908, February 28).

One might notice that there is no cost sharing specified in this contract. It is, in effect, a Firm-fixed-price contract with fixed requirements for weight and distance and a performance incentive for airspeed. The government was communicating to the Wright Brothers that it was willing to spend $2,500 for every mph over target. There is an implicit value statement in the contract in which the government communicated the value of additional performance. If the Wright Brothers could increase speed by incurring a cost of less than $2,500, then, because the reward would increase by $2,500, they would be willing to incur the costs. More discussion will follow on the nature of the government's implicit value statement.

C. 1962, DoD Incentive Contracting Guide

John Kennedy's campaign for the Presidency in 1960 emphasized the missile gap between the United States and the Soviet Union. It is not surprising, therefore, that there was a concerted effort by the Air Force to develop missiles as expeditiously as possible after his inauguration. Initially, numerous Cost-plus-fixed-fee (CPFF) contracts were employed during engineering developments. Such contracts award a contractor the same total fee dollars independently of the cost incurred.

Secretary of Defense Robert McNamara recognized the potential inefficiencies associated with such contracts and directed the increased use of cost incentives. These were employed on both Cost-plus-incentive-fee and Fixed-price-incentive contracts. In the former, the contractor shares cost with the government over a Range of Incentive Effectiveness. Outside this range, the contract form is Cost-plus-fixed-fee. In a Fixed-price-incentive contract, cost sharing applies until the contractor cost reaches the "Point of Total Assumption." At this point, the contractor begins to assume all the costs.[2]

---

[2] In this analysis, we will not display the graphics associated with CPIF or FPI contracts. These are developed adequately in the still-active, *DoD and NASA Guide, Incentive Contracting Guide* (1969,

Robert McNamara argued that each dollar shifted from Cost-plus-fixed-fee to a Fixed-price-incentive contract would save 10 cents.[3] As a result of McNamara's directives, from 1960 to 1964, the percentage of cost-plus-fixed-fee military procurement dollars fell from 39% to 14%. During this same time period, fixed-price-incentive contract dollars rose from 45% to 55% (Snyder, 2001, p. 7).

DoD procurement professionals received detailed guidance in the 1962 *Incentive Contracting Guide*. Of particular note is the recommendation for the increased use of multiple-incentive contracts. The *Guide* states, "Perhaps no other DoD procurement policy offers greater potential rewards than the expanded use of performance incentives in development contracts" (DoD, 1962).

As a result of the expressed importance in performance incentives, courses were developed by Harbridge House and other organizations to provide instruction concerning the use of performance incentives.

D. 1966-1967, USAF Academy Research Reports on Multiple-incentive Contracting

This research was sponsored by the Pricing Division (SSKP), Space Systems Division, Los Angeles Air Force Station. An Air Force Academy research team developed a methodology for structuring multiple-incentive contracts that strongly influenced policy (Cook, Ackerman, Clegg, Krutz & Johnston, 1966; Cook, Clegg, Hildebrandt, Johnston & Zangri, 1967). Though independently developed, the Air Force Academy methodology bore similarities to the solution methods employed by Harbridge House in its course on incentive contracting. The reports also resulted in the development of an office responsible for analyzing multiple-incentive contracts.

October). Furthermore, there will be no discussion of the Weighted Guidelines approach to determining target profit that applies to CPIF and FPI contracts. We will also not discuss the 3% base fee frequently recommended for CPAF contracts.

[3] *Time* magazine, circa 1962,

In addition, the Air Force Academy research efforts also shaped the 1969 *Incentive Contracting Guide.*

E. 1968, DoD Program Office for Evaluating and Structuring Multiple-incentive Contracts (POESMIC)

Based on the recommendations of the Air Force Academy research reports, an office was established at Los Angeles Air Force Station that was responsible for reviewing all multiple-incentive contracts with a value over $5 million. The Program Office for Evaluating and Structuring Multiple-incentive Contracts (POESMIC) evaluated 150 contracts within 2.5 years. The office was disestablished around 1972.[4]

F. 1969, DoD and NASA Guide, Incentive Contracting Guide

This guide, issued jointly by the Department of Defense and the National Aeronautical and Space Administration, is still in effect. It states that a performance incentive achieves two important objectives: "first, it communicates the Government's objectives to the contractor: second of greater significance, <u>it establishes the contractor's profit in direct relationship to the value of combined performance in all areas</u>" (p. 107, emphasis in original).

The guide, therefore, implements the policy recommendations of the Air Force Academy research group and is consistent with the approach taught by Harbridge House.

In the 1969 *Guide*, there is also an extensive discussion of Award Fee contracts (which had been extensively used by NASA) and a detailed discussion of the NASA Planned Interdependent Incentive Model (PIIM) employed on the Gemini space program. PIIM is, perhaps, the most complex incentive contract ever

---

[4] Jones (1970) discusses the history of POESMIC in his text.

employed, and takes account of the fact that the value to the government of, say performance, depends on the levels of cost and schedule.

The 1969 *Guide* also provides an extensive discussion of extra-contractual influences in government contracting—such as company growth, reputation and influence, opportunity for follow-on business, and the utilization of available skills and open capacity. Even though there was awareness of these factors, the DoD *Guide* and the POESMIC office consciously narrowed the focus in the structuring of multiple-incentive contracts. For the next several years, the structure of incentive contracts within the DoD focused on communication and contractor decisions that were guided by government values. As discussed below, these extra-contractual influences can be addressed by combining traditional contracts with objectively measureable performance characteristics and Award Fees.

G. 1972-Present

From around 1972 to the present, we can evaluate DoD incentive contracting from the standpoint of both practice and the theoretical work done by academics.

III. Practice

From the standpoint of practice, questions were raised during the 1970s within the DoD about the complexity of multiple-incentive contracts. Around 1980, the orientation had shifted to Award Fee contracts. One major exception is the F-18 E/F CPAF/IF multiple-incentive contract. The basic structure of this Engineering and Manufacturing Development (EMD) contract formulated and employed during the 1990s is discussed below.

Then, as discussed below, the use of Award Fee contracts was criticized by the GAO in 2005. This has resulted in a policy swing back to incentivizing objectively measurable performance characteristics.

There is, however, another important development in the contracting trends timeline. There has been a change from the use of performance specifications with well-defined Threshold and Objective performance characteristics to the use of System Design Specifications. At the top of the specification pyramid resides the objectively measurable Key Performance Parameters (KPPs). There are also underlying system characteristics not as easily amenable to objective measurement. Some of these measures may also not lend themselves to objective measurement. It seems, therefore, that there may be an important role for CPAF/IF multiple-incentive contracts in future programs.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. Theory

During this time period, there was also extensive research conducted primarily by academic economists on the theory of contracts. Around 1972, the optimal cost-sharing ratio was derived for an incentive contracting context; this emphasized communication and valuation responsiveness, which was addressed in the 1969 *Incentive Contracting Guide*.

Later in the 1970s, the assumption that contractor's maximize the accounting profit received on a particular contract was questioned, and attention shifted to the construction of optimal incentive contracts. In this type of contract, there are activities undertaken by the contractor that are unobservable to the government, but which impact the cost, performance, and schedule outcomes of interest to the government. These activities entail an implicit cost to the contractor that is not included in allowable costs, but which the contractor would take into account in decision-making. As we see below, the information requirements required to implement a contract containing these unobservable activities is demanding.[5] Therefore, we suggest an extension of the approach suggested in the 1960s in which the government, with the aid of the PM and the Defense Contract Administration Services (DCAS), can observe many of these contractor activities.

A. DoD Cost-effectiveness Model

We turn first to the DoD cost-effectiveness model popularized by the Air Force Academy research group. There is a basic logic associated with the structuring technique proposed in this model, and it is helpful to understand this logic before examining the graphical presentation associated with this model.

---

[5] A comprehensive and demanding treatment of this area of theoretical economics is contained in Bolton and Dewatripont (2005).

Suppose the contractor's share of total costs is represented by s (e.g., s = 0.30), and the value to the DoD of an increase in reliability from 0.96 to 0.98 is $10 million.[6] This implies that the DoD is willing to let the contractor spend up to, but not more than, $10 million to increase reliability by the stated amount. However, given a cost-sharing ratio of 0.30, the contractor will lose $3 million in profits by spending $10 million. If the contractor is faced with the possibility of achieving the increase in performance by spending exactly $10 million, the loss in profit from the higher cost will equal $3 million. If the fee associated with this performance increase was $3 million, this would be a point of indifference to the government: the extra costs of $10 million would just equal the value of the additional performance of $10 million. For the contractor to be indifferent between the two alternatives, the appropriate additional profit for the increase in performance should be $3 million, which just equals the value to the government of the increased performance times the contractor's share of costs.

In contrast, if the contractor can increase the performance level by spending $9 million, it will receive $3 million for the increase in performance, and would lose $2.7 million because of cost sharing. Therefore, contractor profits increase by $0.3 million, while the net benefits to the government increase by $1 million. The contractor, therefore, is motivated to spend the $9 million, and both the contractor and the government are better off as a result of the expenditure increase. The government receives a value of $10 million for the increase in performance and incurs a loss from the higher cost of $9 million.

If the cost of improving performance to the contractor is $12 million, then the contractor will lose $3.6 million as a result of cost sharing. This loss is greater than the $3 million earned from the higher performance achieved, and there is a net loss to the contractor of $0.6 million. As a result, the contractor would not choose to

---

[6] In the cost-effectiveness model, this value could result from a decline in the cost of procurement and operations. In the subsequent best-value model, it could simply be associated with an intrinsic military value, which is associated with willingness to spend for additional performance.

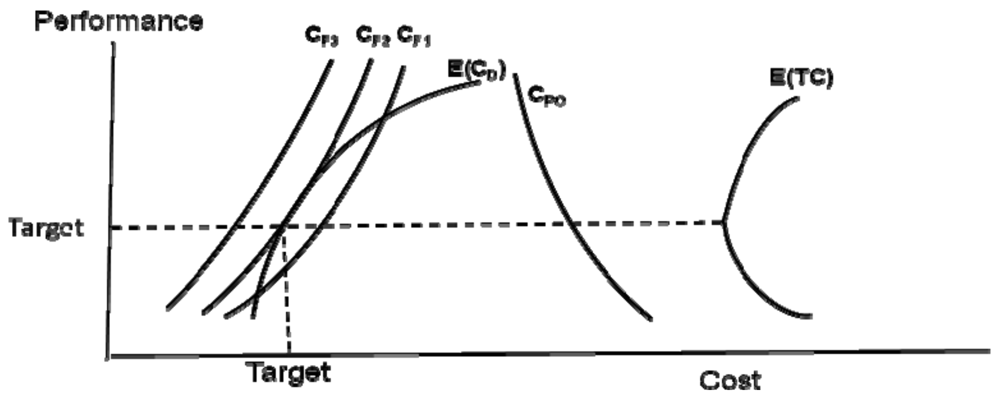
increase performance. At the same time, the government would incur a net loss of $2 million—equal to the additional contract cost of $12 million less the $10 million value of increased performance. As a result, the government would not want the contractor to increase performance from a reliability of 0.96 to 0.98.

When, and only when, the increase in performance-incentive-earned equals the change in the value to the government of increased performance times the cost-sharing ratio will the interests of the contractor and government be aligned. This can be expressed with a simple relationship:

Equation (1) $$P(q2 - q1) = s^*B(q2 - q1),$$

where P(q2 – q1) = profit from a performance increase from q1 to q2, s = contractor's share of cost and B(q2 – q1) equals the benefit to the government of an increase in performance from q1 to q2.

There are two interesting questions raised by Equation (1). How is the contractor's share of costs determined, and how does one compute the value to the government of an increase in performance? We discuss the computation of the sharing ratio below. With respect to the value to the government of a change in performance, the easiest way to demonstrate this value is to use a cost-effectiveness model in which the objective of the government is to achieve a particular level of system performance at least cost. Then, we can discuss the value to the government when the problem is one of obtaining "best value." In other words, the government's objective is to achieve the greatest difference between the benefits and costs of the contract.



$E(C_D)$ = Expected Cost of Development (Alternative ex-post CD curves not displayed)
C_{PO} = Cost of Procurement and Operations
E(TC) = Expected Total Cost
C_F = Constant Fee ($C_{F3} > C_{F2} > C_{F1}$; Mirror Image of C_{PO})

Figure 1. DoD Cost-effectiveness Model

Figure 1 displays some of the key relationships in the cost-effectiveness model that applies to all units of a weapons system.[7] The expected cost-of-development curve $E(C_D)$ depicts the performance level achieved as a function of the "average" development cost. Increases in cost result in increases in the performance level achieved at a decreasing rate. To understand this model, we must first appreciate that there is cost uncertainty. Likewise, a range of development cost curves are possible. For example, the cost of developing performance can be lower than expected, and one could depict this lower-than-expected curve to the left of the one indicated. Similarly, a higher-than-expected cost-of-development curve would be to the right of the one indicated. In order to keep the diagram from being excessively cluttered with curves, low- and high-cost-of-development curves are not shown.

Also depicted is the cost of procurement and operations. This is backward bending because if, for instance, the reliability of a system unit increases, then the

---

[7] Typically, when the cost-effectiveness analysis curves are drawn, cost is on the vertical axis. In this model, however, we want to emphasize that expenditures in cost result in performance improvements, and, therefore, display performance as the dependent variable. Also, we assume in this and the best-value diagram that all future costs have been discounted to present value.

procurement and operating costs of the entire system would decline. In fact, fewer weapons system units might be required to achieve the desired system performance level. Decreases in procurement and operating costs would exert a downward pressure on the cost of the entire system. The sum of the expected cost-of-development curve and the cost of procurement and operations is the expected total cost curve. Because the cost-of-development curve is uncertain, so too is the total cost curve.

In cost-effectiveness analysis, the objective is to minimize the total cost of achieving a desired system-performance level. At the time the contract is awarded, the PM anticipates that this would occur at the time when the expected total cost is minimized. Both target performance and target system cost (target contract cost plus target profit) would likely be set at the expected values of the variables.

In Figure 1, several constant fee curves are indicated. They are upward sloping because increases in cost require a performance increase to maintain constant profits. As cost sharing reduces cost, to maintain a constant fee, there must be an increase in the system performance and associated performance reward.

If one holds performance constant, and there is an increase the cost of development, the fee must decline. Therefore, as indicated in Figure 1, $C_{F3} > C_{F2} < C_{F1}$. Given the expected cost-of-development curve, the contractor maximizes profit by obtaining the point of tangency between C_{F2} and $E(C_D)$.

The constant fee curves must be the mirror image of the cost-of-procurement-and-operations curve. The value to the government of spending additional development dollars to increase performance is the savings in procurement and operations costs. Because the contractor shares in development costs, the performance incentive must be structured so that the contractor receives a like share of the savings in procurement and operations costs.

Now imagine that the cost of development for every performance level turns out to be higher than expected. There would be a new cost-of-development curve (known to the contractor, but not to the government) to the right of $E(C_D)$. One would also expect the gap between the two curves to be larger at higher performance levels; it would be much more difficult to develop high performance. The total cost curve would then shift, and the minimum cost would be achieved at a lower performance level. The contractor would again be motivated to achieve a point of tangency between the ex post cost-of-development curve and the constant fee curve. In this case, a cost-of-development curve (not shown)—which is known to the contractor, but not to the government—would be tangent to the relevant constant fee curve, say C_{F3}. The total cost curve would shift to the right, and because of the indicated shift in the cost-of-development curve, the optimal performance level would be lower than the target level. Once again, as long as the constant fee curve is the mirror image of the cost-of-procurement-and-operations curve, the contractor will select the cost-effective point.

Alternatively, it is possible that for every performance level, development costs are lower than anticipated. The cost-of-development curve will now shift to the left, and the total cost curve will move inward. By selecting the point of tangency between the relevant constant fee curve (say C_{F1}) and the left-shifted cost-of-development curve, a cost-effective outcome will again be achieved. We would now expect the cost-effective performance level to be higher than the target level: at higher performance levels, the cost-of-development curve is likely to shift inward more than at low performance levels.

The cost-effectiveness model, therefore, has the very interesting property that a cost-effectiveness outcome will be achieved when development costs turn out to be different than expected, and, yet, only the contractor knows the shape and position of the cost-of-development curve when the trade-off decisions are made.

Most likely, this is a very stylized view of the actual contractor decision-making process. A contractor can be expected to make numerous trade-off decisions based on known development cost versus performance relationships during engineering development; these accumulate to the total change in performance from the target level. However, making these trade-off decisions is the contractor's area of expertise. The government's area of expertise lies in valuing changes in performance. Within a specified range from low to high performance, the government must be able to estimate the decline in the costs of procurement and operations. Also, as we have structured this model, the government needs to be sufficiently knowledgeable of the expected cost of development and the cost of procurement and operations to determine the target cost and target performance levels. However, the contractor makes trade-off decisions based on a known cost-of-development curve. Therefore, errors in selecting target performance and target cost (which includes target profit) are eliminated when the contractor selects the optimal values defined by the incentive structure.[8]

The information requirements, therefore, are not very demanding. We assume that initially, there is cost uncertainty associated with the development contract. Later, when the optimal sharing rate is discussed, we will assume that the government and contract possess the same degree of uncertainty. During the course of the contract, the cost uncertainty facing the contractor (but not necessarily the government) is resolved, and the contractor makes trade-off decisions. These decisions are based on the value to the government of changes in performance, which are derived from the government's knowledge of the cost-of-procurement-and-operations curve. The government does not need to know the entire cost-of-procurement-and-operations curve, but only the part of the curve in the relevant range between specified minimum and maximum performance. Minimum performance must still meet the requirements of the government and is called "threshold performance." Maximum performance is called "objective performance."

---

[8] If the target profit selected is inappropriate given the difference in risk associated with an incorrect target cost and target performance, then the outcome will still be cost effective, but the distribution of net benefits between the contractor and government may not be optimal.

These are both specified in requirements documents. However, in any specific contract, there are likely to be idiosyncratic factors that prevent the cost-effectiveness model from being used mechanically.

B. Best-value Model

There are situations that do not fit neatly into the cost-effectiveness model. For example, there are variables such as aircraft weight—which for carrier-based aircraft have value not easily computed using cost-effectiveness analysis. For carrier operations, aircraft weight must be less than a certain value (threshold), and there is a value to reducing weight to facilitate aircraft launches and recoveries. Lower weight aircraft may also increase aircraft range. In this type of situation, selecting the optimal performance level is akin to a source-selection competition in which additional performance is subjectively valued by the government, and selection is based on "best value."

When the best-value model is applicable to incentive contracting, the process of determining the dollar value to the government of additional performance is demanding. We can begin with the observation that at the original target cost and target performance level, the expected dollar value of one more unit of performance is just equal to the expected dollar cost of the additional performance. However, when the best-value situation applies, incentive contracts require a determination of the value to the government in dollars of an increase in performance from threshold to objective. One approach is to develop a value statement that indicates how much the government is willing to spend for the additional performance. It is quite possible that the PM, who has a clear sense of the nature of the budget restraints facing the program, can determine this amount.

Also, as noted in Equation (1), for any specified performance incentive there is an implicit value statement. The value to the government equals the dollar value of the performance incentive divided by the contractor's cost-sharing ratio. Quite possibly, by using both Equation (1) and a detailed knowledge of budget restraints facing the program, the PM could develop a realistic value statement.

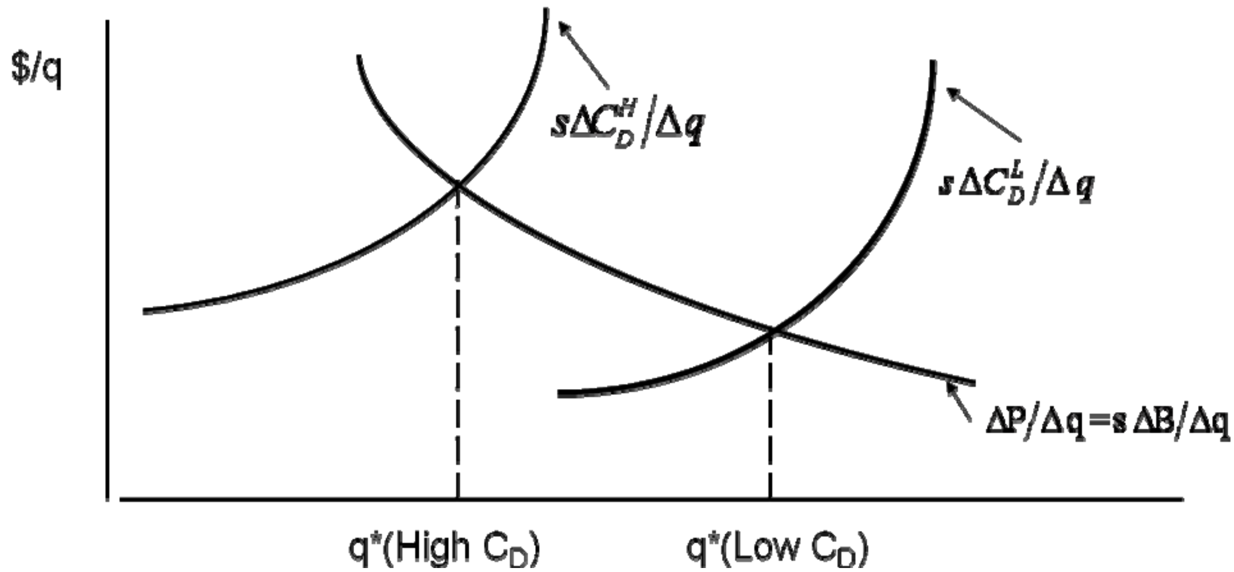


Figure 2. Best-value Model

The diagram used to illustrate the best-value model also applies to the cost-effectiveness model. The relevant trade-off information is now represented in terms of a change in performance Δq. Using the value statement for the change in performance, $\Delta B/\Delta q$, and Equation (1), we depict the performance incentive function, $\Delta P/\Delta q$. Also shown are two curves representing the contractor's cost-sharing ratio times the change in development costs—one resulting from a change in q when development costs are high, and a similar curve when the contractor's cost are low. These two curves are represented, respectively, as $s\Delta C_D^H/\Delta q$ and $s\Delta C_D^L/\Delta q$. The contractor equates marginal benefits and marginal costs when uncertainty is resolved. As a result, a best-value outcome is achieved.

C. COST-sharing Ratio

Cost sharing is relevant to both the cost-effectiveness model and the best-value model because at the time the contract is awarded, there is cost uncertainty facing both the government and the contractor, even though the cost uncertainty to the contractor is resolved at the time of contractor makes trade-off decisions. In this illustration, utility functions are used, and we focus on a particular case—the exponential utility function—which yields a linear sharing rule. In fact, it is unlikely that procurement practitioners actually know the government and contractor's utility functions. However, by exploring the implications of exponential utility functions, a PM can gain insight into both the underlying factors that yield a constant sharing ratio as well as the value of the potential cost-sharing values that are likely to emerge.

When there is a change in benefits and costs associated with a change in performance ($\Delta B/\Delta q$) and a change in total costs ($\Delta C/\Delta q$), then the change in net benefits $\Delta NB = \Delta(B-C)/\Delta q$. The cost or risk-sharing issue addresses how the ΔNB should be divided between the government and the contractor, who are both assumed to be risk-averse. The sum of the two shares equals the net benefits generated from the change in performance, so that $\Delta NB = \Delta NB^G + \Delta NB^C$. As indicated, both the government and the contractor are assumed to have exponential utility functions, which in this situation take on the form: $U^G = -exp(-\lambda^G * \Delta NB^G)$ and $U^C = -exp(-\lambda^C * \Delta NB^C)$.

The coefficients λ^G and λ^C are the coefficients of absolute risk aversion.[9] These coefficients are called the coefficients of risk tolerance, which we designate as τ^G and τ^C. It can be shown that the optimal sharing ratio, s, for the contractor equals

Equation (2) $$s = \tau^C/(\tau^G + \tau^C).$$

---

[9] The coefficient of absolute risk aversion for the government and contractor, respectively, equal $-U^{G''}/U^{G'}$ and $-U^{C''}/U^{C'}$. The coefficient is discussed in Kreps (1990, p. 85). The coefficient of risk tolerance and the derivation of the sharing relationships is discussed on pp. 169-174. Its application to government contracting with Performance Incentives was introduced by Hildebrandt and Tyson Performance Incentives and Planning Under Uncertainty (1979).

The government's share, therefore, equals $1 - s$. There is also a constant term in the risk-sharing relationship. It would be interesting to explore the circumstances in which this constant term approximates the target profit computed using weighted guidelines.

One important feature of this formulation is that the cost-sharing ratio does not depend on the degree of cost uncertainty at the time of contract award. This results from the fact that the contractor knows with certainty the cost of development function when selecting the optimal q As a result, it is the specified utility functions—the coefficient of absolute risk aversion and the related coefficient of risk tolerance—that determine the cost-sharing ratio. Another interesting feature is that, because uncertainty is resolved at the time the contractor makes the trade-off decisions, the cost and performance outcomes are not affected by this sharing ratio. Similarly, target cost and target profit do not affect the final outcomes.

As suggested above, rather than systematically attempting to use this methodology, a PM might use it to develop an understanding of the meaning of risk sharing by examining the resulting sharing ratios when the underlying parameters of the utility function change. Different utility functions might also be examined to better understand the situation in which non-linear sharing ratios are appropriate.

THIS PAGE INTENTIONALLY LEFT BLANK

V. Observations on Cost-effectiveness and Best-value Models

In the two models, it is assumed that the contractor maximizes accounting profit. Although there have been extensive discussions of extra-contractual influences, we do not explicitly account for these in the traditional models. Somewhat related is the fact that contractors are assumed to maximize accounting profit on the contract—as opposed to pursuing the economic profit emphasized by economists in their theoretical work. Economic profit deducts the implicit costs that can be incurred by contractors, but which are not accounting costs. The next model presented is based on recent theoretical developments and takes implicit costs in contractor decision-making into account.

Let us represent the time of contract award at t_1 and the time the contractor makes trade-off decisions as t_2. At t_1, there is cost uncertainty faced by both the government and the contractor. This is why a risk-sharing arrangement is appropriate when both the government and contractor are risk-averse. However, at t_2, the uncertainty originally facing the contractor has been resolved. Most likely, there remains, however, government cost uncertainty. For completeness, we call t_3, the time that costs are measured after the contract is complete, and there is a final settlement on the profits earned by the contractor.

As indicated above, changes in the sharing rate, target cost and target profit do not affect the final outcome in the models we have just described. In addition, because the government communicates to the contractor how much it is willing to spend for a performance improvement, cost overruns may be in the interests of the government.

The limited informational requirements of the cost-effectiveness and best-value models are also an advantage. This is in contrast to employing a more complex model in which the contractor maximizes economic profit, but the informational requirements to structure such a contract are demanding. Additional insights, however, are obtained from the more complex model in which there are contractor activities not observed by the government.

In the cost-effectiveness and best-value models, the government needs to be able to state the dollar value of a change in performance. While this sounds like a stringent requirement, Equation (1) shows that a performance-reward function and a cost-sharing ratio also define the amount the government is willing to spend to increase performance.

The government, however, doesn't really have to know anything about the contractor's cost function at t_1 or t_2. Figure 2 clarifies this. At t_2, it is the contractor that knows which of the marginal cost functions is applicable. The government does not need to possess this information. Yet, if the performance incentive function has been properly structured, the contractor selects the same level of performance as the government would choose if it had the necessary information. At t_3, however, when the contractor receives the fee earned, the government must be able to determine allowable accounting cost and to properly measure the performance level achieved.

If the PM is to calculate the optimal sharing rate, it must know both the government and contractor's utility functions, which embody the degree of risk adversity for both parties. This seems like an unrealistic assumption to make. However, by examining the affect of alternative utility functions on the sharing rate, government and contractor analysts can gain insight into the effect of the risk-averse utility function and the associated degree of risk adversity on the optimal sharing ratio. Yet, the fact that the optimal sharing ratio does not depend on the degree of cost uncertainty at t_1 is contrary to most expectations. In the next, more complex model, this result does not occur.

A. Moral Hazard and Contractor Cost Uncertainty During SDD

The word incentive has different interpretations. One view is simply that profit is the incentive that guides a contractor to appropriate decision-making. Another view argues an incentive mechanism is designed to motivate greater effort. Instead of using these perspectives, we will view the situation as one in which a performance incentive motivates a contractor to take actions that entail implicit costs. Without such an incentive mechanism, the contractor would be unwilling to incur these implicit costs.

This is the problem of moral hazard, a term which comes from the insurance literature. If something—for instance, a house—is fully insured against fire damage, it is believed by some that the insuree will not put forth the appropriate level of effort, a variable not observed by the insurance company, to minimize the risk of a home fire. This has also been applied to automobile, health insurance and a numerous other areas. It is an example of asymmetric information.

To apply this idea to multiple-incentive contracts, we assume that both the government and the contractor know each other's utility function at t_1, the time the contract is awarded. They also both understand the relationship between an action, a, taken at t_2, and the probability, P_i, that a particular outcome—which in this context is a combination of C_i and performance level, q_i ($i = 1, \ldots, N$)—occurs. Although both the government and the contractor know this relationship, the action taken, a, is best interpreted as all the relevant actions that affect C_i and q_i, but is unobservable to the government.

Rather than accounting profit, π^A, we now assume that the contractor maximizes economic profit, π, which equals accounting profit less the implicit cost of the unobservable actions, $h(a)$. These implicit costs reflect opportunity costs that are not included in contractual accounting costs, and may occur because of the impact of these actions on the profits received on another contract or simply because of additional effort put forth by the contractor. The effort itself would not directly receive an Award Fee. This fee would be associated with some outcome that results from this effort. Equation (3) depicts the relationship between accounting profit and economic profit in this situation:

Equation (3) $\pi_i = \pi_i^A - h(a),\ i = 1, \ldots, N.$

Deriving the precise nature of the incentive contract is fairly difficult, and we only present the first-order conditions that apply when there are all-around diminishing returns. We obtain:

Equation (4)

$$U^{G'}\left(B(q_i) - C_i - \pi_i^A\right) = U^{C'}\left(\pi_i^A(C_i, q_i)\right)\left(\lambda + \mu\left(\left(\Delta P_i(a)/\Delta a\right)/P_i(a)\right)\right),$$

where $'$ indicates the derivative of the utility with respect to it's arguments

$i = i\text{th outcome},\ C_i\ ,\ q_i\ ,\ i = 1, \ldots, n$

$P_i = \text{probability ith outcome is achieved with action } a$

$\lambda = \text{shadow price of constractor's reservation utility constraint}$

$\mu = \text{shadow price of contractor's incentive compatibility constraint.}$

The shadow price of the contractor's reservation utility constraint is a computed variable that requires knowledge of the minimum utility required for the contractor to accept the contract. Alternatively, one could approach this situation by assuming that there is a weight associated with both the government and contractor's utility level, and obtain a solution which can be interpreted as optimal risk sharing. The incentive compatibility constraint, which is contained in the full optimization problem, requires that the utility obtained from selected action *a* is greater than that obtained from any other action choice.

The term, $\left(\Delta P_i(a)/\Delta a\right)/P_i(a)$, is a key distinctive feature of this incentive structure. It captures the effect of the uncertainty associated with the contractor's action. Because of this term, cost uncertainty affects the optimal incentive structure. It is also a way of addressing risk explicitly in the incentive structure.

While this incentive structure can be viewed as an "ideal type," there are informational problems in implementing this model. A PM must know both the government and contractor's utility function. Contrast this with the cost-effectiveness and best-value model. For these two models, the utility functions would need to be known to compute the cost-sharing ratio. However, we argued that they could simply be used to develop insight concerning the impact of utility-defined risk adversity. If this model were to be implemented, however, it is necessary for a PM to know these utility functions to derive the optimal incentive contract.

The government also needs to know the model's entire benefit function, $B(q_i)$. This is a much more stringent requirement than simply knowing the dollar value of a change in performance from the minimum acceptable (threshold) to the maximum desired performance level (objective).

While the implicit cost function, $h(a)$, is not explicitly contained in Equation (4), the government needs to know this function to determine the optimal incentive function. Knowledge of the function, $h(a)$, is a very strong assumption at t_1, when the contract is awarded. However, we argue below that the government may have sufficient information at the completion of the contract, t_3, in order to be able to determine h(a). The PM can use this information in the construction of an Award Fee dimension to the contract.

It is also unlikely at t_1 that either the government or the contractor know the relationship between the probability of outcome i, and the action *a* taken.

We conclude that the information requirements to implement this incentive structure are very demanding. William Rogerson, one of the key theorists of the economics of optimal contracts, who has also conducted research in the area of DoD procurement has stated:

> The nature of the optimal contract varies tremendously depending on the precise functional forms of the utility functions and the distribution function […] [summarizing the asymmetric cost uncertainty]. For normative purposes the problem this creates is that the precise nature of the optimal contract is highly dependent on features of the contracting environment that government may be unsure about. For positive purposes, the problem is that the theory does not generate testable predictions […]. [T]he major value […] has been to help clarify the underlying incentive issues rather than to explain specific contracting phenomenon. (Rogerson, 1995)[10]

Nevertheless, the PM's view may be that the underlying assumptions of this contract contain some elements of realism missing from the cost-effectiveness or best-value models, such as the importance of cost uncertainty, or the incentive effects on non-linear cost sharing. The structural insights obtained from this somewhat more comprehensive model might be used to subjectively adjust the incentive structure.

B. Award Fee Contracts

Award Fees are based on the subjective valuation of contractual outcomes that are the result of contractor activities. Many of these activities directed at cost reduction or performance enhancement may result from increases in the contractor's implicit costs. While we discuss an Award Fee received at the completion of a

---

[10] Using hypothetical, but plausible values, an illustrative contract was structured using the moral hazard model. Basaran's (1994) *Performance Incentives for Warship Procurement* assumes a risk-neutral government and a risk-averse contractor. Various combinations of high and low effort achieve assumed combinations: high cost, high performance; high cost, low performance; low cost, high performance; and low cost, low performance. Hypothetical probabilities of each effort to outcome relation also provide assumed alternative cost outcomes. Given a known contractor utility and implicit cost function, Basaron demonstrates that in this simple situation, the necessary computations can be performed. However, obtaining the solution is difficult; in other words, applying the principles to a more complex setting would be very challenging. An alternative approach would be one in which the benefit function of a risk-neutral government is known, as is the contractor's certainty equivalent cost function and the associated risk-aversity parameter. Both are derived from an exponential utility function. When this information is combined with the variance of cost, one obtains a computable linear sharing rate. Additional study of this approach in the DoD context (and one that includes incentives on both cost and performance) is recommended. The methodology is outlined in Milgrom and Roberts (1992, Chapter 7).

contract, these fees are frequently used to reward or penalize outcomes that occur at a particular milestone of the contract such as Critical Design Review.

In fact, at the completion of the contract or at critical milestones, the government is likely to have substantial information about the contractor's implicit cost function, h(a). Both the PM and the Defense Contract Administration Services (DCAS) are continuously monitoring contractor activities. While their level of visibility may not permit the observation of the detailed trade-offs made by the contractor's design engineers, they would be cognizant of major cost-reducing activities and such factors as the quality of the engineers assigned to the contract. Either of these may entail an implicit cost borne by the contractor. With respect to cost-reducing activities, the contractor might improve the design organization by assigning superior managers who could be used on other projects, and there would likely be a net reduction in contract accounting costs—as well as an implicit opportunity cost because these managers are not available for employment on other projects, which might include the preparation of proposals that might have an effect on long-run profits. In our introductory analysis, it was consistent with the policy documents to assume that these activities do not affect the relationship between performance and cost. We designate the Award Fee as A.

Next, we consider a cost-plus-award fee/incentive fee (CPAF/IF) contract, which also contains objectively measurable performance characteristics. For this model, we return to the situation in which the contractor knows the relationship between cost and performance at t_2, when the trade-off decisions are made, but the government does not. As a result, Equation (1) continues to apply. The performance reward for an objectively measurable increase in performance from q_1 to q_2 equals the contractor's share of cost, s, times the dollar value to the government of the change in performance.

With respect to the Award Fee for cost-reducing activities that entail an implicit cost, we know that a successful activity reduces explicit cost, and the accounting profit earned by the contractor increases by $s^*\Delta C/\Delta a$, where $\Delta C/\Delta a$ is negative. The dollar amount, $-\Delta C$, is the incremental benefit associated with the contractor's cost-reducing activities. Because implicit cost is also a social cost, the government and also the contractor incur a cost equal to $\Delta h/\Delta a$. Marginal analysis indicates that the government equates:

Equation (5) $$-\Delta C/\Delta a = \Delta h/\Delta a.$$

In contrast, the contractor, when maximizing economic profit, takes account of the fact that $s^*\Delta C/\Delta a$ is received when explicit costs are reduced. However, additional profit is required as a result of the increase in implicit costs, $\Delta h/\Delta a$. Therefore, the Award Fee received by the contractor must satisfy:

Equation (6) $$\Delta A/\Delta a - s^*\Delta C/\Delta a = \Delta h/\Delta a.$$

Using the government's optimization condition, Equation (5), to substitute for $\Delta C/\Delta a$, we obtain the following relationship for the optimal Award Fee:

Equation (7) $$\Delta A/\Delta a = (1 - s)\Delta h/\Delta a.$$

This states that the optimal change in the Award Fee (that results from an observed change in the contractor's cost-reducing activities) equals the government's share of the change in the observable implicit costs (resulting from the change in the activity level). There is an offset to the change in Award Fee because, as seen in Equation (6), the contractor has already been partially compensated for the decrease in accounting cost resulting from cost sharing. Government personnel would have a sense of the contractor's cost-reducing activities and their effect on C, and also the reduction in accounting cost resulting from these activities.[11]

1. F/A-18E/F CPAF/IF Multiple-incentive Contract during Engineering Development

This contract, awarded during the 1990s, includes both cost and Performance Incentives and an Award Fee provision. The contractor shares a portion of development cost, and the fee is based on both objectively and subjectively determined performance. Fifty percent of the fee is based on technical performance. Seventy percent of this 50% is based on measurable performance. This constitutes the Performance Incentive dimension of the contract. Thirty percent of the 50% is based on a subjective government assessment of technical performance. This would be part of the contract's Award Fee. The other 50% of the total fee is also based on a subjective assessment of the contractor's program management and logistics effectiveness. Therefore, this part of the incentive contract is also part of the contract's Award Fee structure. There is also a feature contained in this contract whereby funds are withheld until first flight is achieved.[12]

---

[11] One can contrast numerous other examples using this methodology. For example, the performance level, *q*, achieved may depend on the quality of engineer, *E*, assigned to the contract. There may be both, and explicit accounting cost associated that reflects the higher pay received by the higher-quality engineers. In addition, q can be expected to increase. However, there may also be an implicit opportunity cost associated with failing to use the engineers on another project. This might be represented by *h(E)*, and in a manner similar to the example provided, the government can construct an Award Fee contract that motivates the contractor to assign the appropriate quality of engineers to the contract.

[12] Information on the F/A-18E/F CPAF/IF multiple-incentive contract is obtained from a briefing presented by Pat Shields at the Naval Postgraduate School in 1996, and also from DoN (1996, April 4, Award Fee). This information was provided by Prof. Jeff Cuskey of the Naval Postgraduate School. There were subsequent revisions to the Award Fee Plan, and we have not yet received information on the final contract outcome.

2. Notional Structure of F/A-18E/F Incentive Contract

Figure 3 displays the qualitative structure of the F/A-18E/F contract. In this figure, the term "Award" refers to profits to be earned based on either objective or subjective outcomes. Only positive Award Fees are shown.

As seen in Figure 3, target cost equals $101, and there is no cost sharing until $105. Likely, this resulted from significant uncertainty about the expected cost around the target level. This uncertainty may result in a disagreement between the government and contractor as to what the appropriate target cost should be. The cost-sharing ratio for an overrun is 75/25—meaning the government bears 75% of the costs and the contractor the remaining 25%. For an underrun below $101, the sharing ratio is 60/40. Therefore, the government incurs a saving of $0.6 for each dollar of cost underrun, and the contractor increases contractual profits by $0.4 for each dollar of cost savings under $101. Because the government effectively bears more risk when there is an overrun than when there is an underrun, the contractor is given a greater incentive to strive for underruns than to avoid overruns. Likely, it is easier to relate this cost-sharing structure to the insights obtained from the moral hazard model than from the discussion of cost sharing that was an augmentation of the cost-effectiveness and best-value models.

Maximum incentive fee occurs at a cost outcome of $89.5, and minimum incentive fee occurs at a cost outcome of $129. Below $89.5 and above $129, the government bears all the cost risk. The incentive outcome, including the sharing ratios, is consistent with a target incentive fee of $4, a maximum incentive fee of $9 and a minimum incentive fee of -$2. A $12.5 underrun below the target of $101 increases the contractor's incentive profit by $5, and a $24 overrun over $105 reduces profit by $6.

Also, note the potential for a $6 "award" fee, which includes the fee earned from both objective and subjective performance measures. As illustrated, the maximum fee on this simulated version of the F/A-18E/F contract is $15, and the minimum fee is -$2.

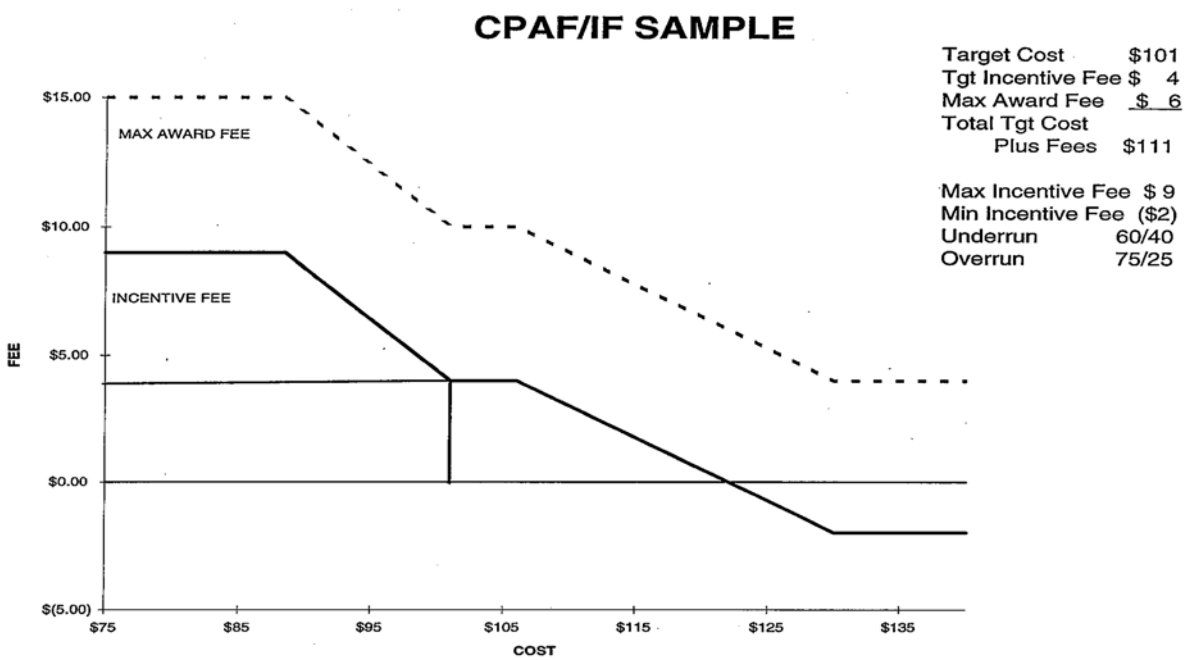


Figure 3. Notional Illustration of F/A-18E/F Incentive Structure

THIS PAGE INTENTIONALLY LEFT BLANK

VI. Technical Performance

We turn to technical performance, which, as indicated, accounts for 50% of the fee. This includes both objectively measurable technical performance and the government's subjective assessment of technical performance.

An example of an objectively measurable performance characteristic is Weight Empty. The following describes the incentive structure over the course of the contract:

1. Weight Empty at Critical Design Review (20% of the Weight Empty Fee)

	Performance Values:
Negative Fee (-200%) at:	36,164 lbs.
Zero Fee at:	29,964 lbs.
Target Fee (90%) at:	29,514-29,814 lbs.
100% Fee at:	29,364 lbs.
Highest Fee (120%) at:	29,1641bs.

2 Weight Empty at First Flight (30% of the Weight Empty Fee)

	Performance Values:
Negative Fee (-20%) at:	30,464 lbs.
Zero Fee at:	30,264 lbs.
Target Fee (90%) at:	28,914-30,014 lbs.
100% Fee at:	29,664 lbs.
Highest Fee (120%) at:	29,464 lbs.

3. Weight Empty at Contract Completion (50% of the Weight Empty Fee)

	Performance Values:
Negative Fee (-20%) at:	31,064 lbs.
Zero Fee at:	30,864 lbs.
Target Fee (90%) at:	30,514.30,614 lbs.
100% Fee at:	30,264 lbs.
Highest Fee (120%) at:	30,064lbs.

There are also fee structures for Aircraft Reliability and Maintainability, for which the performance measures are, respectively, Mean Flight Hours between Failure (MFBF) and Maintenance Manhours per Flying Hour (MMH/FH). Another Reliability and Maintainability related incentive is "Built-in Test," which is measured using Fault Detection, Fault Isolation, and False Alarm Rates.

Fighter Escort Radius, Interdiction Radius, Specific Excess Power, Launch Wind Over Deck, and Approach Speed are also incentivized, and all evaluated by comparing the outcome to the specification requirement.

Fatigue Test, another incentive variable relates to whether the specified dates for various fatigue tests specified in the contract are met. If they are, the total fee for this category is awarded.

In addition to these technical measures, a subjective assessment of program management (particularly as it relates to achieving schedule milestones and cost management) and a subjective assessment of logistics (as this relates to such categories as commonality and supportability) account for 50% of the fee pool. However, it should be noted that the technical assessment of reliability, maintainability, and built-in test—while associated with logistics—would be included in the government subjectively based assessment of technical performance.

Clearly, the F/A-18E/F incentive contract is extremely comprehensive. It captures those factors that are objectively measurable, such as cost and weight empty. Certain technical factors contain measurable indicators, but ultimately require a subjective assessment from system engineers and other specialists to determine fee. Given the importance of subjective factors such as program management and qualitative logistics, the incentive contract provides significant fee opportunities for high qualitative performance of these factors. The special provision to hold back fee until first flight occurs is the key schedule variable added to the incentive structure.[13]

One might consider some of the implications of the variability of the cost-sharing ratio. There is a limited range around target cost in which there is no cost sharing. There is a higher contractor share below target cost than there is above contract costs. This variability suggests that elements of the moral hazard model with cost uncertainty may have influenced the thinking of those responsible for structuring the contract. However, at a certain cost level, the technical Performance Incentives contain an implied willingness-to-pay feature that is embodied in the best-value incentive model. Also, the purely subjective elements suggest that government personnel have the ability to evaluate factors that are not easily measurable but that may well be associated with implicit costs incurred by the contractor.

A. System Design Specifications and Incentive Contracting

Recently, OSD and JCS changed specification policy on major defense programs. Historically, the Operational Requirement Document (ORD) specified both a threshold (minimum required) performance level and an objective (maximum) performance level. In addition, Performance Incentives were employed that permitted significant trade-off opportunities within threshold and objective performance. In addition, Cost as an Independent Variable (CAIV) was implemented. CAIV expands the opportunity to make cost versus performance trade-offs during acquisition.[14]

---

[13] As discussed, the necessary to meet fatigue test milestones is also included in the incentive contract. A specific award is received as the milestone is achieved. Typically, systems and mechanical expertise is required to asses the results of the test. Therefore, the achievement of these milestones would be classified as government subjective assessment of technical performance incentive elements.

[14] For a discussion of CAIV see Kaminski (1991, March 15) and DoD (1995, June 29). CAIV is discussed by Rush (1997).

However, a number of years ago, the ORD and the Mission Needs Statement (MNS) were replaced with new documents under the Joint Capabilities Integration and Development System. These include the Initial Capabilities Document (ICD), the Capabilities Development Document (CDD), and the Capabilities Production Document (CPD). The ICD replaces the MNS at Milestone A, and the CDD replaces the ORD at Milestone B. Milestone B initiates the program as entry into the System Development and Demonstration (SDD) phase begins. Roughly speaking, SDD has replaced Engineering and Manufacturing Development (EMD). Full Scale Development (FSD) formerly occurred during EMD (DoN, 2005, Chapter 3). SDD is that phase of the acquisition process when Key Performance Parameters (KPP) are developed, in detail, and is, therefore, the appropriate phase of the acquisition process for technical Performance Incentives and Award Fees to be used in conjunction with cost incentives. A classic example of this CPAF/IF multiple-incentive contract is the F/A-18E/F, discussed above.

The Navy recently implemented the new policy. In broad terms, System Design Specifications lie somewhere between performance specifications and detailed-design specifications. Frequently, the System Design Specifications have a hierarchical structure—with Key Performance Parameters (KPPs) contained in the CDD at the top of the hierarchy. Underlying the KPPs are lower-level supporting specifications. Provided that both Threshold and Objective Performance levels remain at the top of the hierarchy, the System Design Specifications remains consistent with the use of Performance Incentives, which maintain CAIV objectives at the highest level of system performance.

Lower-level supporting specifications may be amenable to the use of Award Fees. However, at present, the extent to which the lower-level specifications constrain the value of the KPPs achieved may raise an issue concerning the continued use of Threshold and Objective performance.[15]

The new guidance contains appendices devoted to various Navy systems—including Ships, Air, C4I, Land, and Integrated Warfare Combat Weapon Systems. With respect to Air, the SDS is described as “a library of specifications that define the performance, functional, physical, and allocated baselines for a weapon system.” Also, it states that “a specification tree should be included in the SDS” (DoN, 2008b, July 17, Appendix B).

PMs pay special attention to risk in the SDS documents. These documents include the requirement to include both a Risk Management Plan, and Operational and Technical Risk areas. Risk is an integral part of the moral hazard within the contractor-cost-uncertainty/incentive model, but plays a much more limited role in the cost-effectiveness and best-value models.

As discussed, recent Pentagon memoranda indicate that there is a policy swing from subjective to objective Performance Incentives. Clearly, additional research is needed to better understand the relationship between the SDS policy and the use of objective Performance Incentives. Will there be a range of objectively measurable performance outcomes that permit the use of objectively measurable Performance Incentives? How can these be identified in the SDS? How should risk be explicitly handled when structuring an incentive contract?

[15] For an overview of System Design Specifications, see DoN (2008a, July 17). The new policy, as implemented by the Navy, is outlined in (DoN, 2008b, July 17), as directed by the Department of the Navy (DoN) Requirements and Acquisition Process Improvements, July 17, 2008.

THIS PAGE INTENTIONALLY LEFT BLANK

VII. Final Observations

There is a grand simplicity associated with the view that objectively measurable Performance Incentives communicate the government's values to the contractor. This is the basic assumption of the cost-effectiveness and best-value models. Yet, these models do not address the risk associated with cost uncertainty—the sharing ratio simply depends on the degree of risk adversity embodied in the government and contractor's utility functions. The moral hazard model does address the effect of the uncertainty associated with contractor-unobservable actions on cost and performance and does, therefore, incorporate cost and technical risk into the structure. However, as we have seen, a great deal of information is needed to properly structure this type of incentive.

An approach to structuring a subjective Award Fee contracts is discussed above under the assumption that the government does have a great deal of information about the actions taken by the contractor. Even if these actions can be observed, the government must understand how they affect the contractor's implicit cost—as well as the fundamental cost and performance variables that affect the government.

The F/A-18EF contract may represent an example of a multiple-incentive contract that is sensitive to many of the considerations discussed. However, this CPAF/IF multiple-incentive contract is not formally anchored to any of the models outlined. There are elements of communicating value in the Performance Incentives, but at the same time, there is a sensitivity to risk and cost uncertainty in the cost-sharing arrangement. Significant emphasis is also given to those factors that are measured in only a purely subjective manner.

It would be interesting to examine the F/A-18EF incentive structure in the light of the Navy's new System Design Specification policy. Would the range of possible performance outcomes be affected? Would an explicit analysis of risk, as required in a SDS, affect the cost-sharing ratio or any other features of this incentive contract? The answers to these questions await further analysis.

List of References

Assad, S.D. (2007, April 24). Proper use of award fee contracts and award fee provisions. Memorandum. Washington, DC: USD(AT&L).

Basaran, I. (1994). Appropriateness and applicability of the use of performance incentives for warship procurement. Unpublished master's thesis, Naval Postgraduate School, Monterey, CA.

Bolton, J., et al. (2008). Weapon system cost growth: Analysis of 35 major defense programs. Santa Monica, CA: RAND.

Bolton, P., & Dewatripont, M. (2005). Contract theory. Cambridge, MA: MIT Press.

Cook, J., Ackerman, D., Clegg, M., Krutz, R., & Johnston, J. (1966, August). The evaluation and structuring techniques of multiple incentive contracts. Washington, DC: USAF Academy Consulting Team Research Report, Department of the Air Force.

Cook, J., Clegg, M., Hildebrandt, G., Johnston, J., & Zangri, A. (1967, August). The evaluation and structuring techniques of multiple incentive contracts. Washington, DC: USAF Academy Consulting Team Research Report, Department of the Air Force.

Department of Defense (DoD). (1962). Incentive contracting guide. Washington, DC: Author.

Department of Defense (DoD). (1995, June 29). SD-15 performance specifications guide. Washington, DC: Author.

Department of Defense (DoD) & National Aeronautical and Space Administration (NASA). (1969, October). DoD and NASA guide: Incentive contracting guide. Washington, DC: Author.

Department of the Navy (DoN). (1996, 4 April). Award fee plan for F/A-18E/F airframe engineering and management development contract, revision 4. Washington, DC: Author.

Department of the Navy (DoN). (2005). Vision, presence, power 2005: A program guide to the US Navy. Washington, DC: Author.

Department of the Navy (DoN). (2008a, July 17). Presentation: The system design specification (SDS) primer, US Navy, Acquisition process improvements, revision 3. Washington, DC: Author.

Department of the Navy (DoN). (2008b, July 17). System design specification guidebook. Washington, DC: Author.

Dennett, P.A. (2007, December 4). Appropriate use of incentive contracts. Memorandum. Washington, DC: Office of Management and Budget (OMB).

Finley, J.L. (2007, April 4). Award fee contracts (FAR 16, DFARS 215, DFARS 216). Memorandum. Washington, DC: USD(AT&L).

General Accounting Office (GAO). (2005, December). Defense Acquisitions: DoD has paid billions in award fees regardless of incentive outcomes (GAO-06-66). Report to the Subcommittee on Readiness and Management Support, Committee on Armed Services, US Senate. Washington, DC: US Government Printing Office.

Hildebrandt, G., & Tyson, L. (1979). Performance incentives and planning under uncertainty. Journal of Comparative Economics, 3(3), 217-232.

Jaggard, M.F. (2006, April 6). Award fee contracts (FAR 16, DFARS 215, DFARS 216). Memorandum. Washington, DC: Department of the Navy (DoN), Office of the Assistant Secretary (Research, Development & Acquisition).

Jaggard, M.F. (2008, January 22). Proper use of award fee contracts and award fee. Memorandum. Washington, DC: Department of the Navy (DoN), Office of the Assistant Secretary (Research, Development & Acquisition).

Jones, W. (1970, September). Experiences in incentive contracting. Defense Industry Bulletin, 6, 1-5.

Kaminski, P. (1991, March 15). Keynote address given to the Standardization Awards Luncheon.

Kreps, D. (1990). A course in microeconomic theory. Princeton, NJ: Princeton University Press.

Lazear, E., & Gibbs, M. (2009). Personnel economics in practice (2nd ed.). Hoboken, NJ: John Wiley & Sons.

Milgrom, P., & Roberts, J. (1992). Economics, organization and management. Upper Saddle River, NJ: Prentice Hall.

Rogerson, W. (1995). Incentive models of the defense procurement process. In K. Hartley & T. Sandler (Eds.), Handbook of defense economics (pp. 309-346) (Vol.1). Amsterdam: Elsevier.

Rush, B. (1997). Cost as an independent variable. Acquisition Review, 4(2).

Shields, P. (1996). Naval Postgraduate School presentation, Monterey, CA.

Snyder, T. (2001, April). Analysis of Air Force award fee and award term implementation. Montgomery, AL: Air Command and Staff College, Air University.

Under Secretary of Defense (Acquisition, Technology & Logistics) (USD(AT&L)). (2006, March 29). Award fee contracts (FAR 16, DFARS 215, DFARS 216). Memorandum. Washington, DC: Author.

US Army. (1908, February 28). Signal Corps contract (Specification No. 486). Washington, DC: Author.

THIS PAGE INTENTIONALLY LEFT BLANK

2003 - 2009 Sponsored Research Topics

Acquisition Management

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

Contract Management

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

Financial Management

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

Human Resources

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

Logistics Management

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

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

Program Management

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

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

THIS PAGE INTENTIONALLY LEFT BLANK

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

www.acquisitionresearch.org