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THESIS

APPROPRIATENESS AND APPLICABILITY OF
THE USE OF PERFORMANCE INCENTIVES FOR
WARSHIP PROCUREMENT

by

Ismail Zafer Basaran

June 1994

Thesis Advisor:

Gregory G. Hildebrandt

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Warship Procurement

by

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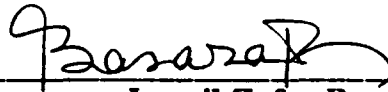
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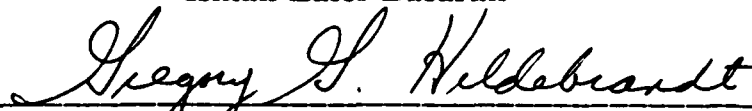
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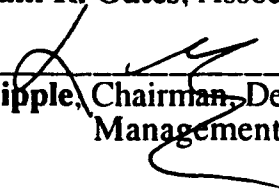
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ABSTRACT

The end of the cold war caused defense budgets to decrease in a sharp manner. This trend requires the Navy, as a branch of the DOD, to tighten its controls over spending and become more cost-effective. Since warship procurement is among the most important financial transactions of the Navy, one instrument that might improve the cost-effectiveness of the Navy is the use of cost and performance incentives in warship procurement.

This thesis studies the traditional and current theories of incentive contracting. It explains the relationship between incentives and cost-effectiveness, and how the use of incentives can encourage contractors to put in a high level of effort on projects so that the government will benefit more.

To define the performance level of a warship, analytical approaches, such as the use of an operations research model with the aid of response surface methodology, and the subjective figure of merit model are discussed. This thesis also presents some views on the principal-agent problem, and it expends the idea of using the contractor's unobservable effort level as means to determine what type of incentives to offer. To compare the traditional and current concepts of incentives, two specific examples are constructed and examined.

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I. INTRODUCTION

Warship procurement is one of the most important financial transactions of the Turkish Navy. These transactions ought to be carried out in a systematic manner with close coordination between the Turkish Navy and the relevant country's industry. Full account must also be given to the unique conditions that apply to the procurement process.

When the Navy begins the process of warship procurement, its main objective is to obtain the most effective warships to meet defense requirements within the given budget constraints. These constraints ultimately require efficient production while accounting for risk sharing between the contracting parties and ensuring that the contractor provides the appropriate effort level.

Each year a great portion of the Navy's budget goes to procuring and maintaining warships. To achieve the desired goals under the uncertainties and risk involved, warship procurement contracts are carefully prepared and reviewed before they are approved. Once a contract has been secured and production begins, the contract cannot be transferred to another contractor, without undesirable costs to the government, especially government to government contracts involving foreign producers.

The warship industry is unique. Each product is different and extremely complex. This industry has many risks and uncertainties due to:

- Rapid technological changes.
- Long lead time from design to completing of production.
- Extensive competition in this type of business.
- Diversification limitations caused by the high technological requirements and integration of different systems.
- Policy changes which can have long-term effects.
- Multi-national technical differences with the associated integration problems.

Subject to the upcoming restraints for the military and the Navy budget; development, equipment and materials procurement became one of the most important areas for improving the Navy's cost effectiveness. For the Navy, one instrument for increasing this cost effectiveness, by improving warship procurement, is using cost and performance type contracts. The real value of these incentive contracts lies in their ability to compensate for the lack of information about economic conditions and for the lack of data about the desired product.

For any particular Navy, the use of incentive contracts might ensure that:

- The Navy receives the most-effective warship to meet its requirements.
- Contract schedules are met or beneficially surpassed.
- Cost is kept to a minimum and there is sufficient profit to properly motivate the contractor.
- An acceptable solution for the engineering problem is achieved.
- The contractor selects the appropriate effort level even when this can not be observed by the government.

The first step for warship procurement is for the Chief of Naval Operations and his staff to determine the warship's military requirements. After approving the necessary funds, design competition is initiated amongst the various firms and their proposals are requested. Incentives might be applicable beginning from this stage, e.g. award for the best design. Then, the Navy selects the contractor. A performance evaluation system might provide an incentive at this step of the procurement process. Upon receiving the procurement request, the Navy's contracting division negotiates with the selected firm to establish contract price, provisions and type. While some argue that the administrative costs of both the planning and the negotiation stages increase with this duration, both the planning and the negotiation stages are carried out carefully and regardless of any time constraint. In establishing incentive contracts, stating the correct specifications and including the right contract incentives are the basics of the expected benefits. Any

administrative costs must be considered insignificant compared to the cost savings and quality advantages that can be gained through incentive contracts.

The profit motive is the essence of incentive contracting. Incentive contracts utilize the drive for financial gain under risk conditions by rewarding the contractor through increased profit for attaining cost (and sometimes cost and schedule) levels more beneficial for the Government than expected (target) and penalizing him through reduced profit for less than (target) expected levels. In stressing the profit making aspects of a company's existence, however, there is no intention to discount the importance of extra contractual incentives, such as to (i) gain future business, (ii) increase profits on other contracts being performed at the same time (by absorbing a portion of the fixed overhead expense which otherwise would be absorbed by other fixed price or incentive type contracts, and thereby increasing the profit margin under those contracts), (iii) contribute to and improve the nation's international reputation, (iv) gain prestige and goodwill, (v) retain and maintain an engineering and/or production capability, and (vi) excel for the sake of excellence.[Ref.1:p.2]

When the contracting parties are not simply two private parties but governments, one could also add 'to secure and to strengthen the mutual cooperation and the alliance' as another extra contractual incentive. So, during all of the previous stages and the final approval stage, extra contractual incentives might also be considered.

Using contractual and extra contractual incentives, regardless of the stage which they are used, provides the greatest potential for improving cost effectiveness in warship procurement.

It is at the contract and price setting stage when the contractor (warship supplier) begins to assume his monopolistic character and also the Navy's contracting personnel can establish mutually satisfactory cost and profit figures, while further extending the quality and time incentives in effect up to this stage, through the effective use of incentive type contracts.[Ref.2:pp.4-5]

As explained in the DOD and NASA Incentive Contracting Guide, pp. viii-ix,

the objective of any incentive contract is to motivate the contractor to earn more compensation by achieving better performance and controlling cost. The incentive arrangement must also reflect in a practical way failure to achieve desired performance and cost control by reduced compensation; it must be designed to relate compensation more accurately to value received. To be meaningful an incentive must

be capable of inducing the generation of some specific and potentially favorable effort that would not otherwise have been initiated by those individuals able to constructively contribute at a point in time so that the added effort can influence the realization of the objective. Of most fundamental significance is the fact that even if incentive contracting is only applied under appropriate circumstances and the proper type of incentive contract is used and the specific incentives are properly structured (selection and relative weighting), the effectiveness of an incentive contract nevertheless will be eroded or completely destroyed during contract performance by inappropriate contract clauses and administrative practices. The incentive contract should communicate the Government's objectives to the contractor and motivate the contractor's management to convey the Government objectives within the contractor's organization... Structuring an incentive should always be an iterative - - empirical - - approach.

The purpose of incentive contracting is to motivate the contractor to performance which is in the best interest of the customer (government). This is accomplished by adjusting the contractor's profit in proportion to the value (to the customer) of the actual completed contract performance in comparison to target profit and performance goals expressed in the contract document. Thus, two primary concepts are involved: (i) motivation of the contractor, and (ii) value to the customer.

During and after World War II, the U.S. Navy developed and authorized cost incentives (Fixed Price Incentive Contract- FPI, Cost Plus Incentive Fee Contract- CPIF, etc.), and performance incentives (speed of an aircraft, schedule etc.). These incentives also consider the risk sharing issue up to a certain limit. Today, theories that guide the incentive contracting present several important approaches for the achieving and sustaining the appropriate effort level by the contractors.

Practically all incentives are established on a negotiated sharing basis. For cost incentives, a cost sharing ratio would be negotiated at 70/30 (for example) whereby the government would be responsible for 70 cents of every dollar of actual cost in excess of the negotiated target cost within the operative cost range, while the contractor would be responsible for the remaining 30 cents. Conversely, for cost underruns, the contractor would receive a 30 percent increase in profit for every dollar saved under target cost within the operative cost range, while the government would realize a 70 cent saving on each dollar of underrun.[Ref.2:p.5]

For performance incentives, targets would be negotiated in areas such as speed, effectiveness, maneuverability and defense capabilities. Predetermined profit rate increases would be offered for percentage increases in performance goals, while failure to attain the goals would reduce the profit rates. Schedule incentives are established like performance incentives substituting target delivery or completion dates for performance targets. For obvious reasons, whenever the performance or schedule incentives are used, a cost controlling incentive is also applied.

Despite the many advantages the incentive contracts offer, in the U.S., they have failed to gain full acceptance for many years. There are many difficult problems that must be overcome to ensure their successful incorporation and administration. Incentive contracts require extensive planning by both the Navy and the contractor's technical personnel, and a sincere cooperation between both parties. Highly qualified personnel are also a necessity to overcome the problems encountered while negotiating effective incentive contracts.

The major problem is determining contract costs. Success of incentive contracting hinges on this factor. The contractor is supposed to determine costs as accurately as possible using all available information. Possible cost reductions, if any exist, must be passed to the Navy before the end of negotiations. Sub-contracting costs are also to be determined as accurately as possible. The Navy's contracting personnel is responsible for evaluating those cost figures, since these figures are the basis for negotiating target profits and profit ranges. Cost savings that may befall the contractor as a result of extra contractual factors, like increased business, must also be weighed. Costs always keep their importance

and should be evaluated continuously. They are subject to the influence of changing factor prices and technology.

The problem with establishing performance incentives is that the performance criteria for any particular product might be difficult to define. Setting schedule incentives requires substantial knowledge about the contractor's production capabilities and predicting the optimum time for the Navy to get the final product. The effectiveness of a schedule incentive hinges on establishing firm specifications and minimizing changes.

To establish multiple incentive contracts, various criteria must be carefully balanced so that any tradeoffs amongst incentives will provide the Navy the most effective warship for the available funds. For successful incentive contracts, establishing and sustaining confident, cooperative relations between the Navy's contracting personnel and the contractor is a pre-condition. One should not expect that the incentive type contracts would provide their greatest advantage, unless such a relationship exists.

It is the contracting personnel's responsibility to provide the contractor with the appropriate performance specifications to minimize the unknown contingencies that the contractor faces. In warship procurement, defining these specifications is also very difficult. The military requirements expected from a warship vary extensively and integrating various technological systems is very complex. It should be noted, however, the use of performance incentives requires that the contractor have specifications that permit a range of performance possibilities. If the specifications written into the contract are too detailed, opportune trade-offs between performance and cost that arise cannot be exploited.

In the following chapters, this thesis presents historical and current incentive theories, an analytical approach for the defining warship performance, a further study of theories of incentives under uncertainty and competition and their applicability to warship procurement.

II. BASIC PRINCIPLES OF INCENTIVE CONTRACTING

The incentive contract is a way of expressing the Government's interests and objectives. It rewards the efficient producers by high profits, and less efficient ones by low profits, or in some cases zero or negative profits. Rewards and penalties, therefore, are two basic elements that determine the effectiveness of any incentive contract. The rewards and penalties in a cost incentive contract are expressed as a ratio (i.e. 75/25 sharing ratio). Basically, a 75/25 sharing ratio means that for every dollar of cost above the contract's target cost, the Government pays 75 cents and the contractor pays 25 cents. It also means that for every dollar of cost under the contract's target cost, the Government saves 75 cents and the contractor earns an additional 25 cents in profit.

There are many reasons why incentive contracting is essential to ensure efficiency in any procurement. Incentive contracts can increase technological progress and provide cost savings for the government. They also promote added effort by the contractor to perform in the government's best interest.

The basic incentive principles are:

- To turn out a product that meets significantly advanced performance goals.
- To substantially reduce the cost of the work.
- To improve on the contract schedule up to and including final delivery.
- To complete the project with an appropriately balanced emphasis on these objectives.[Ref.3:p.5]

In establishing any incentive contract, 'profit' is accepted to be the basic motive of the business enterprise. Generally, however, contract profits are calculated as another element of the price, just as material, labor, overhead, and administrative costs. At the negotiations stage, bargaining skill and leverage of both parties -- the firm's

representatives and the government's negotiation (procurement) team -- often determines the profit level and dollars allotted to certain cost figures.

DOD and NASA Incentive Contracting Guide, October 1969, recognizes that contractors will, generally, select their preferred combination of objectives and not maximize profit as measured by the government. Most of the theories that followed also adopted this recognition. If contractors maximize profits, this is in the government's best interest, as long as the government's objectives are achieved.

The profit is the essence of incentive contracting. Incentive contracts utilize the drive for financial gain under risk conditions by rewarding the contractor through increased profit for attaining cost, performance and schedule levels more beneficial for the government than expected(target) and by penalizing him through reduced profit for less than expected(target) levels.[Ref.1:pp.1-2]

Rewards and penalties which are applied in proportion to the cost, performance and schedule criteria are , indeed, the real reasons that the incentive contracts are successful. By applying a sharing ratio to any performance level, cost overrun/underrun, or the early/late delivery of the product, the contractor is motivated to assure performance, reduce cost, and pay more attention to the delivery date(s) of the final product.

Structuring an incentive type contract is very important. If the type and the contracting figures are unrealistic, it might be a good opportunity for the contractor to increase his profits through cost savings or performance improvement or early delivery. Especially in research and development contracting, the lack of definitive requirements and the inability to measure the relevant technical objectives, might make incentive contracts inefficient. Therefore, the contracting personnel should always be aware of these possibilities and try to minimize the inefficiencies by defining the government's goals and objectives clearly and explaining them openly.

A. COST PLUS INCENTIVES

There are two basic contract types: *fixed-price* and *cost-reimbursement*. Firm-Fixed-Price(FFP) and Cost-Plus-Fixed-Fee(CPFF) contracts represent the two extremes in terms of responsibility for cost variations. The other principal variations of cost incentive contracting are between these extremes.

The general characteristics of fixed-price contracts include:

- There is a price which represents the full payment for the work.
- The final product meets the minimum performance standards.
- The product is delivered by a specified time.

The general characteristics of a cost-plus-fixed-fee contract, on the other hand, include:

- The agreement covers an estimated contract cost.
- The buyer agrees to reimburse the seller for all allowable costs necessary to perform the work.
- A fixed fee beyond the costs is pre-determined by the parties.
- There might be a specified time for delivering the product.

The respective contracting types vary in the responsibility assumed by the contractor for the costs and performance and in the profit incentive offered to the contractor to achieve the specified contract goals. In FFP contracts, the contractor assumes full responsibility for costs and therefore has a higher profit incentive. In CPFF contracts, the contractor assumes the minimal or no cost responsibility and profit does not provide any incentive to control costs. Risk sharing and uncertainty issues will be discussed further in the following subchapters.

Within the two extremes of FFP and CPFF contracts, the 1969 DOD and NASA Incentive Contracting Guide defines the following contract types and provides general guidelines regarding their use:

"1)Cost-Plus-Fixed-Fee (CPFF). Appropriate where "level of effort" is required or where high technical and cost uncertainty exists.

2)Cost-Plus-Award-Fee (CPAF). Appropriate where conditions for use of a CPFF are present but where improved performance is also desired and where performance can not be measured objectively.

3)Cost-Plus-Incentive-Fee (CPIF)(Cost Incentive Only). Appropriate where a given level of performance is desired and confidence in achieving that performance level is reasonably good but where technical and cost uncertainty is excessive for use of a fixed-price incentive.

4)Cost-Plus-Incentive-Fee (Multiple Incentives). Appropriate where expectation of achieving an acceptable performance is good but improvement over that level is desired and where technical and cost uncertainties are excessive for use of FPI.

5)Fixed-Price-Incentive (FPI)(Cost Incentive Only). Appropriate where confidence in achieving performance is high but cost and technical uncertainty can be reasonably identified.

6)Fixed-Price-Incentive (Multiple Incentives). Appropriate where improved performance is desired and technical and cost uncertainties reasonably identifiable.

7)Firm-Fixed-Price (FFP). Appropriate where performance has already been demonstrated and technical and cost uncertainty is low.

8)Firm-Fixed-Price (With Incentives Added). Appropriate where improved performance or schedule is desired and technical and cost uncertainty is low."

Along with these contracting types, the ASPR Manual For Contract Pricing defines several other contracting types:

- 1)Fixed-Price Incentive, Firm Target (FPIF).
- 2)Fixed-Price Incentive, Successive Targets (FPIS).
- 3)Fixed-Price Redetermination (FPR).
- 4)Cost Contract (CR).
- 5)Cost-Sharing Contracts (CS).
- 6)Time and Material Contract (T-M).
- 7)Labor-Hour Contract (L-H).
- 8)Cost-Plus-Award-Fee (CPAF).

In the following subchapters, these cost incentive types will be discussed, based on the DOD and NASA Incentive Contracting Guide, October 1969. This guide contains a Reprint of ASPR Manual For Contract Pricing (ASPM No. 1) Chapters 1 and 2. Since the most commonly used cost incentives are CPIF and FPI, they will be discussed in more detail than the others.

1. Firm Fixed Price (FFP)

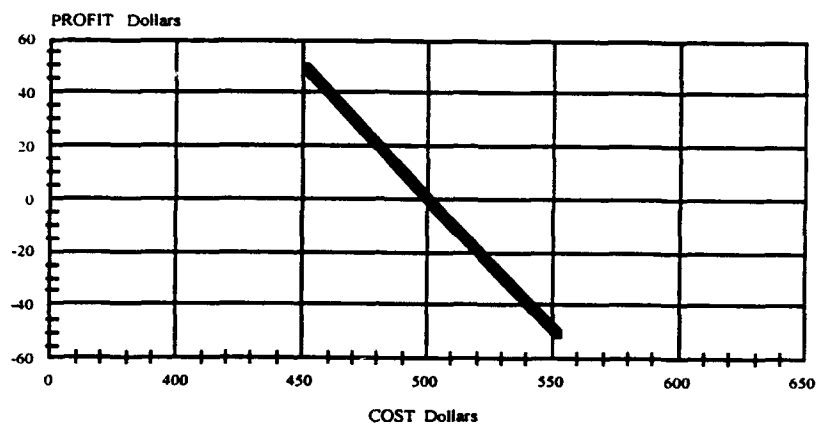
In this type of contract, price is determined before a definitive contract is awarded. It remains the same throughout the life of the contract, unless it is revised pursuant to a change clause in the contract. Therefore, the contractor bears full cost responsibility when he accepts this contract. Profit is directly related to the cost of performing the project, i.e., -- how effectively the contractor controls costs and manages the total contract effort. In essence, the sharing ratio is 0/100. The Government is not responsible for any portion of cost underrun/overruns; the contractor accepts 100% of any differences between the expected and actual costs. The contractor assumes full responsibility, in the form of profit or losses, for all contract costs. For the contractor, every extra dollar of cost means a dollar less profit.

Example:

Contract Price	\$ 500,000	\$ 500,000	\$ 500,000
Final cost	<u>\$ 485,000</u>	<u>\$ 450,000</u>	<u>\$ 530,000</u>
Profit realized	\$ 15,000	\$ 50,000	(\$ 30,000)

Chart 2-I illustrates the relationship between profit and cost for a FFP contract with values of the above example.

CHART 2-I-FFP CONTRACT



2. Fixed Price Incentive, Firm Target (FPIF)

A fixed price incentive contract with a firm target specifies *target cost*, *target profit*, *target price*, *price ceiling* and *sharing ratio*.

Example:

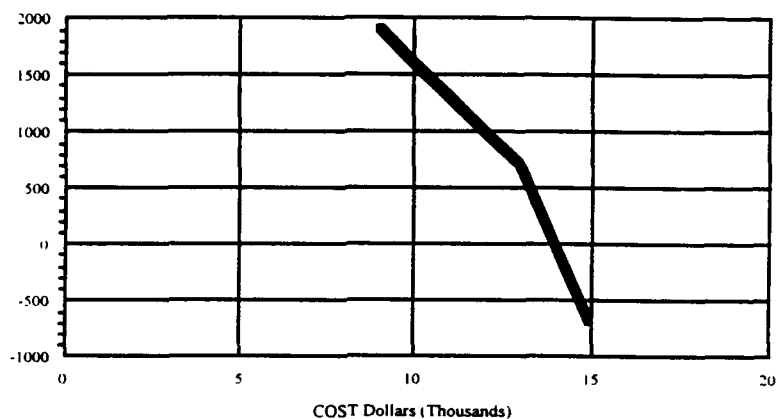
Target cost	\$ 12,000,000
Target profit	\$ 1,000,000
Target price	\$ 13,000,000
Price ceiling	\$ 15,000,000
Sharing ratio	70/30

In FPI contract, there is no profit ceiling, but the ceiling price gives the contractor some incentive to provide the specified product at the lowest possible cost. The contractor

and government share in variations from the target cost up to the price ceiling. When the price ceiling is reached, the cost sharing formula becomes 0/100.

Chart 2-II illustrates the profit/cost chart of a FPIF contract with the parameters given above.

CHART 2-II- FPIF Contract



Contract parameters, like those in the above example, are negotiated at the outset of the contract. After completing the contract, the contractor submits a statement of the costs incurred in performing the contract. These statements are audited to determine whether the costs are allowable under the specific contract. Any unnecessary or questionable costs are disallowed. The contract parameters, the contractor's statement of costs, and the auditor's report are the starting points for analyzing and settling the final contract price.

Changes in the negotiated objective may also increase or decrease the contractor's costs. Analyzing the differences between the expected and actual events, will help the contracting team understand the problems the contractor faced, and which contract costs were reasonable and necessary. This analysis should include the costs figures and engineering, production and management control considerations. What the contracting team concludes from this analysis becomes a part of the negotiations. After the final cost figure

is established, the contractor's profit is determined by applying the sharing ratio. The shares in the sharing ratio may vary depending on the risks and uncertainties involved, the target profit, and the spread between the target cost and ceiling prices. Here are two examples for the applying the ratio using the previous contract parameters:

Example 1:

Assume that the final negotiated cost was \$11,500,000:

Target cost	\$ 12,000,000
Final negotiated cost	\$ 11,500,000
Difference	\$ 500,000 (decrease)

The government receives 70% or \$350,000 of the \$500,000 as a reduction in price; the contractor receives 30% or \$150,000 of the \$500,000 decrease as an increase in profit:

For the Contractor:

Target profit	\$ 1,000,000
Contractor's share	<u>\$ 150,000</u>
Final profit	\$ 1,150,000

For the Government:

Final negotiated cost	\$ 11,500,000
Final profit	<u>\$ 1,150,000</u>
Final price	\$ 12,650,000
Target price	<u>\$ 13,000,000</u>
Price reduction	\$ 350,000

Example 2:

Assume that the final negotiated cost was \$ 12,700,000:

Target cost	\$ 12,000,000
Final negotiated cost	<u>\$ 12,700,000</u>
Difference	\$ 700,000 (increase)

The government receives 70% or \$490,000 of the \$700,000 as an increase in price; the contractor receives 30% or \$210,000 of the \$700,000 increase as a decrease in profit:

For the Contractor:

Target profit	\$ 1,000,000
Contractor' share	<u>\$ 210,000</u>
Final profit	\$ 790,000

For the Government:

Final negotiated cost	\$ 12,700,000
Final profit	<u>\$ 790,000</u>
Final price	\$ 13,490,000
Target price	<u>\$ 13,000,000</u>
Price increase	\$ 490,000

If the final negotiated cost is in excess of the contract ceiling price, the ceiling price becomes the final price.

The elements of a fixed price incentive contract -- target profit, target cost, ceiling price and sharing ratio -- must be established so that they provide a cost incentive to the contractor. The greater the effort required to reduce the costs lower than estimated, the greater the incentive that should be provided to the contractor. To motivate the contractor to increase effort requires a greater potential profit. In such circumstances, a tight target cost, a relatively high target profit, a high government/contractor sharing ratio and a tight price ceiling can be combined.

The government/contractor sharing ratio does not necessarily have to be a straight line. Depending on the negotiations, the incentive contract may have several sharing ratios, i.e., up to the target cost, and between target cost and price ceiling. However, sophisticated contracts do not always represent the government's actual objectives as well as simpler contracts. The rule is: the simpler the incentive, the more effective it is likely to be as long as it satisfies the government's objectives. To achieve the maximum incentive, it is vital to

sign the contract before production begins. This makes the contractor aware of the profit implications for every extra dollar spent for the project.

3. Fixed-Price Incentive, Successive Targets (FPIS)

This contract type, which is used infrequently, is designed for situations involving the first and second production quantities of a newly developed item. Approval of any follow-on contracts requires the first or second delivered items to be successful and provide cost stability. The FPIS contract establishes an overall ceiling price and gives the contractor some degree of cost responsibility and profit incentive until a realistic firm arrangement can be negotiated.

When the FPIS contract is used, a firm contract should be negotiated before the first item on the contract is delivered. The main difference from a FPIF contract is that FPIS contracts include ceiling and floor on the target profit. The elements of FPIS are: ceiling price, initial target cost, initial target profit, initial target price, initial share formula and a ceiling and floor on profit.

Upon delivering the first item, two follow-on contracts can be negotiated: FFP or FPIF. A FFP contract may be negotiated, including a negotiated cost and firm target profit. In the absence of an agreed firm price, or if the parties agree that the follow-on contract still involves uncertainties, a firm target incentive contract may be negotiated. For the follow-on contract, a new sharing ratio is determined.

There are some critical factors to consider in a FPIS contract:

- The firm pricing arrangement must be negotiated early in performance, usually before shipment begins,
- Since the pricing arrangement subsequently negotiated will be realistic, the initial share should not provide as great a degree of contractor cost responsibility as would a formula negotiated under an FPIF contract, i.e. 90/10.

- The ability to establish a firm pricing arrangement early does not depend on cost or pricing data from the contract itself, but the availability of data as the project processes.

4. Fixed Price with Redetermination (FPR)

FPR contracts are like FPI contracts. The main difference is that the degree of cost responsibility (i.e., cost sharing ratio) in a FPR contract is negotiated at the price redetermination stage, after the project is completed. The redetermined price and sharing ratio depend on the subjective evaluation of the contractor's performance. Since the contractors do not know the definitive cost sharing ratio, they do not know their actual incentives to control costs. This type of contract is generally reserved for small, short term research and development contracts.

In the ASPM Manual, two types of FPR contracts are discussed: prospective and retroactive. Prospective FPR contracts negotiate fixed prices in a prospective period; they can be defined as a series of firm fixed-price contracts that are negotiated at stated times during the project. Retroactive FPR contracts adjust contract price after completing the project.

5. Cost-Plus-Incentive-Fee (CPIF)

The elements of a CPIF contract are: target cost, target fee, maximum fee, minimum fee, and sharing ratio. It is designed for procuring advanced, engineering or operational systems development and first production. Generally, performance uncertainties may preclude using a fixed-price contract, or they may not be significant enough to justify a cost-plus-fixed fee contract.

The CPIF contract employs an incentive sharing ratio and there is no price ceiling. Both maximum and minimum fees are negotiated. This establishes two points under and over the target cost where the fee becomes fixed at the maximum or minimum levels, and the contract converts into a CPFF arrangement. Generally, the maximum and minimum fees and the sharing ratio for a CPIF contract are negotiated so that the incentive remains in

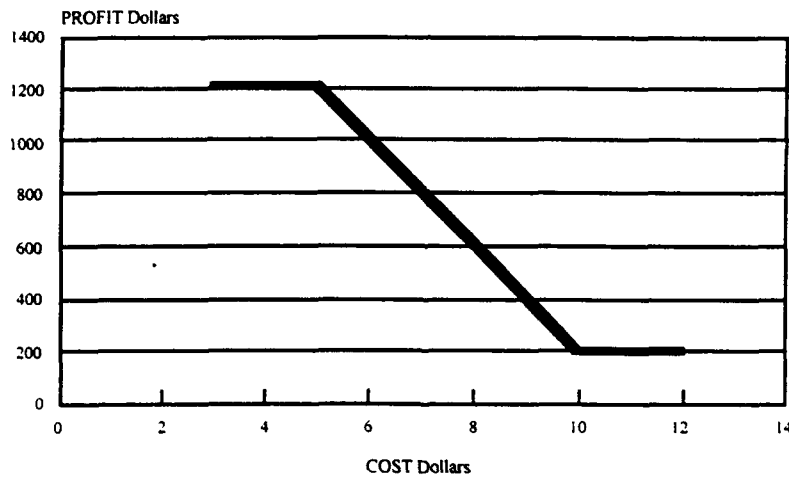
effect over a wide range of possible cost outcomes. In essence, this cost uncertainty is what makes CPIF contract necessary in the first place. (The degree of confidence in setting incentive targets determines the choice between FPI and CPIF contracts).

Example:

Target cost	\$ 8,000,000
Target fee	\$ 600,000
Maximum fee	\$ 1,200,000
Minimum fee	\$ 200,000
Sharing ratio	80/20

Chart 2-III illustrates this example.

CHART 2-III- CPIF CONTRACT



Now, assume that the final cost is \$ 7,200,000:

Target cost	\$ 8,000,000
Final cost	<u>\$ 7,200,000</u>
Difference	\$ 800,000

The contractor receives 20% or \$160,000 of the \$800,000 difference as an *increase* in fee; and the Government receives 80% or \$640,000 of the \$800,000 difference as a *reduction* in price.

The incentive in this example is effective as the final cost moves from \$5,000,000 to \$10,000,000, representing an underrun of 37.5% and an overrun of 25%. The contractor's share of a \$3,000,000 underrun would be 20% or \$600,000; his share of a \$2,000,000 overrun would be 20% or \$400,000. Added to or subtracted from the \$600,000 target fee, the contractor could achieve a maximum fee of \$1,200,000 and a minimum fee of \$200,000.

It is important that CPIF contracts are negotiated to provide the widest fee swing practicable under the circumstances. The wider the swing between maximum and minimum fee levels, the greater the contractor's sharing percentage without limiting the range of cost variation over which the incentive is effective.

It is possible to include more than one sharing ratio in the contract. One can have a 95/5 share for $\pm 10\%$ from target cost and a 50/50 share from $\pm 10\%$ to the maximum and minimum fees. Using different sharing ratios can give the contractor a greater incentive to avoid large cost overruns.

6. Cost Contract (CR)

This type of contract has only one requirement: the government reimburses all allowable and allocable costs, but pays no fee. Generally, CR contracts are only used for research contracts with educational institutions and contracts that provide facilities to contractors.

In research contracts with an educational institution, a cost/no fee contract may be useful; it depends on the institution's characteristics and whether it is a non-profit or the project is in the institution's interest. In such cases, reimbursing research costs can be sufficient compensation.

For some contractors, it may be acceptable to sign a contract allowing them to use government-provided facilities to earn profits. In this instance, a CR contract is also appropriate.

7. Cost Sharing Contracts (CS)

In this type of contract, the government agrees to reimburse a predetermined portion of the allowable and allocable costs. It is designed for research and procurement. Contractors may be willing to sign this type of contract if they expect extra contractual benefits. For example, they might expect to earn substantial profits in a related business activity or they might expect to gain a preferred position for a possible future contract.

8. Cost-Plus-a-Fixed-Fee (CPFF)

The elements of a CPFF contract include estimated cost and fixed fee. In this type of contract, the government reimburses all allowable and allocable costs and pays a fixed fee above the cost. CPFF is mainly designed for research, exploratory and advanced development projects where the level of contractor effort is not known. Usually, the financial transactions are significant and the uncertainties cannot be specified.

CPFF contracts are at the other end of the spectrum from FFP contracts. In practice, the sharing ratio for CPFF contract is 100/0. Thus, the contractor has little responsibility or incentive to complete the process economically and efficiently. CPFF contracts require extreme caution and are limited to those situations where other contracts would adversely affect the best interest of the parties.

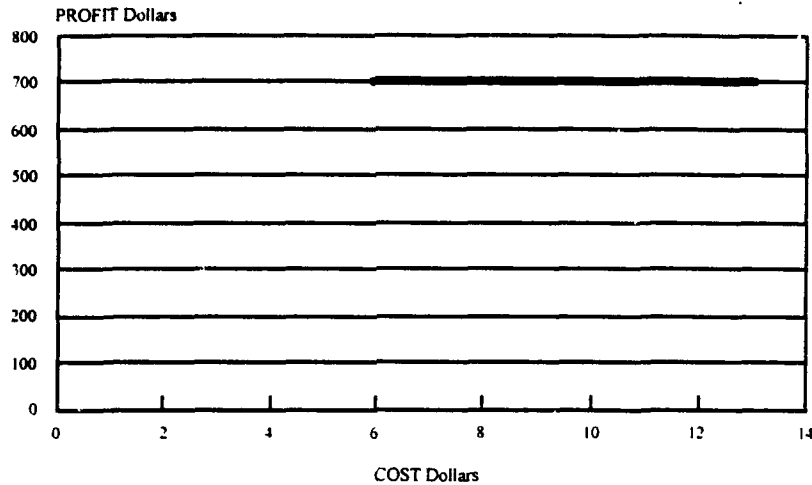
Example:

Estimated cost	\$ 10,000,000
Fixed fee	\$ 700,000
Estimated cost plus fee	\$ 10,700,000

Chart 2-IV illustrates this example.

CHART 2-IV- CPFF CONTRACT

[DOLLARS- ADD 000]



Assume that final costs are \$8,500,000 or \$12,300,000:

Final cost	\$ 8,500,000	\$ 12,300,000
Fixed fee	<u>\$ 700,000</u>	<u>\$ 700,000</u>
Final cost plus fee	\$ 9,200,000	\$ 13,000,000

When the costs are less or more than the target, the contractor still receives the same fixed fee.

9. Time and Material Contract (T-M)

This contract purchases time and materials at a fixed and specified hourly or per unit rate. It is designed to be used when the amount or duration of work can not be predicted. As a result, the costs can not be realistically estimated. Any material or labor that is needed to perform the contract is provided by the contractor and the costs are reimbursed by the government. An example is buying overhaul repair and services. However, using a T-M contract is not preferred. It provides no incentive for the contractor to use labor and material economically. Furthermore, to increase profits, the contractor may use a lower

graded labor or materials than defined and priced out in the contract. It is also necessary to administrate T -M contracts very carefully and monitor them very closely so that the contractor has proper controls and restraint. Any material that is needed to perform the contract is also provided by the contractor and the government reimburses the cost of acquisition and other costs that have been agreed on.

10. Labor Hour Contract (L-H)

This contract is the same as T-M contracts, except that the materials are supplied by the government, not by the contractor.

11. Cost-Plus-Award-Fee (CPAF)

This contract is designed to provide the contractor more incentives in situations where a CPFF contract would be used otherwise. In the CPAF contract, the government reimburses all allowable costs, pays a fixed fee, and also gives the contractor an opportunity to earn additional profit based award fees. The award fees are determined unilaterally by the government after evaluating the contractor's performance in several areas, i.e., the level of performance and/or effort, or any schedule improvements.

B. PERFORMANCE INCENTIVES

Performance incentives basically encourage the selection of performance level that is optimal from the standpoint of the government. These incentives are the best means to strengthen the traditional best efforts environment. Therefore, the negotiating parties should evaluate technological achievements in a different manner than they evaluate cost or schedule incentives. Technical personnel will establish this part of the contract. The technical personnel of the negotiation team determine which material characteristics will be incentivised, what is the superior technical achievement, what levels of performance will be acceptable, what targets are reasonable, how characteristics will be used, and finally the relative importance of each characteristic.

Performance incentives have been used mainly for development projects. The way they are used is:

by attaching a reward/penalty formula to specific equipment parameters, such as weight, speed, reliability. The main purpose of the performance incentives is to appraise significant cost/performance tradeoffs in advance of contract award, thereby, permitting the government to specify with precision the nominal cost/performance results that are desired.[Ref.4:p.35]

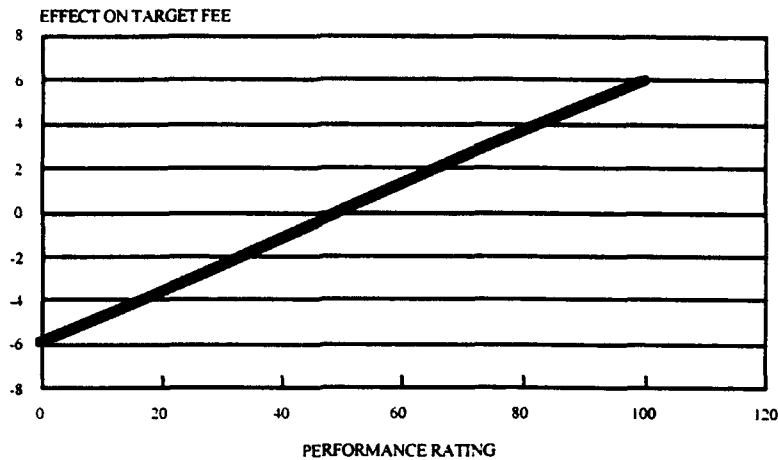
Thus, the performance incentive induces the contractor to meet or surpass the government's performance objectives. These incentives are designed to provide the government with a tool to express the project's desired performance level to the contractor so that the contractor can balance cost and performance issues. Therefore, the performance incentives are an additional part of the basic cost incentives.

The initial step of structuring a performance incentive is to select the project or system characteristics that government wishes to incentivise. At this level, defining the parameters may require objectively analyzing both the government's specifications and the contractor's technical proposal. As a general rule, these specifications are set a little higher than required by the mission. If there are several performance criteria, which is usually the case, then the best combination of performance characteristics within the desired cost framework should be selected. Whatever the case, for the incentives to be successful, the procurement team should ensure that the technical aspects of the procurement are firmly established and clearly understood.

Performance parameters are commonly defined on the range between zero-and-one hundred percent, zero representing the minimum desired performance level and one hundred the maximum attainable. Chart 2-V illustrates an example of performance incentives.

CHART 2-V

[DOLLARS- MILLIONS]



For a parameter to be important, it should meet one or more of the following criteria:

1)Some degree of flexibility in the level of performance is permissible and there is real value in obtaining the maximum performance possible under the proposed design approach.

2)Improvement in the particular characteristic is quite feasible under the proposed design and may reduce the scope and cost of more advance developments contemplated for the future.

3)Improvement in contractor performance will reduce cost to the Government.[Ref.4:p.37]

Thus, it is obvious that the parameters will differ for each particular procurement, depending on the characteristics of that procurement, like mission requirements, effect for the future plans and the purpose. The goal, however, should be 'to decide the smallest number of areas that will define the performance level sufficiently.'

The definition of each performance level specified in the contract must be clear to both of the parties. Before determining the performance target, cost figures or incentive patterns,

the contractor and the government must agree on the tests that will define the parameters and determine their final value.

After selecting and defining the performance criteria, final structuring begins. Considering the government's needs and contractor's proposals, the final structure includes:

- Minimum acceptable level.
- A range of performance involving incentive payments.
- A weighting relative to the other performance elements.
- A reward/penalty arrangement.

There are many situations in which the government may specify the performance levels with greater precision and have more confidence that they can be met. It may not be as necessary to offer any rewards for performance that exceeds the target. The best way to decide is to consider the unique conditions in every procurement.

C. SCHEDULE INCENTIVES

Schedule generally receives less emphasis than cost and/or performance level. However, in some circumstances, a positive incentive on the schedule might be useful. The profit and fee can vary with schedule as well as cost and performance. The focus of schedule incentives should be 'the delivery of the finished product.' Usually, schedule incentives are used in conjunction with a cost and/or performance incentive.

It is critical to select realistic target dates, otherwise the contractor might under-emphasize the other incentives to capture the benefits of an unrealistic target date. The procurement team should not give the contractor an incentive payment for providing the final product ahead of schedule but with a poor performance.

In some cases, delivering a product early might be desirable, but in others, it might have no value. For example, if the final product of a project can only be used with other components of the system, there is no benefit in receiving one product before the other

components are provided. If the item is used independently, then the early delivery might benefit the government.

Typically, the contractor receives the full schedule incentive for delivering the product on or before the target date. Penalty is imposed for any delinquency.

Chart 2-VI(a)/(b) illustrate two different schedule incentives.

CHART VI-(a)- GO/NO GO SCHEDULE INCENTIVE

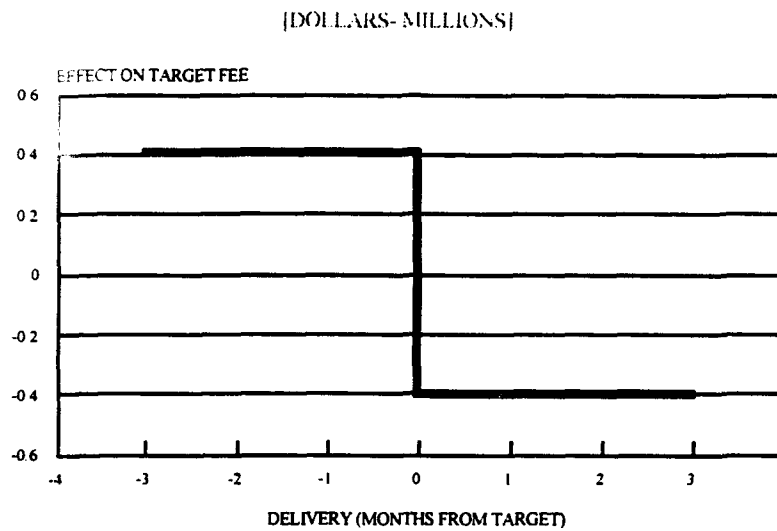
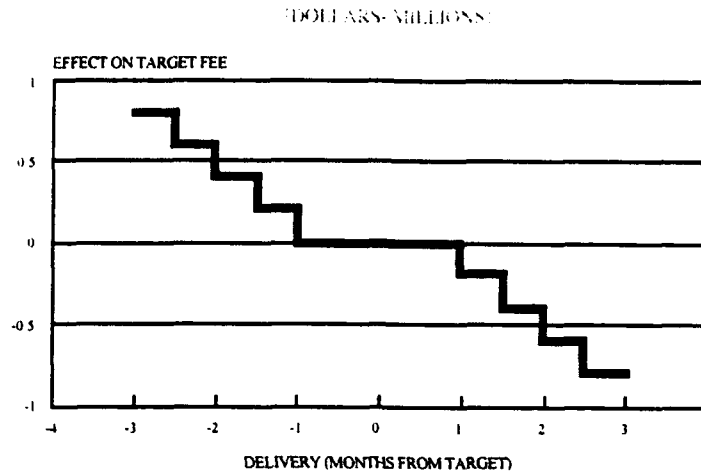


CHART VI-(b)- INCREMENTAL SCHEDULE INCENTIVE



D. MULTIPLE INCENTIVES

Traditionally, three basic elements of a successful contract are considered to be a satisfactory end product or service at a reasonable cost, and within certain time limit. These three elements are inter-dependent. If any contract places too heavy a premium on any of them, then that contract loses control over the others.

A multiple incentive contract is designed to serve two basic purposes:

First, it should motivate the contractor to strive for outstanding results in all three incentive areas; in other words his objective at the outset should be to earn maximum profit, and the contract should be structured so that there is a real possibility that he can do this. Second, if it becomes apparent to the contractor that outstanding results can not be achieved in all areas, the incentive structure should compel decisions as between cost, time and performance that are in consonance with the over-all procurement objectives of the Government. Realization of the first objective depends largely on the range of effectiveness established for each incentive element and the probability of achieving outstanding performance in all three areas. Realization of the second purpose, on the other hand, turns mainly on the relative weights, along with the separate ranges of incentive effectiveness, that will establish the various break-even points for trade-off decisions between cost, schedule, and performance.[Ref.4:p.47]

Multiple incentives simultaneously motivate the contractor for technological progress, timely delivery, and effective cost control. The ultimate objective is to attain an appropriate balance between all three incentive areas.

To be sound, the concept of multiple incentive contracting must quantitatively relate profit motivation directly and in accordance with the Government's objectives. Multiple incentives must identify the alternative technical levels of performance and place the relative value on the alternatives as affected by the inherent interrelationship between cost, performance and schedule decisions... The proper balancing of objectives provides two important results: first it communicates the government's objectives and second it establishes the contractor's profit in direct relationship to the value of the combined level of performance in all areas.[Ref.1:p.107]

The contractor's trade-offs between cost and performance should be guided by the multiple incentive structure.

Chart 2-VII(a)/(b)/(c) illustrate a multiple incentive contract with the following parameters:

Target cost	\$ 80 M
Confidence in target cost	\$ 20 M ($\pm 20\%$)
Target profit	\$ 10 M
Target delivery	24 months after the contract is signed
Share ratio	80/20

Performance incentive- speed

Target 25 kts

Maximum usable 30 kts

Minimum acceptable 20 kts

The following weights are assigned:

Cost 60 % (± 3 M)

Performance 20 % (± 1 M)

Schedule 20 % (± 1 M)

As a reasonable profit 15% is determined to meet the maximum incentive goals and 5% to meet the minimum incentive goals.

CHART VII-(a)- COST INCENTIVE (FPI CONTRACT)

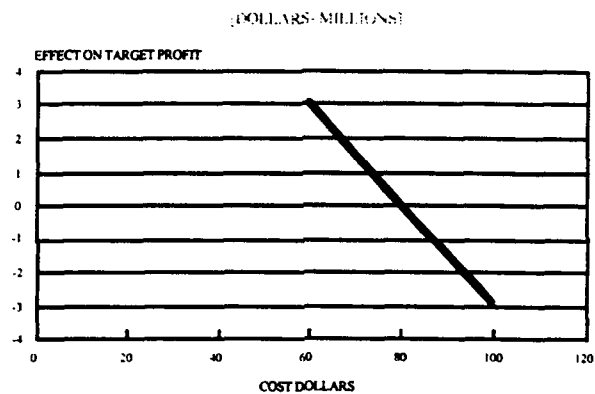


CHART VII-(b)- PERFORMANCE INCENTIVE (SPEED)

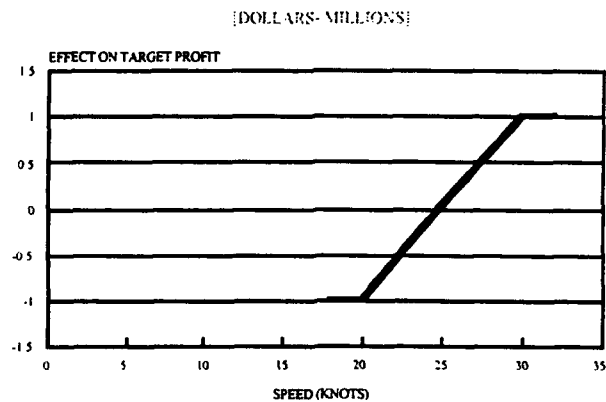
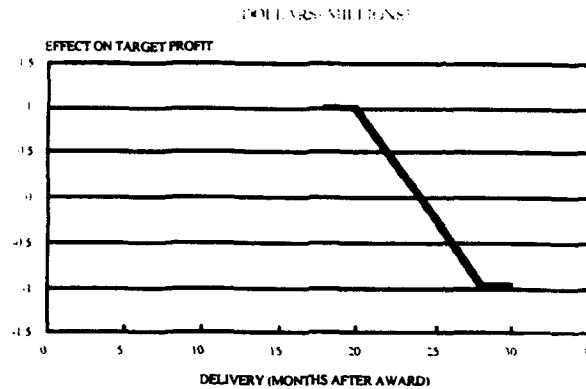


CHART VII-4- SCHEDULE INCENTIVE



Under multiple incentive contracts, the performance incentive and cost incentive are interrelated through profit. They are not discrete elements that can be considered independently. It is also reasonable that contractors will attempt to assume trade-offs during the negotiation stage or the budgeting process of the contract. The assumption of the later trade-offs is limited. Therefore, the government should structure and approve a contract following a complete evaluation and understanding of possible trade-off results.

It must be understood that 'the multiple incentive contract which requires the contractor to deliver a product with maximum performance, at the earliest time possible, and at minimum cost to earn maximum fee' is not necessarily the most efficient contract. In most of the CPIF-multiple incentive contracts, a contractor delivering a final product that satisfies the maximum performance requirements earns the maximum fee.

Multiple incentives should be balanced so that they don't encourage the contractor to disregard one objective to capture an incentive in another one. Incentives should motivate the contractor in a direction that the contractor will try to achieve all desired goals and receive their expected fee. Finally, the incentives should represent the government's real objectives and clearly communicate the government's real relative value of project cost, performance and schedule targets.

When structuring a multiple incentive contract, the following seven step procedure might be useful:

Step I is to identify those key parameters whose improvement will add to overall mission accomplishment.

Step II is the formulation of minimum and a maximum level of performance for each parameter. Minimum must be high enough to satisfy the mission and the maximum should not be so high that it is unattainable.

Step III is rating the performance parameters by weighting each parameter according to its relative importance, and assigning this weight to the maximum performance level.

Step IV is the evaluation of the performance arrangement.

Step V relates the Government cost estimates with the technical combinations selected in Step IV.

Step VI is the development of the cost-performance relationship by using the trade-off curves.

Step VII is the final analysis of the entire incentive structure.[Ref.1:pp.118-119]

E. TRADE-OFF CURVES

Trade-off curves are constant fee (isofee) lines that depict cost and performance combinations for which the contractor will receive the same fee. It is also possible to illustrate trade-offs between schedule and the other two incentive elements. There are many cost and performance combinations which yield the same fee or profit. For any given increase in cost, there is a specific improvement in performance that will leave the fee unchanged; for any cost reduction, there is a specific performance degradation that can restore the fee to the original level. By having cost and performance as the axes and plotting all the possible combinations that provide the same fee, the result is a trade-off curve.

Chart 2-VIII (a)/(b)/(c) are illustrative examples.¹

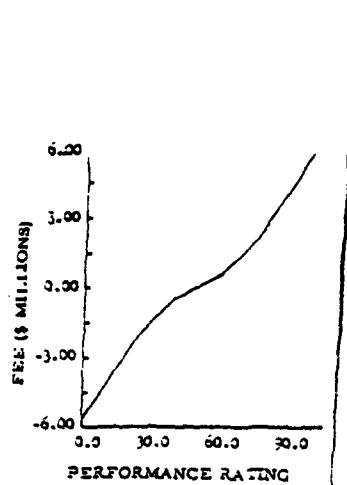


Chart VIII (a)

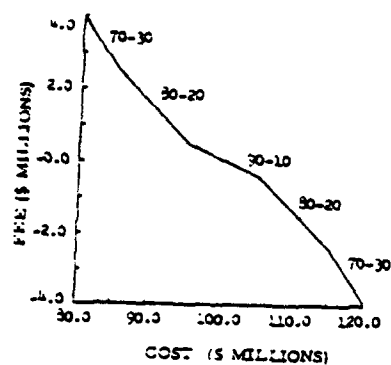


Chart VIII (b)

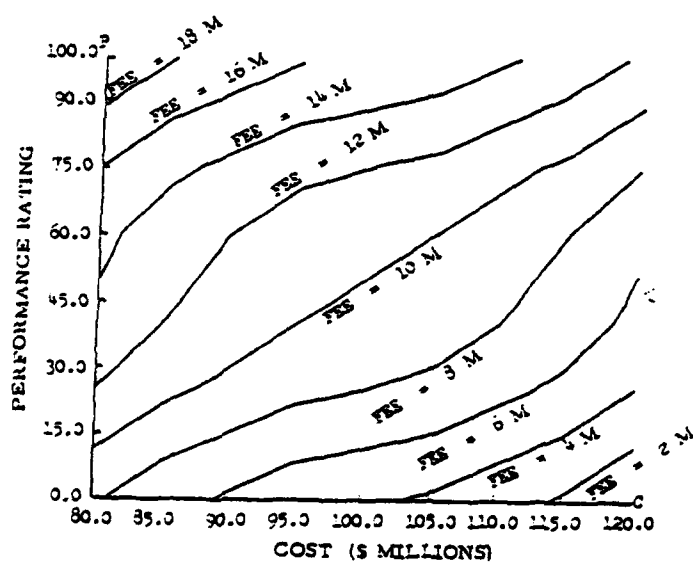


Chart VIII (c)

¹These graphs are copied from Reference 3, p.11.

The trade-off curves provide one of the simplest checks to see if the proposed contract structure balances the government's emphasis among the incentive elements. They show the negotiator how the contractor is influenced by the incentive arrangement to trade-off one element for another. By analyzing the trade-off curves

the negotiator can gain insight into the contractor's trade-off possibilities in sacrificing one element for another to maintain a desired fee or increase in the fee earned; and also the contractor can learn which trade-offs are advantageous to the Government and which are not.[Ref.3:p.13]

In the analysis, the performance level is generally scaled by giving the minimum performance 0 points and the maximum performance 100 points. This scale can be applied to any contract, no matter how performance is measured.

The general graph of a trade-off curve is illustrated in Chart 2-IX.²

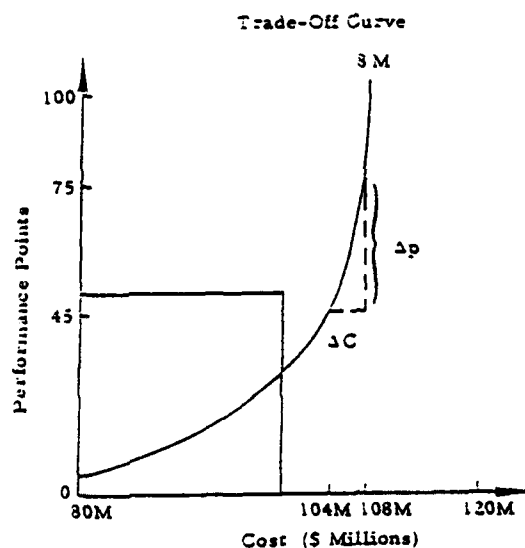


Chart 2-IX

²This chart is copied from Reference 3, p.13. For broader theoretical and mathematical discussion and justification of the shape of the tradeoff curves, see Reference 3, pp.120-126.

The slopes of the trade-off curves indicate how much the government is willing to pay for an increment of performance. Because the government is willing to spend ΔC for ΔP , the additional profit for ΔP (with cost held constant) must be $s \cdot \Delta C$ (s : sharing ratio). For when the contractor spends ΔC and the sharing ratio is s , profits will decline by $s \cdot \Delta C$. To motivate the contractor to spend at least ΔC for ΔP , the profit for ΔP must equal $s \cdot \Delta C$. Clearly the value to the government ΔV of the ΔP must equal ΔC . So we have

$$\frac{\Delta \text{Profit}}{\Delta P} = s \cdot \frac{\Delta V}{\Delta P}.$$

The steeper the slope of trade-off curves, the more important the C(ost)-axis variable relative to the P(erformance)-axis. This emphasizes the importance of the slope of the curves. For example, consider the slope of the curve in Chart 2-IX. As the achieved performance level declines, the government is more critically interested in increasing the performance level. Hence, the government will be willing to pay more to encourage the increase in performance. As the performance level increases, the amount that the government is willing to pay to increase performance declines. This is the main reason why the trade-off curves have a continuously increasing slope.

III. DEFINITION OF PERFORMANCE LEVEL OF A WARSHIP

As indicated in the previous chapter, performance incentives are basically the motivation that encourage the optimal combination of cost and performance. Performance incentives *attach a reward/penalty formula to specific parameters, such as weight, speed, reliability*. The main purpose is to quantify significant tradeoffs in advance of contract award, allowing the government to specify the nominal cost/performance results desired.

The performance incentives augment the basic cost incentives. They are structured in the following steps:

Step I -- Select the system characteristics that the government wishes to incentivise.

Step II -- Define the performance criteria, which may require an objective analysis of the government's specifications and the contractor's proposal.

Step III -- Define the contractor's profit which will ultimately depend on the performance incentives.

Every procurement project has unique conditions. Regardless of the performance criteria used, performance incentives will automatically affect the contractor's profit. Therefore, to use performance incentives, the negotiation team must develop a measure of performance. Schedule incentives -- if they are used -- also affect profits; therefore, the same argument applies.

Research to develop a measure of warship performance has identified several methodologies, though none of them is perfect. Some methodologies include:

- Operations Research Model; defines a production function by using the Response Surface Methodology (RSM) to summarize the input-output relationship of a multiple simulation model.
- Subjective Figure of Merit; e.g. the Tascform Methodology -- Sea Model.
- Regression Analysis; running regressions from operational exercise data.

- Technological Relationship Model: force potential of a warship can be determined by technological specifications and definitions. Assuming the technological aspects of potential warship roles are under the contractor's control, one can illustrate the interrelations among the various parameters and determine the overall output performance level.

Before applying any of these methodologies, the priorities of the CNO and the Staff should be considered. Full account must also be given to the Navy's doctrines and new requirements considering the defined possible threat or enemy. The priorities and policies that direct and determine the warship's specifications ought to represent long term goals and needs; specifically, the interrelationships between the Navy and the Armed Forces -- and more narrowly, that particular warship's mission relative to the fleet. This thesis will assume that top management has already selected and clearly explained the warship's specific mission to the negotiation team. The negotiation team's job is to translate the big picture of mission into the individual performance specifications. This chapter will try to identify methods to define the performance levels of a multi-purpose combatant. This will ultimately help the negotiation team gain an advantage in negotiations. These methods can also help define performance level for any other smaller or less complicated warship.

Before defining the details of any of the methods, it is useful to highlight the issues that might affect the definition of warship's performance level. Some of these issues are:

- Compatibility of the different systems and technologies that are being used in constructing the warship, whether they will be easily integrated and provide the expected results.
- Expectations and requirements for performing different tasks simultaneously (for analytical and methodological reasons, it might be more practical to perform each task at a specific time rather than performing all tasks at the same time).
- Construction design and engineering capabilities.
- Different warfare areas such as AAW, ASUW, ASW, and their interdependencies.

- Required extra training for personnel (systems that are complex require significant amount of extra personnel training and education; costs which should be taken into account).
- The contractor's effort level may play a role in affecting output.
- It may be more convenient for the contractor to deal with the sub-contractors, making the sub-contractors responsible for the desired overall performance level.

Defining warship performance is not easy. It involves a lot of variables, reflecting the ship's complexity, and it must integrate lots of different systems. It might be easier, to consider each task of a warship individually and combine them by defining the interrelations. The integrated values of the individual subsystems define the overall ship performance. Even defining performance for a single task is complicated. Tascform Methodology -- Sea Model, provides a methodology for aggregating figures of merit for individual combat systems into figures of merit for general purpose naval forces.

The following subsections will briefly explain the above-mentioned methodologies and comment on how they can be used by the negotiation team in negotiation process.

A. OPERATIONS RESEARCH MODEL USING THE RESPONSE SURFACE METHODOLOGY

By using an operations research model, one can simulate a system, no matter how complex. The whole concept of simulation is widely accepted by many professions in many different fields of industry. In Operations Research,

simulation is useful in solving a business problem where all values of the variables are not known or partly known in advance and there is no easy way to find these values... Simulation utilizes a method of finding the successive states in a problem by repeatedly applying the rules under which the system is operated... Simulation involves the construction of some type of mathematical model that describes the system's operation in terms of individual events and components. The system is further divided into elements and the interrelationships of those elements with predictable behavior, at least in terms of probability distribution, for each of the various possible states of the system and its inputs.[Ref.5:pp.470-471]

Simulation divides the model building process into smaller parts and combines them in their natural and logical order. A computer program can present the effect of interactions between parts. It is impossible to expect an optimal answer, but at least one can gain insight to the interrelations among the variables. Simulation models perform experiments on the sample input data rather than on all possible variable values.

A general and inclusive definition of simulation is:

A quantitative technique used for evaluating alternative courses of action based upon facts and assumptions with a computerized mathematical model in order to represent actual decision making under conditions of uncertainty.[Ref.5:p.471]

Defining the performance level of a warship fits perfectly with the simulation approach: a warship includes a lot of tasks and parts which have strong interrelations; some of the variables are known and some are not; it might be possible to define a mathematical model that will describe the system's operation; the behavior of subsystems is sometimes predictable; and uncertainty exists.

There are different methods of simulation, including: Monte Carlo, Operational Gaming, System Simulation, etc. For warship performance definition, system simulation appears to be the most suitable method.

The system simulation method involves operating a simulation model that represents the warship's operating environment. The simulation results can give the user very clear insights about the different variables and their interrelations. By using this method, one might be able to determine each variable's affect on the warship's overall performance. The

negotiation team, subsequently, might have an idea about how the performance incentives should be structured.

To summarize, some of the advantages and limits of simulation techniques include:

- They allow us to experiment with a model of the system rather than the actual operating system.
- They can be used to foresee the upcoming difficulties.

It is easier to utilize a simulated process than it is to develop and elaborate mathematical model representing the entire process under study.

- Simulation enables one to determine the controlled variable values that will generate the best results for the firm.
- It is beneficial to the training of management personnel at all levels.
- Computer simulation allows one to incorporate time into an analysis of an essentially dynamic situation.
- The non technical manager can comprehend simulation easier than a complex mathematical model.
- It does not produce optimum solutions.
- Reliance on this technique too often because of its relative ease of application might result in substituting simulation for mathematical analytical techniques where they are best suited.
- It is possible that all known inputs are not included in the model due to errors of omission or commission and some inputs and outputs relationships may not be known or are impossible to ascertain.
- Executive simulation suffers from several shortcomings. The overly simplified simulation makes the participant feel that management is over-rated since it is so simple to make decisions.[Ref.5:pp.474-477]

Simulation of a warship with its various components can be the first step of the Response Surface Methodology (RSM), that is multidimensional impact analysis. The concept of this methodology is that: *one simulates the system with a model; runs the model*

using certain inputs; collects data; re-runs the model as many times as necessary; and summarizes the output using a production function.

1. Response Surface Methodology (RSM)

Even though it is fairly hard to define any system completely, "the objective of the analysis is to gain insight into complex problems for assisting in decision making." [Ref.6:p.55] The common approach for defining the performance of any particular output is to define performance for every single component of the output and determine what effect the specific component's performance level will have on the overall output. From this view, the problem, or one might say the solution is usually one-dimensional or two at most. In reality, however, the critical factors and their unique impact on the measures of effectiveness over a wide range of values are not one-dimensional. They have multidimensional affects and relations. It is also important to define or to understand the relations among the various key factors.

The multidimensional impact analysis methodology uses response surface and experimental design concepts with deterministic models. [Ref.6:p.55]

By varying the critical variable levels, under a limited number of model runs, the model output is captured for several alternative structures. This approach then defines relationships among the key factors to aid in the decision making process and to evaluate the model itself. It also provides an opportunity to evaluate the impact of multiple changes in factor levels without re-running the model.

Instead of a one-dimensional sensitivity analysis, which can not reflect multi-level relations among the different factors,

the methodology involves the combination of Mathematical Programming techniques with Response Surface Methodology (RSM) and Statistical Experimental Design. RSM concept has been used extensively in industry to explore factor relationships and to determine combinations of factors which provide optimum outcomes... Besides providing a capability to conduct multidimensional impact analysis, the methodology provides a measure of effectiveness which is new to applied operations research technology,... and information which can be used in conjunction

with operational, political and economical aspects to help point direction. The methodology uses Statistical Experimental Design to optimally select a limited number of combinations of the input parameter values to be evaluated in the analysis process. Mathematical Programming techniques such as linear or quadratic programming can then be used to find the optimum value of the response variable for each of the selected combinations of input parameters. Finally, the coefficients of the mathematical expression that defines the response surface can be determined by a multiple stepwise linear regression technique. Once the equation is completely developed, the value of the response variable can be determined with good accuracy for various combinations of factor values, not just the ones used to develop the equation.[Ref.6:p.58]

This methodology can define the performance of any warship with a lot of defined and undefined variables. It can also determine the coefficients of the production function, namely the equation which predicts values of the warship performance level for given input variables. Because of their limited importance, some of these variables can be disregarded, to facilitate the calculations and make the output more visible for the negotiating team.

B. SUBJECTIVE FIGURE OF MERIT

Another way to measure warship performance level is by subjective figures of merit; e.g.; the Tascform Methodology -- Sea Model.

1. The Tascform Methodology -- Sea Model

The TASCFORM -- Sea Model represents an effort to develop a methodology for aggregating figures of merit for individual combat systems into figures of merit useful in assessing general purpose naval forces. The basic thrust of TASCFORM-SEA is the combination of adjusted weapon system performance (ASWP) values for combat systems found aboard a given platform with measures for platform specific sensor capability, mobility, availability and survivability.[Ref.7:p.9-1]

When developing this model, The Analytic Sciences Corporation -- TASC considered the major conventional weapon systems and combatant ship and submarine classes in the U.S. naval inventories from 1965 to 2005. The Tascform Methodology--Sea Model combines the Adjusted Weapon System Performance (AWSP) values for

different combat systems, such as ASW, AAW, ASUW, etc. Therefore, it is first necessary to explain the methodology for producing figures of merit to index the performance potential of weapon suites designed to perform specific duties. As an example of the subsystem Tascform model, The Tascform -- ASW model is briefly summarized. In developing Individual Naval Combatant Figures of Merit, Individual AWSP values are obtained by applying various Tascform models, such as the ASW model.

a. The Tascform -- ASW model

As with other naval weapon systems, the performance potential of ASW weapons is dependent on the capabilities of the acquisition and tracking sensors on the platform that carries it. However, unlike other systems, the ASW sensor suite that the platform carries is much more critical in determining the success of an ASW engagement. Hence, the Tascform -- ASW Model produces a figure of merit that measures the entire ASW capability and not just the ASW weapon system.[Ref.7:p.8-1]

Almost all the systems that a warship carries have similar characteristics to the ASW system; weapon systems are interrelated with other performance measures.

Figure 3-1 shows how TASCFORM-ASW figures of merit are developed.³

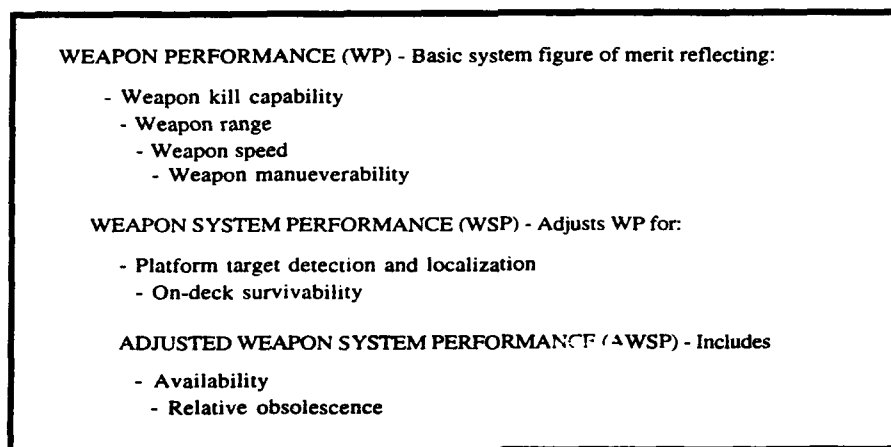


Figure 3-1 Development of TASCFORM-ASW Figures of Merit

³For further details of the development of the model, see Reference 7, Ch.8. The Weapon Performance (WP), Weapon System Performance (WSP), and Adjusted Weapon System Performance (AWSP) as the steps in developing ASW system figures of merit are explained here.

Even though the input variables and the interrelations among them are difficult to understand, the Tascform -- ASW model can give an idea about the factors that directly and indirectly affect the ASW performance. Some of these factors are; payload kill capacity, detection and localization capability, maneuverability, range of platform, weapon speed, navigation capability, survivability, etc. The Tascform -- ASW model presents the WP, WSP and AWSP expressions and the tables which are to be used for calculations. Some of the above-mentioned factors also have sub-factors that determine their values.

Selected examples of the AWSP values of the respective systems as computed by this model follow:⁴

SYSTEM	YAVUZ,FFG	HARPOON BLOCK 1C	NATO SEA SPARROW
REMARKS	SQS-56,TORP	-	-
DESCRIPTION	ASW SCORE, INNER MID ZO	SSM (SHIP TO SHIP)	POINT DEFENSE SYSTEM
TF C	INSH	MSRF	PDMS
AREA	ASW	ASUW	AAW
NATION	FRG/TU	US	US/FRG
IOC	1982	1982	1988
WSP IOC	2.86	1.03	8.27
AWSP85	3.43	1.03	0
AWSP90	3.43	1.03	2.16
AWSP95	4.87	1.03	2.16
AWSP00	4.86	1.03	2.16
AWSP05	4.86	1.03	2.16

After computing Adjusted Weapon System Performance (AWSP) for every sub-system (ASW, AAW, ASUW, STRIKE); Single Ship Adjusted Weapon System Performance (SHAWSP) can be developed. Figure 3.2 summarizes the development of Individual Naval Combatant Figures of Merit in the Tascform -- Sea Model.

⁴This data is provided by The Analytic Science Corporation (TASC).

SINGLE SHIP ADJUSTED WEAPON SYSTEM PERFORMANCE (SHAWSP) -- Adjusts ASWP values for onboard weapon systems to account for:

- Platform mobility
- Platform survivability
- Platform seakeeping qualities
- Hull and machinery availability
- Platform obsolescence

UNWEIGHTED SINGLE SHIP PERFORMANCE -- Combines SHAWSP values in the basic single ship figure of merit

DESIGNATED FORCE PERFORMANCE (DFP) -- Basic force level figure of merit combining:

- Single ship performance figures of merit
- Ship inventories

**Figure 3-2 Development of Individual Naval Combatant
Figures of Merit**

Single ship adjusted weapon system performance (SHAWSP) value is a reflective of the total performance potential of a ship in each of the four naval warfare areas: AAW, STRIKE, ASUW, ASW.[Ref.7:p.9-3]

Here, the AWSP values are combined with factors like ship mobility, ship seakeeping, ship survivability, hull and machinery availability, and ship relative obsolescence. Individual AWSP values that are obtained by applying various Tascform models, and the tables for the other factor values, can be used to compute the overall performance value for a single warship.

The synergistic effect of placing ships in task groupings clearly has considerable effect on both the performance potential of combat systems able to share target acquisition information and the survivability of individual platforms. Thus, one must also account for the groupings of the naval combatants, namely task forces. The Tascform -- Sea model also demonstrates how this can be computed.

IV. THE PRINCIPAL-AGENT PROBLEM AND EFFORT INCENTIVES

In the economics literature, risk sharing and the moral hazard comprise the principal-agent problem. Moral hazard is observed basically,

where one party to a transaction may undertake certain actions that (a) affect the other party's valuation of the transaction but that (b) the second party cannot monitor/enforce perfectly... The 'solution' to a problem of moral hazard is the use of incentives -- structuring the transaction so that the party who undertakes the actions will, in his own best interests, take the actions that the second party would (relatively) prefer.[Ref.8: p.577]

One can give the following examples for moral hazard, which is also called hidden action : In the fire insurance business, an insurance company would want the insuree to store flammable materials carefully, keep quality fire extinguishers on hand, etc. In the leasing of a car, the leasing agency would prefer the car to be serviced regularly, driven carefully and so forth. When we hire anybody for any particular job, we want that employee to work hard at the required tasks.

For these examples, it is possible to monitor and enforce levels of care, service, or effort. Insurance companies might send inspectors, a car lease contract might include the requirements for routine maintenance, and employers might hire monitors to observe that employee's level of effort. In the US, the government does monitor the contractor through its representatives.

After applying incentives, in most cases, perfectly monitoring and enforcing the requirements is difficult or even impossible. Hence, the incentives should be structured so that the party who undertakes the hidden action faces the full consequences of those actions. The insurance company may refuse to give insurance; instead of leasing the car, one might decide to buy it; and the employee's payments might be adjusted as a function of the output produced.

In defining a general principal-agent problem, the principal (the Government) hires the agent (the contractor) to perform a task.

The agent's output or cost depends upon two variables: the agent's level of effort (which the agent chooses), and some random element which is beyond the control of the agent. The agent obviously knows his own effort and also knows the outcome of the random variable. The principle, however, is assumed not to be able to observe this random variable. The principle cannot, therefore, deduce, from his observation of the agent's output, what level of effort the agent chose. It is this asymmetry of information which is the crucial element of the principal-agent problem.[Ref.9:p.2-15]

If it were possible to observe the contractor's effort, the government could easily structure an incentive scheme to induce the desired effort from the contractor; the optimal reward scheme would pay the contractor an amount equal to the marginal product of effort. With the asymmetry of information, the government cannot disentangle the consequences of the agent's effort from the consequences of the random variable; paying a contractor according to its marginal product is infeasible.

A typical solution to the principal-agent problem involves two stages, where the solution process typically solves the problem in reverse. At the first stage, the agent's own best action is computed, by addressing the question 'given a particular contract, how will the agent act in its own interest?' The principal, after handling the first stage of the problem, can predict the response of the agent for any particular contract and ultimately chooses the best contract structure from the principal's point of view. For the government, this type of contract is designed so that it maximizes the government's net benefits. To find this optimal contract, the government must be able to predict the contractor's response to the contract; which ultimately requires considering risk-sharing and moral hazard.

The agent is assumed to be willing to undertake a task offered by the principal as long as the net utility from performing the task is at least as large as his net utility from his next best opportunity. This is referred to as the agent's reservation level of utility.

Following is a summary of using effort as an incentive from A Course in Microeconomic Theory by David M.Kreps, Chapter sixteen: Moral Hazard and Incentives.

Once the agent is hired, if he is hired, then he must decide whether to work hard or not in this particular job. Since hard work is not the taste of this particular agent, all other things equal, he will prefer not to work hard. Whether this agent works hard or not determines the value to the principal of having this agent work. If the agent is not going to work hard, then the principal will get very little from the deal -- so little that it is not worth his while to pay the agent his reservation wage (a wage high enough so that combined with not working hard the agent's net utility exceeds his reservation level of utility). But if the agent does work hard, then the principal will get enough out of the transaction to make it worthwhile for both sides.[Ref.8:p.580]

Kreps follows on with a numerical example. Suppose the agent is risk averse and his overall von Neumann-Morgenstern utility function is:

$$U(w,a) = \sqrt{w} - a.$$

In this equation, w is the agent's wage, and a is how hard he works. The level of a , measured by monitoring terms, can be "hard" or "high," denoted by $A1$, or it can be "not hard" or "low," denoted by $A2$ (say $A1=5$ and $A2=0$). If the agent works hard, and is successfully accomplishes the task, the accomplished task is worth \$ XX to the principal; that is, the principal is willing to pay \$ XX to the agent for the desired product. If the agent does not work hard, and does not successfully accomplish the task, it is worth only \$ YY to the principal (YY is relatively smaller than XX). To get the agent work at a low level of effort, the principal must offer the agent wages high enough so that $U(w,a)=\sqrt{w}-A2 \geq RU$ (Reservation level of utility). This implies $w \geq (RU+A2)^2$. Call this \$ ZZ. If the principal's value for the job with low level of effort (\$ YY) is less than \$ ZZ, there will be no deal.

To persuade the agent to work at a higher effort level, the principal must offer the agent high enough wages so that $U(w,a)=\sqrt{w}-A1 \geq RU$, or $w \geq (RU+A1)^2$. Call this wage \$ NN. If the principal's value for the job with a high level of effort (\$ XX) is more than \$ NN, it is a worthwhile deal.

One way of establishing the contract that promotes hard work is to offer a fixed fee and trust the agent to provide high effort. This will not always work. Trust might sound nice and even work sometimes, but the issues like moral hazard do not allow us to accept

such uncertainties. In such a contract, the agent will likely receive the money, put in low effort and let the principal pay for a job that is worth a lot less than the fee paid.

The other way of establishing a contract is to let the agent's pay depend on the effort applied. If this contract is enforceable, it will include a reasonable fee for the job done with high level of effort and a smaller fee (below the agent's RU) for the job done with low level of effort. A high effort level is the agent's only reasonable choice.

The question then becomes, 'is the contract enforceable?' One can face a situation where the agent signs the contract, does not work hard, but claims to have worked hard. The principal needs tangible evidence to prove that the agent did not work hard. However, there may be no way to observe this evidence. There might not be enough evidence to enforce the contract; or it may be prohibitively expensive to convince the courts to accept the evidence. For these reasons, this approach might not work.

It is also possible for the principal to monitor the agent's effort with a contract allowing the principal to fire the agent for low effort level. In this case, monitoring costs will certainly exist. Other costs are likely if it is necessary to terminate the contract through the courts.

In the moral hazard problem, the principal-agent approach designs incentives to motivate the agent to work according to the principal's desires.

Even if the principal cannot tie the worker's wage directly to his level of effort, the principal might be able to find some indirect measure of effort to which the wages can be tied in a contract that will stand up in the court.[Ref.8:p.582]

These measures depend on what kind of relationship the principal-agent have. Another matter of concern is whether the principal and the agent are risk-neutral, or risk-averse.

The attitude towards risk can be characterized by the notion of the risk premium. The risk premium is the amount of money an individual will pay to avoid risk... A risk neutral firm is one that is just as happy with the expected value for sure as with accepting the risk, so the risk premium for a risk neutral firm is zero. That is, a risk neutral firm will pay nothing to avoid this risk. A risk averse firm will pay some

amount (namely, the risk premium) to avoid the risk. From the government's perspective, the risk premium is the cost of the risk.[Ref.9:p2.8]

The government, at any given time, is involved in many different transactions. If these different transactions are independent, the uncertainties associated with any one transaction may be disregarded. The burden of risks associated with public projects are born by the government (all taxpayers). This risk spreading means that the cost of risk-bearing is insignificant. For these reasons, the government is not supposed to avoid risk; instead it is more efficient for the government to choose its transactions in a risk-neutral way.

There are some occasions where the government tends to be risk averse. The government's decisions are made by individuals; these individuals bear some consequences of their decisions, i.e., in terms of career. To prevent the government officials from behaving in a risk averse manner, it is important to remember that decisions about a particular project are made under uncertainty. Regardless of the project's ultimate success or failure, the initial decision may have been the right one given the information available at the time. Recognizing this will prevent the political tendency to judge decisions on ex post grounds. Ex post judgments encourage risk averse behavior.

This thesis assumes the principal is risk-neutral.

If the agent is also risk-neutral, the agent's utility function is $u(w,a) = w - a$. In this case, the principal may offer the agent a contract that provides a reasonable fee (relative to the agent's RU) if the agent works hard and no fee/lesser fee (relative to the agent's RU) if the agent does not work hard. If the contract motivates agents to work hard to further their own interests, agents will internalize the effects of their effort decisions. In such a contract, the agent will face the full responsibility and cost of a low level of effort.

if the agent is risk-averse, the agent's assumed utility function is $u(w,a) = \sqrt{w - a}$. In this case, two countervailing forces exist:

- The most efficient arrangement is one in which the agent's wage is certain, because, in general, if one party is risk-neutral and the other is risk-averse, then it is efficient for the risk-neutral party to bear all the risks. If the principal pays the agent a

random wage, then the agent evaluates the wage according to his expected utility. Being risk averse, if the wage is at all risky the agent values it at less than its expected value. But the principal, being risk neutral, values the cost of the wages paid at their expected value.

- If the principal gives the agent a riskless wage, the agent has no incentive to work hard. To induce the agent to work hard, the principal will have to give up some of the efficiency that is obtained by putting all the risk on the principal.[Ref.8:pp.583-584]

From the principal's point of view, the best possible contract, subject to the constraints that the agent will accept the contract and work hard, is obtained when the principal minimizes the expected wage subject to the individual rationality or participation constraint and the incentive constraint. The individual rationality or participation constraint requires that the contractor willingly signs on the dotted line; the incentive constraint requires that the agent chooses a high level of effort. Both constraints bind at the optimum: the principal does not want to pay the agent more than necessary or put any more risk on the agent than is necessary to get the agent to work hard. It is costly to put risk on the agent.

The objective is 'to get the agent to take the job and to put in high effort'. To give the agent the right incentives, the principal needs to bear some of the risk by rewarding the agent for outcomes that are more likely if the agent puts in greater level of effort.

A. FINITELY MANY ACTIONS AND OUTCOMES

We imagine an agent who may agree to undertake a task for a principal, and who then chooses an action a to take out some finite set $A=\{a_1, \dots, a_N\}$. The action choice by the agent is not observed by the principal; instead the principal sees an imperfect signal of what the agent did. The used model says that the principal (and the agent) observe a signal s that is drawn from a finite set $S=\{s_1, \dots, s_M\}$. If the agent chooses

action a_n , the probability that signal s_m is produced is π_{nm} , where $\sum_{m=1}^M \pi_{nm} = 1$ for each

n . The principal is unable to write a contract that makes the agent's compensation directly dependent on a ; the best the principal can do is to make his compensation a function of s . [Ref.8:p.586]

Since the area of concern is complex, some assumptions are made to facilitate analysis. In particular, 'every outcome is possible under every action,' and 'the agent's utility function is strictly increasing, continuously differentiable, and concave.' Then the basic principal-agent problem -- to find out the optimal incentive scheme for the principal to offer the agent -- is solved step by step.⁵

B. CONNECTING TO GAME THEORY

The principal-agent problem can be connected with the game theory as follows: The principal offers the agent a contract. The agent either accepts or rejects the contract. If the contract is accepted, the agent chooses an action. The possible contract types that the principal may offer are limited; the payoff for an agent rejecting the contract is the reservation level of utility.

The solution concept for the connecting the principal-agent problem to the game theory

is subgame perfect Nash equilibrium. The subgame perfection is used; by assuming that the agent accepts the contract and chooses his action optimally given the

⁵ Solving the basic problem consists of a) for each $a_n \in A$ define the cheapest way to induce the agent to take the job and choose action a_n and b) which $a \in A$, maximizes the principal's net benefit $B(a_n)$ minus the minimal expected cost of inducing the agent to select that action $C(a_n)$. Further discussion will be laid out in the next chapter.

contract. It is also possible to construct the game as subgame imperfect equilibria where the agent threatens to reject any contract that does not give him some amount more than his RU.[Ref.8:p.603]

There are many pros and cons of connecting the principal-agent problem to game theory. However, it appears that applying game theory to gain better insight into the relations between the contractor and the government might help the negotiators to perform their duties more efficiently. Whatever solution method -- if any -- is used, establishing the game might itself turn on some lights in the minds of the negotiation team.

C. MULTIPLE AGENTS AND MULTIPLE PRINCIPALS

In many contracting situations, there are competitors, i.e., multiple agents and multiple principals. For warship procurement, there is more than one potential contractor; and probably more than one government willing to purchase the product. Competitiveness on both sides of the deal surely affects the outcome. The competitors and their relative abilities to enforce the negotiation results will determine whether the contract will be optimal or not.

The economics of contests examines different aspects of these situations, including 'auctions.' One might find solutions for multiple principals and multiple agents problems by referring to auction theory.

There are three possibilities:

- Multiple agents with a single principal. Here, competition occurs among the agents. The principal might establish a contract assuming that 'once the contract offers the agents' reservation level of utility or more, one or more of the agents will agree and accept the contract.'
- Multiple principals with single agent. Here, the competition is among the principals. Assuming that the value of the output to the principal is the amount the principal is willing to pay for the contract; the agent has a good chance of

negotiating a contract that involves the principal with the highest reservation level of utility.

- Multiple principals and multiple agents. Here, the competition is among both the agents and the principals. One might expect the contract price to settle in an equilibrium between the principal's value and the agent's reservation level of utility. However, other extra contractual factors mentioned in Chapter I may affect the outcome.

In the most common situation, multiple agents with a single principal, the principal must evaluate the performance of the agent(s). The effort level promised and supplied by the contractors may differ. Hence, the government may need to develop performance evaluations and to apply them properly.

A different situation may arise if the project requires group work. For warship procurement, a single contractor might not be able to provide all the service and equipment required; a number of individual subcontractors might need to contribute to a single project. This raises concerns about compatibility, internal and external monitoring, agent-agent relations, etc.

In situations where one agent has to work simultaneously for many different principals, principals would compete to get the agent to devote relatively more time and effort to their interests, at the expense of the other principals' interests. Here again, other than the extra-contractual factors that might affect the agent's decision, the principals compete and the one with the highest value and ability to pay will have the greatest influence on the agent.

D. MULTIPERIOD INCENTIVES

In the event that the relationship between the principal and agent lasts more than one period or the project requires a substantial amount of time, the principal might be able to improve the agent's incentives. Depending on how hard the agent appears to be working, the incentives might be re-newed. The question then becomes 'how can the principal solve

some type of continuing programming problem?' This program will probably allow the principal to follow changes in the production process in a continuous manner, and subsequently provide the necessary tools to change the incentives. The biggest advantage of multiperiod incentives is that the principal might look forward and reason back to solve or re-shape the incentives at each stage.

Most of the models suggest that the optimal incentives schemes will be very complex, according to the structure of the environment. However, the incentive schemes in practice are usually quite simple. The principal typically lacks information about the actions of the agent and the agent has limited ability to change the course of action over time as consequences are realized. Multiperiod incentives provide ways to overcome these obstacles. The principal observes the agent's outcomes in early periods and learns about the difficulty of the tasks and the agent's effort. The principal might then change the incentives. Knowing that incentives can be adjusted, the agent might act strategically. Therefore, the principal may want to design the incentives in the initial contract to be more stable and commit to not changing them over time. Unless the agent is unable to change behavior over time, the principal should pay close attention to the incentive structure.

V. A COMPARISON OF THE TRADITIONAL AND NEW CONCEPTS OF INCENTIVE CONTRACTS

A. TRADITIONAL CONCEPT

In traditional incentive contracting, the *accounting profit* is considered to be the contractor's basic motive. Effort is not taken to be an explicit variable that effects the outcome. However, the effort level may be implicitly considered through the final product's actual cost and performance, both of which are related to the contractor's effort .

Multiple incentives (cost, performance and schedule) are designed to provide the government a satisfactory end product, at a reasonable price and within a certain time limit. The appropriate use of schedule incentives in contracts was discussed in Chapter II. In structuring performance incentives as part of a multiple incentive contract, one should consider all the basic criteria that were presented in Chapter III.

Risk sharing and determination of the appropriate sharing ratio are also important. They depend on the government's and the contractor's perceptions during the early stages of negotiations. Whether the parties to the contract are risk averse or risk neutral affects the appropriate choice for the sharing ratio. One should emphasize that risk perceptions are the basics in the traditional concept. Defining the optimal sharing ratio is difficult, but it can be determined by examining the circumstances carefully and evaluating the available information intensely.

The traditional concept can be illustrated by referring to 1969 DOD and NASA Guide. As an example, this thesis will develop a CPIF contract with cost and performance incentives.

Example:

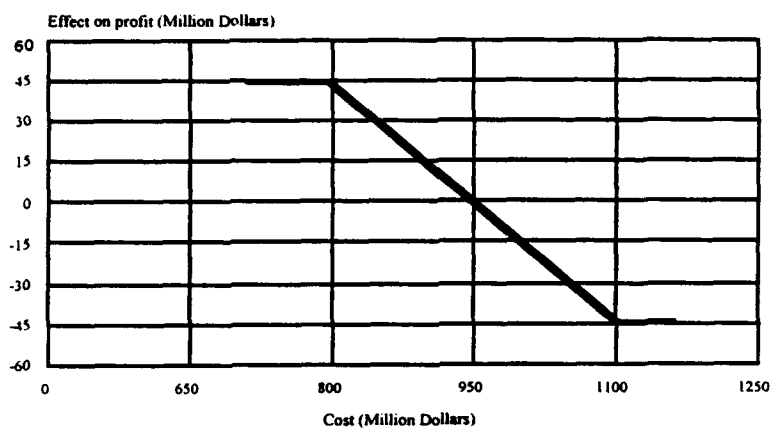
Suppose that the negotiation team has already decided to use the Tascform Methodology, introduced in Chapter III, to define warship performance. The performance rating is taken between 0 (zero) and 100 (one hundred). The graphs below illustrate the value of additional cost reduction/increase and the value of additional performance to the government. The share ratio determines how the government and the contractor split any cost underruns/overruns.

The following data illustrates this example. The government is assumed to be risk neutral and the contractor risk averse.

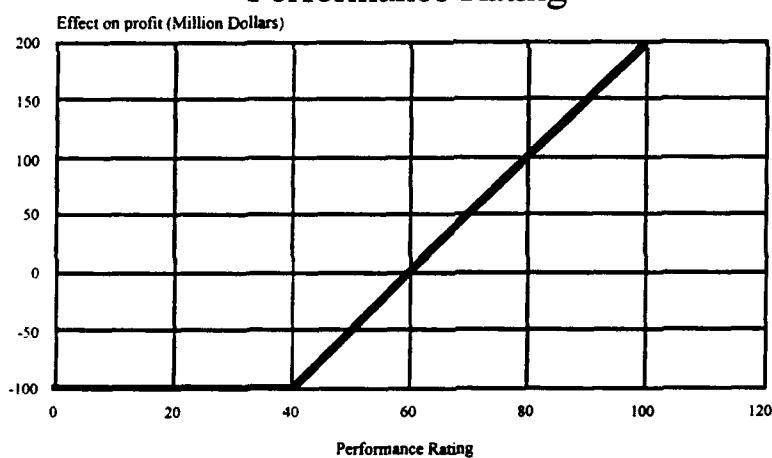
Target cost	\$950 M
Target profit	\$150 M
Share ratio	70/30
Performance incentives:	
minimum acceptable	40% on a 0-100 rating scale
target	60% on a 0-100 rating scale
maximum	100% on a 0-100 rating scale
Incentive assigned:	
cost	(\$45 M,\$-45 M)
B(Q) ⁶	(\$667 M,\$-333 M)
performance	(\$200 M,\$-100 M)
Maximum profit	\$395 M
Minimum profit	\$5 M

⁶Along the same lines with the discussion on page 34, this represents the gross benefits to the government of performance changes and how the government values these changes.

Effect on Target Profit - Cost



Effect on Target profit - Performance Rating



These graphs represent the incentive structure specified by the contract. Presumably this reflects the government's preferences. If the contractor meets the maximum incentive requirements, i.e., reduces cost down to \$800 M, and achieves a 100% performance level as measured by the Tascform scoring methodology, the contractor's total profit will be as

much as \$395 M (150+200+45). On the other hand, if the contractor only satisfies the minimum acceptable incentive requirements, i.e., cost goes up to \$1100 M, and the product has a 40% or lower performance level, total profit will be as low as \$5 M (150-100-45).

B. NEW CONCEPT

According to the new principal-agent concept of incentives, effort is accounted for explicitly and included in the calculations. This subchapter explains and illustrates the theory as presented in A Course in Microeconomic Theory by David M. Kreps, Princeton University Press, Princeton/New Jersey, 1990, Chapter XIV, pp.586-590.

For simplicity, assume that the government is risk neutral and the contractor is risk averse. This assumption can be changed within this theory.

Let the set $A = \{a_1, \dots, a_N\}$ be the contractor's action set where a_n is a function of E (quality of the engineers assigned by the contractor to the project), and e (contractor's effort level for cost control). The set $S = \{s_1, \dots, s_M\}$ is the signals the government will observe. The contractor's payments depends on the signal observed. Q represents the end product's performance rating, $Q = f(E, \theta_1)$, and C_a represents the end product's accounting cost, $C_a = f(E, e, \theta_1, \theta_2)$. If the contractor takes the action a_n , the probability that the signal s_m is produced is π_{nm} , where $\sum_{m=1}^M \pi_{nm} = 1$ for each n . Every outcome is possible under every action. In applying this concept, it may be difficult to determine these probabilities. Presumably, the negotiation team will include a member who is familiar with this issue.

The contractor's utility depends on the wages he receives, w (profit), and the action he takes, that is a . The contractor's assumed von Neumann-Morgenstern utility function is $U(w, a) = u(w) - d(a)$. We assume that the contractor is risk averse with a utility function of $u = \sqrt{w - a}$. His reservation level of utility is u_0 .

$B(a_n)$, gives the end product's gross benefits to the government if the contractor chooses action a_n .

The government's net benefit is defined as $B(u_n) - C_g(u_n)$. This equation is the government's gross benefits for a given contractor action minus the government's cost for the same contractor action.

$$E(C_g) = E(\text{contractor profit}) + E(C_a).^7$$

The problem is 'to find the optimal incentive scheme for the government to offer the contractor.'

The solution can be obtained in two steps: Step I: Find the minimum cost way to induce action a for each $a \in A$, and Step II: Choose the optimal a by comparing benefits and costs.⁸

Step I: For each $a_n \in A$, what is the cheapest way -- in terms of expected wages that must be paid -- to induce the contractor to take the job and choose action a_n ? This question can be answered by solving a constrained maximization problem.

The contractor is concerned about the wage utility. Wage utility is determined by the utility function and the signal s the government observes. Wage utility is measured by variable x_m for $m=1, \dots, M$, where the wage paid to the contractor is $w(s_m)$ when the signal s_m is observed. Then,

$$x_m = u(w(s_m)) .$$

The function $u(\cdot)$ is assumed to be a strictly increasing and continuous function, and $v(\cdot)$ the inverse of u . Thus, the wage paid to the contractor if signal s_m is produced, as a function of the variable x_m , is

$$w(s_m) = v(x_m) .$$

Hence, the expected wage the government must pay if the contractor takes action a_n is a function of the variables $X = \{x_1, \dots, x_M\}$: $\sum_{m=1}^M \pi_{nm} \cdot v(x_m)$.

⁷Some would argue that when the government and the contractor are from the same country, the contractor's effort should also be considered as a 'social cost.' This argument recognizes that both the contractor and the government contribute to the well-being of the same nation.

⁸One can also consider a one-step solution, where the problem is designed as 'finding the maximum benefit-cost difference' from the government's point of view.

The first constraint -- called 'the participation constraint' -- ensures that the contractor's payment at least equals the reservation level of utility, and

$$(I) \quad \sum_{m=1}^M \pi_{nm} \cdot x_m - d(a_n) \geq u_0.$$

The second constraint -- called 'the relative incentive constraint' -- ensures that choosing n is better than choosing some other action n' ,

$$(II) \quad \sum_{m=1}^M \pi_{nm} x_m - d(a_n) \geq \sum_{m=1}^M \pi_{n'm} x_m - d(a_{n'}), \forall n' \in \{1 \dots N, n \neq n'\}.$$

The minimization problem for step I can be specified as:

$$\begin{aligned} & \text{minimize} \quad \sum_{m=1}^M \pi_{nm} \cdot v(x_m) \\ & \text{subject to} \quad \sum_{m=1}^M \pi_{nm} \cdot x_m - d(a_n) \geq u_0 \quad \text{and} \\ & \quad \sum_{m=1}^M \pi_{nm} \cdot x_m - d(a_n) \geq \sum_{m=1}^M \pi_{n'm} \cdot x_m - d(a_{n'}), \forall n' \in \{1 \dots N, n \neq n'\}. \end{aligned}$$

The solutions to this optimization problem, for each a_n , indicates the amount the government will pay the contractor and the contractor's expected profit $E(P)$.

Given probabilities and C_a values, expected accounting costs for the project, $E(C_a)$ can be calculated. This determines C_g , overall project cost to the government.

Step II: For which $a \in A$ is $B(a_n) - C_g(a_n)$ maximized? This is a simple maximization problem.

Example:

Assume that the government is risk-neutral and the contractor is risk averse.

$B(a_n)$: the end product's gross benefits to the government

$d(a_n)$: the disutility of contractor's action

u_0 : the contractor's reservation level of utility

E : the quality of the engineers assigned by the contractor to the project

e : the contractor's effort level to control the costs

Q : end product's quality (performance) level, $Q=f(E, \theta_1)$

C_a : Cost accounting, $C_a=f(E, e, \theta_1, \theta_2)$

θ_1 : unobservable random variable representing a state of the world and its affects on the end product's quality (performance) level

θ_2 : unobservable random variable representing a state of the world and its affects on the end product's accounting cost

a : action taken by the contractor, A : set for combinations of parameters E and e

s : signals observed by the government, S : set for combinations of parameters Q and C_a

P : Profit to the contractor

$E(P)$: expected profit to the contractor, $E(P) = \sum_{m=1}^M \pi_{nm} \cdot v(x_m)$

C_g : Cost to the government,

$E(C_g)$: Expected cost to the government, $E(C_g) = E(P) + \sum_{m=1}^M \pi_{nm} \cdot C_a$

the contractor's utility function: $u = \sqrt{w - a}$

π_{nm} : the probabilities of observing signal s_m given the action a_n

$w(s_m) = v(x_m) = P = x_m^2$

$N=4$

$M=4$

$u_0=8$

$A: \{a_1: E_{Low}, e_{Low}; a_2: E_{Low}, e_{High}; a_3: E_{High}, e_{Low}; a_4: E_{High}, e_{High}\}$

$S: \{s_1: Q_{Low}, C_{Low}; s_2: Q_{Low}, C_{High}; s_3: Q_{High}, C_{Low}; s_4: Q_{High}, C_{High}\}$

Given this data, find the solution to the following problem:

minimize $\sum_{m=1}^M \pi_{nm} \cdot v(x_m)$

subject to $\sum_{m=1}^M \pi_{nm} \cdot x_m - d(a_n) \geq u_0$ and

$\sum_{m=1}^M \pi_{nm} \cdot x_m - d(a_n) \geq \sum_{m=1}^M \pi_{n'm} \cdot x_m - d(a_{n'}), \forall n' \in \{1 \dots N, n \neq n'\}.$

The probabilities table:⁹

π_{nm}	Qlow,Clow	Qlow,Chigh	Qhigh,Clow	Qhigh,Chigh	d(a _n)
Elow,elow	.2	.5	.1	.2	0
Elow,ehigh	.4	.2	.3	.1	2
Ehigh,elow	.2	.2	.3	.3	3
Ehigh,ehigh	.2	.1	.5	.2	5

The C_a table:

C _a	Clow	Chigh	Clow	Chigh
Elow,elow	800	900	850	950
Elow,ehigh	850	950	900	1000
Ehigh,elow	900	1000	950	1050
Ehigh,ehigh	950	1050	1000	1100

Using the above values, the respective P values can be determined:

	P1	P2	P3	P4
Elow,elow	64	64	64	64
Elow,ehigh	127.16	38.07	136.93	55.45
Ehigh,elow	79.71	16.31	198.63	193.99
Ehigh,ehigh	60.15	4.09	302.42	162.71

⁹These probabilities are based on the functional relations among the respective parameters. For example, when the contractor chooses a₄, that is Ehigh,ehigh combination, the probability of observing the signal s₃, Qhigh,Clow is the highest for a₄.

The solution for step II and for the problem can be obtained from the following table:

	$B(a_n)$	$E(P)$	$E(C_a)$	$E(C_g)$	$B(a_n)-E(C_g)$
$E_{low,low}$	1000	64	885	949	51
$E_{low,high}$	1075	105.10	900	1005.10	69.90
$E_{high,low}$	1175	136.99	980	1116.99	58.01
$E_{high,high}$	1300	196.2	1015	1211.2	88.8

For the above example, the government's maximum net benefit -- $\max [B(a_n)-E(C_g)]$ -- occurs when the contractor chooses the action a_4 , $E_{high,high}$. The incentive structure that the government should offer is presented below.¹⁰ To give the contractor right incentives, the contractor has to bear some of the risk. Thus, the contractor's reward depends on the outcome. The outcome is random, but influenced by the contractor's effort level.

The incentives table:

$Q_{low,C_{low}}$	$Q_{low,C_{high}}$	$Q_{high,C_{low}}$	$Q_{high,C_{high}}$
60.15	4.09	302.42	162.71

The new incentives concept provides almost all the necessary information for the government to determine what kind of incentives -- payments -- to offer to the contractor. However, there are important issues to solve in determining the probabilities and cost level. In a real situation, there are several possible signals, which will make the problem more complicated. In such a situation, the negotiation team might prefer to use the traditional

¹⁰The incentive structure ensures that the contractor will indeed accept the contract and choose action a_4 , i.e., provide high quality engineers and a high level of effort to control costs. This action also maximizes the government's net benefit.

concept. The new approach, however, might serve the purpose of providing insights that would help the government to employ more effectively the traditional incentives.

VI. CONCLUSIONS

Since warship procurement is among the important financial transactions of the Turkish Navy, these transactions should be carried out in a systematic manner. A close coordination between the Turkish Navy and the relevant country's industry is one of the first requirements for an effective end product.

The government's main objective is to obtain a warship that effectively meets defense requirements within the given budget constraints; efficient production, risk sharing between the contracting parties, and the contractor's appropriate effort level are among the major issues with which the government must deal.

The warship industry is dynamic and its end products are extremely complex. This introduces many uncertainties and problems; some of which have been discussed in the previous chapters. These issues and military budget constraints causes the government and ultimately the Turkish Navy to look for appropriate instruments to increase cost-effectiveness. One instrument is using incentive type contracts in warship procurement. Incentive contracts can be employed to compensate for the lack of information about economic conditions and specifications for the end product ahead of time; they provide tools to overcome uncertainties.

Incentive contracting procedures have been developed and improved extensively over time. Today, procurement incentives play a significant role both in the public and private sectors. For many branches of the government, procurement incentives provide several advantages, including the potential to attain a high degree of effectiveness in production, motivating the contractor for a higher effort level, and promoting a successful end product which will meet the government's requirements and standards.

The objective of incentive contracts is to motivate the contractor to earn more compensation by achieving better performance and controlling cost. This objective requires the government to clearly communicate its goals to the contractor.

In a situation where using contract incentives is a matter of negotiation, the contractor's willingness to accept an incentive contract will depend on various factors, including the contractor's business volume and financial status during the contract negotiation. If there is more than one firm capable of providing the end product within the desired performance limits, the government might be able to award the contract only to firms willing to share an equitable portion of the contract risks through an incentive contract. Incentives might also be used to discourage the contractors from producing below the standard and to reward performance that exceeds the standards.

The advantages of incentive contracts rely heavily on establishing realistic incentive limits. The minimum acceptable standards must meet the government's requirements while the maximum incentives must be attainable by the contractor and valuable to the government. Incentives must be used consistently so that the contractor can estimate profits commensurate with effort, but they should not be standardized too much or they may end up with a fixed fee character. A certain amount of flexibility is desirable. This flexibility will help if it becomes necessary to re-arrange the incentives. For example, if conditions change, the incentives may no longer match the government's requirements; substantial changes could benefit both the contractor and the government. Incentive targets should also be evaluated very carefully. If possible, specific evaluation criteria should be laid out during the negotiation stage. To get realistic results, all specifications, incentive targets, the sharing ratio, and any other element of the contract should be mutually agreed upon by the government and the contractor.

Even though the 'profit' motive is the essence of incentive contracting, extra contractual factors, discussed earlier, also play a significant role. Even if extra contractual factors are not included in the contract, their significant effects on contractors should be considered. They can help encourage the contractor to accept the contract and provide the desired end product.

A successful implementation of the incentive contracts ensure that:

- The Navy gets the most-effective warship.

- Contract schedules are met.
- Cost is controlled.
- The contractor receives sufficient profit.
- Risk sharing is shared in an appropriate manner.
- The contractor applies an appropriate effort level balancing cost control and product performance.

Despite the many advantages incentive contracts offer, they might fail to achieve the desired goals. Their successful incorporation and administration is difficult. They require extensive planning and comprehensive technical cooperation between the contracting parties.

The major problem in incentive contracts is determining cost, performance and schedule targets. The Navy's contracting personnel are responsible for evaluating cost figures and providing the contractor with the firmest possible government specifications. Defining and evaluating performance criteria might be very difficult or impossible, though the methodologies discussed earlier can assist in this process. Schedule incentives require predictions and assumptions regarding the contractor's production capabilities. They may not necessarily reflect the project's real processing time. Multiple incentive contracts must balance the trade-offs amongst different incentives.

In establishing incentive contracts, negotiating skill and strength play an important role in determining the profit level and the cost targets and ceiling. Structuring and writing the terms of the contract is also important.

As discussed in the previous chapters, performance incentives can encourage technological progress by attaching a reward/penalty formula to specific parameters. The purpose is to specify the government's cost/performance trade-offs in advance of contract award and encourage the contractor to think about cost, performance and quality.

The steps for using performance incentives are:

- Select the characteristics to be incentivised.
- Select appropriate performance criteria.

- Establish measures to evaluate the defined performance criteria.
- Structure incentives by considering the desired performance level and acceptable limits.

The goal in defining a product's performance level should be 'to formulate the minimum number of criteria to sufficiently define performance.' The performance criteria must be clear to both parties, and evaluation and testing measures must be mutually agreed upon. Performance awards should consider maintainability of the warship as well as technical performance specifications.

Even though cost/performance incentives generally receive the greatest emphasis, schedule incentives might be appropriate under certain circumstances. Schedule incentives should focus on the end product's delivery and on selecting realistic target dates.

Defining warship performance is difficult. The methods that are discussed in Chapter III -- Operations Research Model, Subjective Figure of Merit, Regression Analysis, and Technological Relationship Model -- help resolve this fairly difficult problem. For efficiency purposes, the government should probably select one or more of these models. When applying these models, it is important that the model be dynamic so that the basic criteria might be modified if necessary. The government could benefit most, if the incentives are determined with the use of 'look forward and reason back technique'.

Though they require more calculations, extensive planning and a long-execution process, new incentive contracting theories provide the means to structure incentive contracts more efficiently. The principal-agent problem and the solutions for moral-hazard issues allow the government to effect the end product by rewarding observable outcomes, even if the government cannot directly observe the contractor's effort and the quality of the engineers assigned to the project.

Using of incentives in an uncertain environment such as warship procurement, would require additional administrative expenses, and complicated procedures. But, **using performance incentives in warship procurement is both appropriate and applicable.** The general principles which guide incentive contracts apply to warship

procurement incentive contracts. The benefits that the government will achieve by using well structured incentives in development and procurement contracts can enhance the efficiency with which the resources are employed.

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