MEMORANDUM
RM-5122-PR
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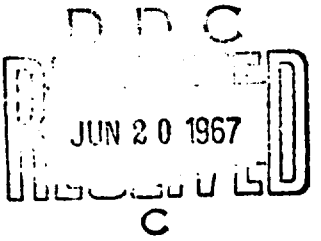
Ralph E. Miller



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PREFACE

Selection of an appropriate sharing rate for cost incentive contracts might save the Federal Government large sums of money each year. Theoretical criteria for making this choice have long been known; however, no results have been established because suitable empirical analyses of the problem are lacking.

This Memorandum considers the empirical evidence necessary for determining appropriate sharing proportions. It shows what data are needed, indicates how they should be used, and proposes a method for collecting them.

The author is a consultant to The RAND Corporation.

SUMMARY

Investigating the effects that cost incentives have on contractor efficiency is important because it is the basis for choosing the appropriate sharing rate for Government contracts. The rationale for incentive sharing arrangements is that they induce the contractor to achieve a lower level of allowable cost than he would without incentives, or than he would if the incentives were weaker. At present, there exists no useful empirical information relating cost performance to the sharing proportions. The only norm now available is the cost target negotiated for each contract.

This study proposes that contractor efficiency be examined by negotiating several sets of contract provisions for each future procurement action, the sets corresponding to different sharing rates. (Actual contract performance would naturally be governed by only one set of provisions chosen after all the sets had been negotiated.) In this way, the effect of incentive arrangements on cost targets can be studied directly. The norm of each procurement becomes the simple average of the several sets of data obtained. The cost score is the difference between the norm and the allowable cost, expressed as a percentage of the norm. The average of the cost scores for the contracts performed at each sharing rate is a measure of expected performance at that sharing rate.

The averaging method proposed here is cross-section analysis, which measures an average response throughout the aerospace industry to differences in sharing arrangements. Unfortunately, cross-section analysis obscures differences among individual contractors, but it does not make this type of analysis useless. When trying to select preferred sharing arrangements, certainly an industry-wide average description of contractor behavior is a better basis for choice than no information at all. The extent to which the industry average is useful depends upon the magnitude of the variations it conceals. One cannot be certain in advance that the similarities are great enough to justify the analysis proposed. After the results are available, however, the size of the unexplained variations, judged in relation to the industry average, will reveal the extent to which this average is a useful guide.

The contracting process proposed here differs from present practice in three ways. First, the Government must choose, at the beginning, the exact nature of the sharing arrangements to be considered, leaving only the levels of cost and profit targets for determination by negotiation. Especially with very large contracts, there is now a tendency for the contractor to negotiate about or even suggest the numerical values of the incentive sharing arrangements. Second, the contractor and the Government must reach agreement on pairs of targets associated with each of several sharing proportions, whereas they presently need agree only on one proportion and its associated targets. Third, before the final sharing proportion is selected, the contractor should be allowed to make offsetting adjustments in the negotiated fee and cost targets for each proposed sharing rate, substituting one for the other in proportion to the sharing rate value. These adjustments have no counterpart in present practice.

These changes to the contracting process are proposed to provide data for the empirical analysis. For the analysis to be meaningful, three conditions must be satisfied. These are that: (1) steps be taken to ensure that the contract provisions negotiated at each sharing proportion are the same as would have occurred had that sharing proportion been the only one negotiated for that procurement; (2) different sets of contract provisions encompass a wide range of sharing rates; and (3) aspects of the incentive arrangements other than the sharing proportion itself be kept uniform for all procurements studied in the analysis.

A brief investigation of the institutional environment of contract negotiations suggests that the proposed innovations are feasible. The data generated under this proposal will clarify the relationships between the sharing rate, target cost and target profit, and will provide a basis for evaluating the effect of cost incentives on contractor efficiency.

CONTENTS

I. INTRODUCTION

The weapons budget of the United States Government is very large. Even small savings in it, on the order of a few percent, amount to hundreds of millions of dollars each year. One possible way to achieve such savings is to improve the contractual arrangements under which private companies develop and produce the weapons that the Government buys.

Research on contracting touches only one aspect of the weapons acquisition process. It is not concerned at all with what the Government should buy. It shows evidence of only slight interest in whom to buy it from. Its major emphasis is on the choice of preferred contractual arrangements, once the Government has decided what it wants and whom it wants to supply it. This choice, restricted though it be, is still an important one. Its importance is indicated by a recent report of the Secretary of Defense that "ten cents is saved for each dollar shifted from CPFF (cost-plus-fixed-fee) to other forms of contracts."

In conformity with its belief that contracting does matter, and that incentive contracts are better than CPFF contracts, the Department of Defense has encouraged the use of incentive contracts. As a result, procurements worth about $5.5 billion each year have been shifted from cost-plus-fixed-fee to firm-fixed-price (FFP) and fixed-price incentive (FPI) contract forms.

The theoretical justification for incentive contracting can be easily explained once the operation of the process is described. When negotiating the contract, the Government and the contractor agree upon a project's target cost and target profit. At the same time, they choose a sharing formula. When the project is completed, the two parties negotiate to determine what allowable expenditures were made in doing the work. The Government then pays these allowable costs, plus the contractor's profit. If the allowable costs are less than the target cost, the contractor's profit is increased by some proportion of the savings. This proportion is determined by the sharing formula agreed upon in the original negotiations. Similarly, if the

allowable costs exceed the target, the contractor's profit is reduced by his share of the overrun.

Algebraically, the final cost to the Government is given by the following

$$C_f = P^* + r(C^* - C) + C$$

$$= P^* + rC^* + C(1 - r)$$

where C_f = final cost to the Government,

P^* = target profit,

C^* = target cost,

C = actual cost,

r = sharing rate.

The sharing formula in most incentive contracts specifies that the contractor's profit is increased by a fixed percentage of the difference between target cost and allowable cost. If actual cost exceeds the target, this difference is negative, and the contractor's profit is reduced by the same percentage of the overrun. This percentage is called the sharing rate. In virtually all fixed-price incentive contracts, it is between 5 and 40 percent--most often it is 20 percent.

Incentive sharing is an important feature of contracting because it is believed that the incentives lead to lower allowable costs. The reason is obvious: by reducing allowable costs, the contractor increases his profit; and since the project management is in a good position to control costs, it takes advantage of this opportunity to increase its profit.

Furthermore, the higher the sharing rate, the stronger the incentive to reduce allowable cost. It may therefore be expected that

higher sharing rates lead to lower levels of allowable cost. If this argument is carried to its logical conclusion, it appears that firm-fixed-price contracts, which offer the strongest possible incentives,† should lead to the lowest possible costs for the Government. Since cost reduction is desirable, why not negotiate all contracts on a fixed-price basis? The answer lies in the fact that the large cost uncertainties inherent in so many of the products purchased by the military introduce so great an element of risk that larger target profits would be necessary to induce contractors to accept many contracts. Should target profits be held relatively constant, the risk factor would appear in inflated target costs. The basic problem of incentive contracting is to decide how strong cost incentives should be, given that imposition of stronger incentives also requires the Government to pay higher risk premiums.

Higher incentive rates not only provide impetus for the reduction of allowable costs, but also provide a conflicting impetus. The higher the sharing rate, the greater the benefit to the contractor of negotiating an inflated target cost. The question that has not yet been satisfactorily answered is how inflated target costs are traded off against cost reductions as a function of the sharing rate. It is the purpose of this Memorandum to suggest a means whereby this question may be resolved.

The importance of empirical information showing the effect of different incentive sharing arrangements on total cost to the Air Force should not be underestimated. Consider, for example, the problem of trying to minimize the total price for a given contract, and suppose that two alternative arrangements are a CPFF contract and an FPI contract. To decide which leads to a lower total price, it is necessary to know whether the reduction in allowable cost induced by the incentive provision does or does not exceed the addition to profit resulting from an increased target cost that may be expected on the FPI contract.

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†An FFP contract, in effect, allows the contractor to retain, as profit, the full amount of any cost reductions that he can achieve, and similarly forces him to absorb completely any unexpected additional costs that are incurred.

In fact, the empirical information needed to make this determination is not available. Section II of this Memorandum explains why existing data are inadequate for empirically studying the effects of cost incentives on total cost. It goes on to show what additional information is needed for estimating these effects. Section III discusses in detail a proposal for obtaining the necessary data by expanding the scope of contract negotiations. Section IV then explains how the data obtained under this proposal can be used to determine the preferred incentive sharing arrangements.

Throughout this Introduction, it has been tacitly understood that the preferred sharing rate in question is the one leading to the lowest total price for the Government. This assumption is retained for Secs. II and III. In effect, it provides the criterion for solving the basic contracting problem posed above.

This particular criterion is not, however, the only possibility. It is used here only because it is the simplest way to focus attention on the problem of empirically determining the relationships among the sharing rate, profits, and allowable cost. A broader and more accurate view of the role of contracting requires consideration of additional factors. For example, an argument for preferring fixed-price arrangements is that they facilitate direct price competition. And even when FFP arrangements are not used, stronger incentives ease the task of choosing the contractor apt to achieve the lowest cost, as J. J. McCall points out.† Other perspectives on contracting, questioning the importance of price cutting, are shown in R. E. Bickner's study.†† The suitability of various preference criteria involving cost and profits is discussed briefly in Sec. IV of this Memorandum as well.

These and other studies show that additional work is needed to develop proper criteria for selecting preferred incentive arrangements. But whatever criteria are used, they are likely to give at least some

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†J. J. McCall, An Analysis of Military Procurement Policies, The RAND Corporation, RM-4062-PR (DDC No. AD 454929), November 1964.

††R. E. Bickner, The Changing Relationship Between The Air Force and the Aerospace Industry, The RAND Corporation, RM-4101-PR (DDC No. AD 609779), July 1964.

weight to the levels of cost and profit that are achieved. It is therefore important to continue also with the empirical work discussed here, which is aimed at measuring the achievable combinations of cost and profits.

II. AN EMPIRICAL METHOD FOR MEASURING THE EFFECTS OF INCENTIVES

From the Introduction, it is clear that the selection of the sharing proportion affects both the allowable cost and the target cost. To choose the preferred sharing proportion, an empirical estimate of the magnitude of these effects is required. This section shows that present contracting procedures do not generate sufficient information to make this empirical determination. It then explains a modification of existing contracting practice that will, if adopted, provide the data necessary for empirical measurement of the effect of incentives on allowable cost and on profit.

THE BASIC PRINCIPLES: A PREVIEW

The basic ideas are quite simple. For each procurement action, the effect of incentives on allowable cost is measured with respect to a cost norm for that procurement. The higher the sharing rate, the lower the allowable cost should be, expressed as a percentage of the norm. The difficulty in measuring the magnitude of this effect arises because the norms are hard to establish. The problem is that different procurements are for different products, or entail different kinds of work.

The only possible cost norm that is presently available for each procurement action is the cost target in the contract covering that procurement. But this target is not a satisfactory norm, at least not for measuring the effect of different sharing rates on allowable cost. The reason is that the target itself, as determined in the negotiation process, may depend upon the sharing rate. It is therefore impossible to determine whether allowable cost, expressed as a percentage of this norm, responds differently to different sharing rates because of cost savings or because of changes in the norm.

Note that this argument is not an absolute objection to the normative use of negotiated cost targets, but applies only because targets are negotiated at different sharing proportions. An obvious way to construct norms, then, is to negotiate cost targets for all procurement

actions at the same sharing rate. But it is impossible to negotiate all cost targets for all procurements at the same sharing rate: the cost target is an essential part of the contract and must be negotiated at the sharing rate under which the contract is performed. The solution is to negotiate two or more cost targets for each procurement action: one (or more) at a sharing rate common to other procurements, and therefore suitable as a cost norm; another at the sharing rate under which the contract is actually to be performed.

Once the principle of negotiating cost targets at more than one sharing proportion is recognized, there is a more general way of applying it to the empirical analysis of the relationships among the sharing proportion, costs, and profits. One first computes an average relationship between the sharing proportion and the ratio of allowable cost to target cost. This relationship encompasses two effects: the impact of the sharing rate on negotiated target costs; and the cost reductions resulting from improved efficiency. The first is measured by using the data generated in the multiple sets of negotiations to establish empirically an average relationship showing the impact of different sharing rates on cost targets. This is then used to abstract the impact of the sharing rate on cost targets. What remains is a relationship reflecting the changes in allowable cost that result from changes in the sharing rate. The purpose of this entire section is to explore in detail the method for empirically developing this average relationship between the sharing proportions and allowable cost.

Consider first the nature of the information desired. We wish to know, for an individual procurement, how the sharing proportion in the contract will affect the allowable cost achieved by the contractor. This information might show, for example, that allowable cost will be 3 percent lower if a 40-percent sharing rate is adopted instead of a 20-percent rate. Information of this kind cannot, of course, be obtained by studying any single procurement in isolation. With only one contract and only one cost outcome, no comparisons can be made.

What is required, then, is an analysis of a number of different procurements, performed under contracts with different sharing

proportions. Cost comparisons between contracts are based on the assumption that a given sharing proportion has a similar effect on whatever contract it is applied to. Using this assumption, it is possible to make such a statement as, "On the average, allowable cost is 3 percent lower in contracts with a 40-percent sharing rate than in contracts with a 20-percent sharing rate."

The difficulty in making this type of comparison between different procurements is that the sharing proportion is not the only factor affecting allowable cost. One contract may be for 33 B-52 jet bombers, another for half a dozen radar tracking sets of advanced design; it is absurd to attribute the difference in allowable cost between these procurements only to differences in the sharing proportion. For cost comparisons between contracts to be meaningful, it is first necessary to take account of the other factors affecting cost; chief among these is some notion of the size of the job, or the amount of work to be done. This can be accomplished using a cost norm for each procurement. The cost norms should reflect the expected differences in allowable cost if all contracts are performed under the same sharing proportion. The purpose of negotiating more than one cost target for each procurement is to help establish cost norms having this essential property.

Once a set of cost norms is obtained, the allowable cost achieved on each contract is stated as a percentage of the norm for that contract. These percentages, or cost scores, are then compared for contracts performed at different sharing proportions. If the average score on contracts performed at a 40-percent sharing rate is 95 percent, whereas the average score at 20-percent sharing is 98 percent, this evidence is the basis for the assertion that, on the average, allowable cost is 3 percent lower at 40- than at 20-percent sharing.

No attempt is made to explain exactly the level of allowable cost achieved on each individual contract; and it is not certain that variations in the sharing arrangements have exactly the same effect on all contracts. It is hoped only to compute an industry-wide average for the cost reductions that can be achieved with the appropriate sharing proportion. What the assertion implies, then, is that adopting a 40-percent sharing rate instead of a 20-percent rate can be

expected to save, on the average over a number of future procurements, approximately 3 percent of allowable cost, just as it presumably would have saved an average of about 3 percent of allowable cost on the past contracts actually negotiated at 20 percent, had they been performed instead at 40-percent sharing.†

We reemphasize that this type of assertion is a statistical inference, based on the assumption that the forces determining a contractor's negotiating behavior and cost performance are similar on all procurements. There are, of course, unexplained variations in allowable cost on individual contracts. However, if they are random events--or at least occur randomly with respect to the sharing rates--then they tend to average out over a number of contracts.

There is always a danger that some systematic but unrecognized determinant of the relationships among the sharing proportion, negotiating behavior, and cost performance will be omitted from the analysis. If this unrecognized determinant is not distributed randomly with respect to the sharing rates, then some of the variations in allowable cost that it causes will be mistakenly attributed to variations in the incentive arrangements. Moreover, if the systematic relationship between this determinant and the sharing rate changes in the future, then predictions based on past performance will be somewhat in error on account of its omission. In general, the accuracy of predictions based on the forthcoming analysis will depend upon the extent to which all of the relevant factors are included in it.

MODIFIED CONTRACTING ARRANGEMENTS ARE NEEDED

The preview gave the theoretical basis for measuring the impact of incentive sharing arrangements on allowable cost. Turn now to the

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†It is not certain a priori that changes in the sharing arrangements have a fixed percentage effect on allowable cost for all contracts. This assumption is used here only for concreteness in the example. It is certainly more plausible than the other obvious and simple possibility, namely that incentives have the same absolute effect on allowable cost for all contracts. A complete econometric analysis will, of course, consider these and other possibilities, in order to discover the true nature of this effect. A more rigorous model of the proposed empirical analysis is presented in the Appendix.

practical problems of measuring this impact. In particular, consider the problem of defining the cost norm for each contract.

Note first that the only norm available under existing contracting arrangements is the cost target negotiated for each contract. Unfortunately, normative use of cost targets is unwarranted, and may lead to systematic distortion of the true relationship between the sharing proportion and allowable cost. This subsection develops this point in detail, and explains why contracting arrangements must be modified to generate adequate data for an empirical measurement of the effects that cost incentives have on allowable cost.

If cost targets are given normative significance, then the cost score on a contract depends simply on the percentage underrun. Suppose that the average underrun is 3 percent on contracts with 15-percent sharing, and 7 percent on contracts with 30-percent sharing. Does this mean that contractors are, on the average, able to reduce allowable cost by 4 percent more when the sharing rate is 30 percent than when it is 15 percent? Certainly not. This argument fails to consider that the targets in contracts with 30-percent sharing may be systematically different--slacker or tighter--than they are in contracts with 15-percent sharing.

There are at least three reasons for expecting targets to be chosen differently for contracts at different sharing rates. First, the higher the sharing rate, the stronger the contractor's incentive to bargain harder for a high target. At a low sharing rate, it does not make much difference what the target cost is; but at a high sharing rate, there are large rewards for negotiating a slack target. Second, contracts with high sharing rates are riskier for the contractor than contracts with low sharing rates, because overruns lead to greater losses. One possible reaction to the danger of a large and costly overrun is to insist upon a higher target if the sharing rate is high rather than if it is low.†

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†An experimental study of risk aversion in incentive contracting, using college students as subjects, is reported in G. J. Feeney, W. H. McGlothlin, R. J. Wolfson, Risk-Aversion in Incentive Contracting: An Experiment, The RAND Corporation, RM-4231-PR (DDC No. AD 604851), August 1964. The results support the suggestion given here.

A third factor that may influence the negotiation of target costs indicates that targets may be lower, rather than higher, for high sharing rates. If a contractor expects an underrun, an increase in the sharing proportion increases his expected profit, because it increases his share of the expected underrun. A contractor expecting a large underrun may decide that this gain outweighs the added risk of a high sharing rate, and he may accept a lower target at a high sharing rate than he would at a low one. For example, an underrun of 10 percent of target cost adds only 1.5 percentage points to profit at a sharing proportion of 15 percent, but adds 3 percentage points at a sharing proportion of 30 percent. A contractor expecting such an underrun foresees, if he accepts a 30-percent instead of a 15-percent sharing rate, an additional profit equal to 1.5 percent of allowable cost, simply because the sharing proportion is higher. He may therefore be willing to accept a lower cost target that takes away part, but not all, of this expected gain.

Since there is no empirical evidence about the effect of different sharing rates on the negotiation of cost targets, an observed relationship between the sharing proportion and the average underrun proves nothing about the effect of cost incentives on allowable cost. This is because the observable relationship confounds the effect of the sharing rate on allowable cost with its effect on cost targets; and the two effects cannot be separated without additional information. Moreover, because the impact of cost incentives on cost targets involves forces acting in opposing directions, it is not even known whether targets are higher or lower at higher sharing rates. Therefore, an increase in the percentage underrun may either overstate or understate the cost reductions obtained by going from a lower sharing proportion to a higher one.

Unfortunately, the relationship between the sharing rate and the percentage underrun is the only one that can be determined from the historical record of procurement contracts. Its inadequacy suggests a new departure. To measure the relationship between sharing rates and allowable cost, it is first necessary to know something about the way sharing rates affect the negotiation of cost targets. The way to

find out what these effects are is to actually negotiate two or more different targets for a single procurement, each target corresponding to a different sharing rate. In this way, the effect of the incentive arrangements on cost targets can be studied directly.

This proposal involves a change in existing contracting procedures. The administrative aspects of implementing the proposed change are discussed in Sec. III. The remaining parts of the current section are devoted to a detailed analysis showing how the proposed change will provide the information necessary to determine the effect of cost incentives on allowable cost.

ILLUSTRATIVE USE OF THE PROPOSAL

The use of multiple sets of negotiated cost and profit targets is illustrated in this subsection by a sequence of examples. An oversimplified example, involving only two procurements, is discussed first. A realistic version of this example, involving the same two hypothetical procurements, is then considered. An attempt to interpret the results of this example indicates why a number of contracts are necessary for the analysis in order to obtain reliable average relationships. The power of the averaging method is then illustrated by a final example, involving nine hypothetical procurements. That leaves, for the final subsection, a statement of the more general method for using sets of negotiations to study the effect of incentive sharing arrangements on allowable cost.

Two Simple Examples

In the first example, one of the hypothetical contracts is for missile production and the other for aircraft production. Each contractor is told that targets must be negotiated for sharing rates of both 15 and 30 percent. These negotiations are completed before either contractor is informed which sharing formula will be used to determine his actual profit. The results of the negotiations are shown in Table 1 (the other information in the table may be disregarded for the moment). The missile contractor is seen to have asked for a higher

target profit at the 30-percent sharing rate (and has also negotiated a higher target cost). The aircraft contractor has chosen targets in the same pattern, but they are exactly three times the size of the targets for the missile contract.

Table 1

RESULTS OF TARGET NEGOTIATIONS: FIXED RATIO

	r = .15		r = .30		Avg	Allow-	
Contract	Target Profit	Target Cost	Target Profit	Target Cost	Target Cost	able Cost	Cost Score
Missiles	17	203	18	205.7	204.3	193	94.4
Aircraft	51	609	54	617	613	600	97.9

After the negotiations are completed, but before production begins, the missile contractor is told that the 30-percent sharing rule, and the targets corresponding to it, will be used to determine his actual profit. The aircraft contractor is told to operate according to the 15-percent sharing rule with the appropriate targets.

Now suppose the actual outcomes are the ones shown in Table 1. A comparison of the two sets of targets for each contract is convincing evidence that the aircraft procurement is expected to require exactly three times as much work as the missile procurement. However, if the allowable cost of the missiles is multipled by three, it is still 3.5 percent less than the allowable cost of the aircraft, indicating the missile contractor was 3.5 percent more effective in cutting costs than the aircraft contractor.

This result can also be obtained by computing a cost score for each contract. To eliminate the sharing rate's effect on the targets, the norm for each procurement is defined as the average of the targets for the two sharing rates. The allowable cost of the missiles is 94.4 percent of the average of the two targets, and this is 3.5 points better than the score for the aircraft contractor. The result is the same as that given by direct comparison of the costs.

This example is oversimplified because the way the targets are constructed avoids a problem certain to arise if two sharing rules are actually negotiated for a pair of contracts. In the hypothetical contracts described here, the ratio of the cost targets for aircraft and missiles is exactly the same, 3:1, at each of the two sharing rates. Furthermore, the ratio of the profit targets is also 3:1 at each sharing rate. Under these conditions, it is easy to infer that the aircraft procurement is expected to require exactly three times as much work as the missile procurement, in some normative sense. In realistic negotiations, the two contractors will not react in exactly the same way to a change in the sharing rate, and the results may resemble Table 2. Now there are four different estimates of the relative sizes of the two contracts, obtained from the ratios of the cost targets and the profit targets at each sharing proportion. The problem is to combine these estimates into a single measure of the relative amounts of work required for the two procurements.

Table 2

RESULTS OF TARGET NEGOTIATIONS: REALISTIC

	r = .15			r = .30					
Contract	P^*_{15}	C^*_{15}	S_{15}	P^*_{30}	C^*_{30}	S_{30}	Norm (N)	Allowable Cost (C)	Cost Score
Missiles	17	203	201.9	18	205.7	207.0	204.5	193	94.4
Aircraft	48	624	602.6	51	630	623.4	613.0	600	97.9

The profit targets as well as the cost targets are relevant because the sharing formula for determining actual profit includes both targets. The total profit is the target profit P^* plus the product of the sharing proportion r (written as a decimal fraction, not as a percentage) and the cost underrun $(C^* - C)$, or[†]

[†]This formulation is strictly correct only in the range where price ceilings, cost ceilings, etc., do not come into play. These complications will be mentioned in Sec. III and discussed in the Appendix.

(1) $$P = P^* + r(C^* - C).$$

This can be rewritten as

(2) $$P = (P^* + rC^*) - rC.$$

This equation shows that an increase of one dollar in the target cost exactly balances a decrease of r dollars in the target profit.

Some contractors may prefer higher target profits and tighter cost targets, whereas others prefer lower target profits and more slack in their cost targets. During the original negotiations, it is possible for the contractor to trade higher target profits for lower cost targets,[†] so the cost targets alone are not an unbiased estimate of contract size.

Comparing Table 2 with Table 1, it is apparent that the aircraft contractor prefers slack cost targets, especially at high sharing rates, even though his target profits are lower because of them. This preference makes him look very inefficient if only his cost targets are considered when establishing the norm for contract size. A more reasonable procedure is to include both target profit and target cost in the estimate of contract size, according to the weights with which they appear in sharing formula (2). Thus, the expression $(P^* + rC^*)$ is taken as a standard for measuring contract size. This standard is, of course, about $(8.5 + 100 \cdot r)$ percent of target cost, because target profit is usually about 8.5 percent of cost. It is therefore convenient to divide $(P^* + rC^*)$ by $(r + .085)$ in order to obtain an estimate that is approximately the same size as the final negotiated cost will actually be. The quantity

$$\left(\frac{P_r^* + rC_r^*}{r + .085}\right)$$

[†]See L. E. Preston, Contract Negotiations and Results in Aircraft Procurement: Case Studies of B-52 and B-58, The RAND Corporation, RM-3254-PR, September 1962.

is denoted by S_r in Table 2 (the subscripts distinguish targets negotiated at different sharing rates). S_r is thus a standard way of measuring, on the basis of a single pair of cost and profit targets negotiated at the sharing rate r, the probable amount of work required in a procurement action. When comparing different procurements, division by $(r + .085)$ does not affect the relative size of the two contracts, as estimated from the targets negotiated at the same sharing rate, because the factor $(r + .085)$ cancels from the ratio. The arbitrariness of the factor does, however, mean that the standard cannot be used for computing an absolute measure of cost performance; but neither are cost targets alone an absolute standard for performance even in the fortunate case that profit targets are in exactly the same ratio as cost targets.

This definition of contract size introduces target profits into the estimate, but it still leaves two different estimates of the relative sizes of the two procurements, one obtained at each sharing rate. In the example shown in Table 2, the combined target S_{15} for aircraft is less than three times the combined target S_{15} for the missile procurement; but at a 30-percent sharing rate, the combined target for the aircraft procurement is more than three times that for the missiles. This result occurs because the table illustrates a realistic case in which the two contractors do not react the same way during the negotiations to changes in the sharing proportion. Both contractors have higher target profits at 30- than at 15-percent sharing, but the cost target is lower for missiles and higher for aircraft at the higher sharing proportion. Divergences like these are certain to occur when multiple sets of negotiations are undertaken, and the method of analysis must be prepared for them.

The obvious solution is to let the average of the two S_r's be used to compute the relative amounts of work expected for the two procurements. This average is called the norm for the procurement. In general, the norm is the best measure of the probable work required in a procurement, because it is obtained by averaging all the distinct measures S_r that are known for that procurement. In Table 2, the ratio of the norms is 2.9976:1; and since 2.9976 times the allowable cost of the missiles is 3.5 percent less than the allowable cost of the aircraft, the inference

is that the missile contractor was 3.5 percent more effective in controlling cost than the aircraft contractor.

As in Table 1, this same result can be obtained more simply by comparing the allowable cost for each contract directly to the norm for that contract, calling the ratio of allowable cost to the norm the cost score. The difference between the cost scores is 3.5 percent, which is the same as the figure obtained by the first method. Note, incidentally, that the cost scores computed in Table 2 are better than those in Table 1, where the target profits averaged more than 8.5 percent of the cost targets; but the cost scores for both the missile contractor and the aircraft contractor are reduced by approximately the same amount, and the difference between the two scores, which measures the cost reduction induced by using the higher instead of the lower sharing rate, is unchanged.

Interpreting the Results

The second of the two examples just presented illustrates the problem of combining more than one set of cost and profit targets to define a norm against which a contractor's cost performance can be measured. Further consideration of this problem is deferred to the last part of this subsection. The suspension is necessary because one cannot discuss the proper way of defining the norm without knowing exactly how it will be used; and this means knowing how the score obtained by comparing allowable cost to the norm will be interpreted. Now consider this problem of interpretation.

Suppose that some contractor has a large overrun, say on the order of 20 percent. This will give him a very poor cost score. Does it also mean that he was grossly inefficient, and did a poor job of controlling costs? It may, but the large overrun will probably be attributed, even by impartial judges, to some unavoidable circumstance not foreseen when the contract was signed. It will probably be argued that no contractor could have done the job for the target cost actually chosen, although a more perceptive contractor might have foreseen the obstacles and chosen a higher target. In short, a large overrun is usually attributed to an unrealistic cost estimate, not to the poor performance of the contractor. This is just another way of saying that allowable cost

is, to some extent, a random variable that the contractor controls only partially, and that he cannot estimate with certainty when the contract is signed. Good management reduces the expected value of allowable cost, but adverse random effects give some efficient contractors a very poor score, and sheer good luck gives some inefficient ones a good score. Although these random events exist, they are outweighed, on the average, by the good scores that go to most efficient contractors and the poor scores for most inefficient ones. This argument proves, then, that a cost score is not a very good measure for the performance of a single contractor.

But cost scores are not designed to judge the performance of an individual contractor. Their object is to show what average effects on allowable cost are due to differences in the sharing proportion on different groups of contracts. The question is not whether one missile contractor with a 30-percent sharing rate had a better cost record than one aircraft manufacturer with a 15-percent sharing rate. The question is whether costs are controlled more effectively on the average in all contracts performed with 30-percent sharing than they are in those with 15-percent sharing. To find out, the cost scores for a number of procurements are grouped according to the sharing rates under which the contracts were actually performed, and the average score for each group is calculated. The average score of many contractors still contains random elements, but if the number of procurements is large, the random fluctuations on individual contracts tend to cancel out.

Averaging a Number of Contracts

To show how this method of averaging works, nine hypothetical procurements, each negotiated for sharing rates of 10, 15, and 25 percent, are described in Table 3. The actual outcomes, and the targets corresponding to the sharing rates actually used, were taken from the historical record.† The targets corresponding to the other two sharing rates for each contract were, of course, invented. The quantity S_r is computed as

$$\frac{P_r + r \cdot C_r}{r + .085}$$

†The data were supplied by R. E. Johnson of The RAND Corporation, and apply to contracts negotiated during fiscal 1962 and 1963.

Table 3

HYPOTHETICAL CONTRACT NEGOTIATIONS, OUTCOMES, AND EFFICIENCY SCORES

Contract Number	r	P^*_{10}	C^*_{10}	S^*_{10}	P^*_{15}	C^*_{15}	S^*_{15}	P^*_{25}	C^*_{25}	S^*_{25}	Norm	Allowable Cost	Cost Score	Avg Cost Score
1	.10	590	5900	6378	600	6000	6383	620	6200	6478	6413	5960	92.9	95.2
2		1936	22780	22778	1936	22950	22887	1950	23040	23015	22894	22450	98.1	
3		2650	29440	30238	2700	29440	30281	2710	29890	30396	30305	28690	94.7	
4	.15	1835	17100	19162	1898	17100	18991	1900	17420	18672	18942	16340	86.3	93.8
5		507	6100	6038	513	6110	6083	593	6050	6285	6135	5670	92.4	
6		160	1800	1838	164	1820	1860	165	1830	1858	1852	1900	102.6	
7	.25	119	1120	1249	123	1160	1264	123	1230	1285	1266	1080	85.3	92.0
8		1425	18160	17519	1430	18200	17702	1436	18510	18100	17774	17330	97.5	
9		280	3125	3203	284	3150	3219	286	3180	3227	3216	3000	93.3	

The column headed "r" shows the sharing proportion at which the contract was actually negotiated and performed. The columns P^*_r and C^*_r (r = 10, 15, 25) give profit and cost targets.

$$S^*_r = \frac{P^*_r + r \cdot C^*_r}{r + .085} .$$

The norm is

$$N = 1/3(S^*_{10} + S^*_{15} + S^*_{25}).$$

The cost score equals

$$\frac{\text{allowable cost}}{\text{norm}} \times 100 .$$

The allowable cost outcomes, together with the targets corresponding to the sharing rate actually used, are taken from the historical record of actual contracts (all money amounts expressed in thousands of dollars). Other data are invented or are calculated as shown.

for each contract, and for each of the three sharing rates, r = 10, 15, and 25 percent. The norm for each procurement is the simple average of the three S_r's. The cost score is the allowable cost, expressed as a percentage of the norm. The average of the cost scores for the three contracts performed at each sharing rate is a measure of expected performance at that sharing rate.

The data chosen for this example show better cost scores at higher sharing rates. This illustration is not, of course, empirical evidence of better performance at higher sharing rates in the past, because two-thirds of the targets used in making up the norms were invented precisely to show this pattern. In order to apply the method in practice, it is necessary to actually negotiate several sets of target costs on a single procurement contract.

The averaging method proposed here is called cross-section analysis, because it studies the behavior of different contractors in a whole range of different--but hopefully similar--situations. It should be noted that this type of analysis measures an average response, throughout the aerospace industry, to differences in sharing arrangements. If the responses of the different contractors are precisely similar, then the industry average describes what can be expected of each of them individually. Almost certainly, however, there are variations in the way different contractors respond to similar changes in the sharing arrangements; and the analysis proposed here makes no attempt to measure these variations.[†] Indeed, it either ignores them or treats them as disturbances that mask an otherwise clear relationship.

One place where variations in contractor behavior appear is in the choice of a combination of cost and profit targets, and in the way that choice varies with changes in the sharing proportion. Because of these

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[†]The mathematical Appendix explains how it is possible to use the same data, provided it is gathered in sufficient quantities, for this measurement also. It shows, however, that many years may be required before enough experience is gained with each individual contractor to try to measure his performance separately.

variations when comparing two procurements, the ratios of cost and profit targets at different sharing proportions are not all the same, as in the first of our simple examples. That is why the second simple example introduced an arbitrary evaluation formula to remove the differences among these ratios. In the alternative approach discussed in the subsection immediately following, these variations will appear as random disturbances clustered about an average relationship between the sharing proportion and the targets.

The second place where variations in contractor behavior appear is in the response of their cost performances to changes in the sharing arrangements. The analysis proposed here will estimate a single, industry-wide average response, and again treat firm-to-firm variations as random disturbances clustered about this average relationship. These variations, together with allowable cost which is not perfectly controllable, account for differences between the cost scores of contractors working under the same sharing arrangements, but on different procurements. Such differences were illustrated in our last example, where they too were removed by an averaging procedure.

The fact that cross-section analysis obscures differences among individual contractors is unfortunate, but it does not make this type of analysis useless. At present, there exists no useful empirical information relating cost performance to the sharing proportion. When trying to select the preferred sharing proportion, certainly an industry-wide average description of contractor behavior is a better basis for choice than no information at all. The extent to which the industry average is useful depends upon the magnitude of the variations it conceals. If the individual firms differ widely in their contracting behavior and cost performance, then the cross-section average is little better than pure guesswork in dealing with a single contractor on a single procurement. On the other hand, if different firms exhibit closely similar responses, then the industry average may be extremely valuable as a guide. One cannot be certain in advance that the similarities are great enough to justify the analysis proposed here. After the results are available, however, the size of the unexplained variations, judged in relation to the industry average, will reveal the

extent to which this average is a useful guide. Meanwhile, since businesses everywhere must respond to the same types of market and nonmarket forces, and since cross-section analysis has been used successfully to study many other industries, it may be expected that our proposal will also generate useful information.

USE OF THE PROPOSAL: AN ALTERNATIVE APPROACH

The examples in the preceding subsection illustrate the type of result that can be achieved by implementing the proposal embodied in this Memorandum. This subsection explains a more general analytical approach to the data that the proposal will generate. This approach is stated intuitively, and a mathematical treatment is contained in the Appendix.

The basic principle, as stated earlier, is to estimate a relationship showing the impact of the sharing proportion on the cost and profit targets. This relationship is then used as a tool for measuring the impact of the sharing proportion on cost performance. This second relationship, of course, is the objective of the entire analysis.

Information about the impact of the sharing proportion on cost and profit targets is obtained whenever two (or more) sets of contractual arrangements, each involving a sharing rate and associated cost and profit targets, are negotiated for a single procurement. Suppose, for example, that cost targets for each of several procurements are negotiated at sharing proportions of both 20 and 30 percent. For each procurement, the target at 30-percent sharing can then be expressed as a percentage of the target at 20-percent sharing, as shown in Table 4. An average of these percentages indicates that a 10-percent increase in the sharing proportion induces, on average, a 3.1-percent increase in cost targets. Table 5 shows a similar calculation for procurements with targets negotiated at 5- and 25-percent sharing. Here, the addition of 20 percent to the sharing rate caused a 5-percent average increase in cost targets, giving the somewhat different result of a 2.5-percent increase in targets for each 10-point increase in the sharing proportion. Information from all other procurements for which two or more sets of targets are negotiated is treated in the same way.

The results of all these calculations may then be averaged, to provide a single best estimate of the impact of the sharing proportion on cost targets. For the data in Tables 4 and 5, this overall average is a 2.8-percent increase in the cost target for each 10-point increase in the sharing proportion.

Table 4

PROCUREMENTS WITH TARGETS NEGOTIATED AT 20- AND 30-PERCENT SHARING

Contract	Cost Targets		Target at 30% as Percentage of Target at 20%	Average Change
	20% Sharing	30% Sharing		
A	3.74	3.92	104.8	3.1%
B	7.96	8.04	101.0	
C	29.40	30.40	103.4	

Table 5

PROCUREMENTS WITH TARGETS NEGOTIATED AT 5- AND 25-PERCENT SHARING

Contract	Cost Targets		Target at 25% as Percentage of Target at 5%	Average Change
	5% Sharing	25% Sharing		
D	1.80	2.00	111.1	5.0%
E	9.60	53.10	107.1	
F	30.50	29.50	96.7	

This result can be represented by a line on a graph. In the graph shown in Fig. 1, the cost targets for a procurement are expressed as an index relative to some base level for that procurement. Here it is assumed that for each procurement the cost target at a 20-percent sharing rate is the one designated as 100 percent. This arbitrary assumption does not affect the following analysis, but merely defines one point on the line representing the relationship between sharing proportions and targets. The slope of the line represents the 2.8-percent increase in the cost targets that is caused, on the average of all

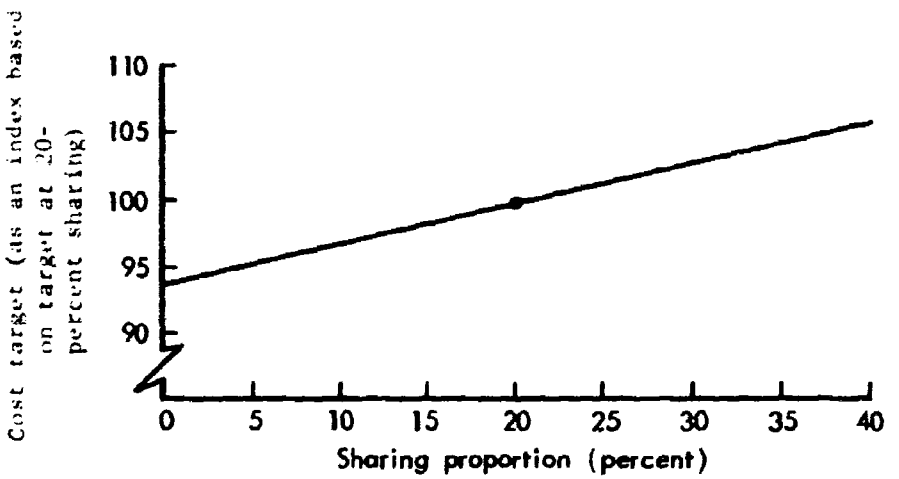

Fig. 1—Relationship between cost targets and the sharing proportion

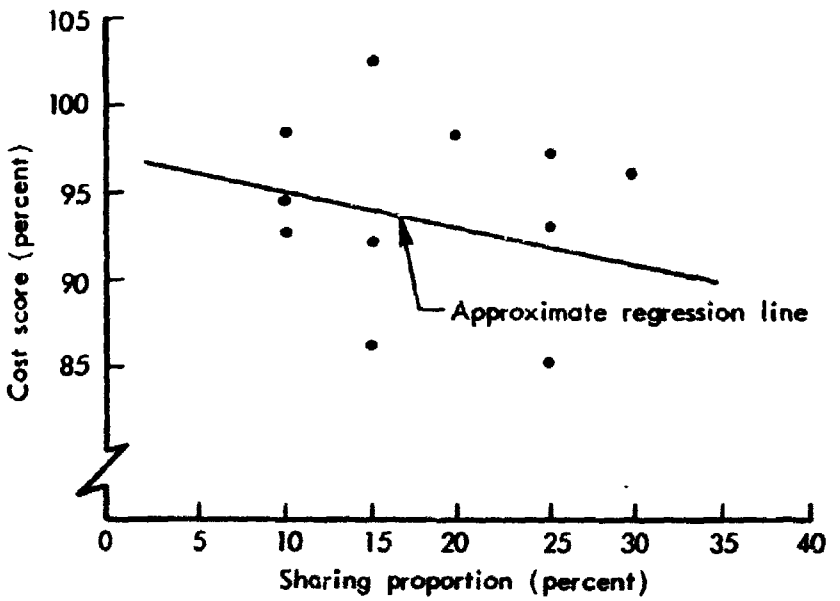

Fig. 2—Relationship between cost scores and the sharing proportion

(the eleven points shown represent the outcome of the hypothetical contracts in Table 3 together with the two examples in the text)

contracting situations studied in the above example, by a 10-point increase in the sharing proportion.†

Once the relationship between the sharing proportion and the targets is established, it can be used to help determine the impact of the sharing proportion on allowable cost. Cost targets themselves cannot be used as norms for evaluating allowable cost because they are biased estimates of cost negotiated at different sharing rates. Use of the relationship just derived to remove this bias yields cost targets corrected to a standard sharing proportion, say, 20 percent. For example, a target of $1.43 million negotiated at 30-percent sharing is equivalent to a target of $1.39 million at 20-percent sharing, because the 10 point difference in the sharing rate is equivalent to 2.8 percent of the target. Similarly, a target of $9.48 million at 15-percent sharing is equivalent to $9.61 million at 20-percent sharing. If the allowable costs on these two contracts are $1.34 and $9.46 million, the correct cost scores are $\frac{1.34}{1.39}$, or 96.4 percent, and $\frac{9.46}{9.61}$, or 98.4 percent. This example indicates a saving of 2 percent of allowable cost when the sharing proportion is 30 instead of 15 percent.

Note that the results would be considerably different if the actual cost targets of $1.43 and $9.48 million had been used instead of the adjusted targets. In that case, the cost scores would have been 93.7 and 99.8 percent, and a much larger saving in allowable cost would have been suggested by the data.

When the adjusted targets are used to compute cost scores for a large number of contracts (some performed at each of several different sharing proportions), the direct computation of cost savings, as done above, is impossible. The outcome of each contract can instead be represented as one point on a diagram relating the cost score to the

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†More precisely, in the graph shown here, the induced increase is 2.8 percent of the target at 20-percent sharing for each 10-point increase in the sharing proportion.

When data are actually available, the possibility of a nonlinear relationship will of course be explored. Also, instead of estimating the relationship between the sharing proportion and the cost targets alone, some combination of cost and profit targets will be used, as suggested in the second of our simple examples.

sharing proportion (see Fig. 2). The statistical technique of regression analysis is then used to draw a line that approximates the distribution of the points representing the outcomes of all the contracts studied, thereby estimating the average relationship between the sharing proportion at which a contract is performed and the cost score that is achieved. The slope of the regression line shows the percentage of allowable cost saved, again on the average of all procurements studied, for each percentage point increase in the sharing proportion. Empirical measurement of this quantity, as proposed here, is shown in Sec. IV to be necessary for determining preferred sharing arrangements.

III. A PROPOSAL FOR EXTENDING THE SCOPE OF CONTRACT NEGOTIATIONS

The main reason for proposing changes in the contracting process is the one discussed in Sec. II: to provide data for empirically estimating the impact of different sharing proportions on the cost performance of contractors. That discussion reveals a deficiency in the information available for making such an estimate--nothing is known about the way differences in the sharing proportion affect cost and profit targets. It is proposed here that this deficiency be removed by extending the scope of contract negotiations. The specific form of the proposal is: on future incentive contracts, several pairs of cost and profit targets be negotiated, one pair corresponding to each of several different sharing rates.

This section examines the proposal. The first part explains in detail exactly what changes are proposed. The second part examines three further requirements, all easily satisfied, that must be met if the data generated under the proposal are to be useful for measuring the effect of incentive sharing arrangements on allowable cost. The third part considers the prospects of implementing the proposed policies.

MECHANICS OF THE PROPOSAL

For each procurement, it is required that the Government and the contractor reach a formal agreement on the cost and profit targets for each of two or more sharing proportions. After this agreement has been reached, the Government designates which sharing proportion, with its associated targets, is to govern contract performance. This designation, of course, is made shortly after the original agreement on a set of targets is reached, and before the contractor begins work under the terms of the contract. For further discussion of the proposal to be fruitful, it is first necessary to state exactly what it entails. For a sole source procurement, it is suggested that the following steps be included in the contracting process.

1. The Government describes the work it wants done, and selects several sharing proportions for which target pairs are to be negotiated.

2. The contractor submits bids of a cost and a profit target for each of these sharing rates, along with design specifications (if the latter are required).

3. The contractor and the Government negotiate about the design and the several pairs of cost and profit targets. The purpose of this negotiation will generally, but not always, be to reduce the targets proposed by the contractor. The contracting officer may bargain about all targets together or attack each one separately. When he and the contractor agree upon a set of targets, one pair for each proposed sharing proportion, this phase ends.

4. The contractor is free to change the structure of the targets, subject to rules ensuring that the overall attractiveness of the entire set of targets will not be increased. In particular, he should be allowed to increase the profit target associated with one sharing proportion, provided he decreases the profit target associated with another sharing rate by an equal amount. He should also be allowed to adjust the profit and cost targets corresponding to a single one of the sharing proportions, provided this adjustment does not alter the way the profit fee is eventually calculated. In other words, since the formula for determining the actual profit fee paid at sharing proportion r depends upon the targets only in the expression $(P_r^* + rC_r^*)$, the contractor should be free to adjust P_r^* and C_r^* in whatever way he pleases, provided that the expression $(P_r^* + rC_r^*)$ is unchanged.†

5. When the contractor has finished adjusting the structure of the set of targets, he informs the Government of his changes, which the Government must accept. The Government then chooses the sharing rule, together with its associated cost and profit targets, under which the contract will be performed.

For contracts let after a design competition, the contracting process under the proposal must involve at least the one additional step of selecting a contractor. One way of incorporating this choice

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†This allows him to exchange, at any sharing rate r, one dollar of target profit for $(1/r)$ dollars of target cost.

is to have each of the competing firms complete steps 2, 3, and 4. These steps would be taken separately, but concurrently, by the different firms. The Government would then announce both its choice of a contractor and of a sharing rule (and associated targets) at the same time. (The targets would, of course, be those agreed upon by the Government and the chosen contractor for the design that the contractor proposed.)

An alternative way of incorporating the contractor choice in the contracting process takes into account the fact that negotiating several pairs of targets with a number of competing contractors is a time-consuming and expensive process. The Government might wish to select the contractor after proceeding only part of the way through step 3 with all the competitors. It could make this selection after a general agreement with each competing firm on that firm's design specifications and on the approximate levels of cost and profit targets associated with that design for one or more of the selected sharing proportions. After choosing the contractor, the Government would complete the negotiations for step 3 and continue with steps 4 and 5 as in a sole source procurement.

If a procurement is to be let on an incentive basis, but with some competitive bidding, each of the competing firms should be required to offer target bids for each of the sharing formulas. These bids would correspond to steps 3 and 4 of the process for a sole source negotiation. If these bids are firm commitments by the competing bidders, the Government can immediately choose a contractor and select the sharing rate under which he is to operate.† If the bids are not firm commitments, steps 3, 4, and 5 must be carried out with the chosen contractor. (It is important that the Government not choose the sharing rate for performing the contract until after the contractor makes a firm commitment about the entire set of targets.)

The contracting process proposed here differs from present practice in only three ways. First, the Government must choose, at the

†The procedure would normally be to select a sharing rate and then choose the contractor offering the lowest bid at that sharing rate.

beginning, the exact nature of the sharing arrangements to be considered, leaving only the levels of the cost and profit targets for determination by negotiation. Especially with very large contracts, there is now a tendency for the contractor to negotiate about or even suggest the numerical values of the incentive sharing arrangements.† Second, the contractor and the Government must reach agreement on pairs of targets associated with each of several sharing proportions, whereas they presently need agree only on one proportion and its associated targets. Third, before the final sharing proportion is selected, the contractor should be allowed to make offsetting adjustments in the negotiated fee and cost targets for each proposed sharing rate, substituting one for the other in proportion to the sharing rate value. These adjustments have no counterpart in present practice.

The reasons for proposing these changes are discussed in the following subsection. The feasibility of implementing the changes is considered in the final subsection. The danger that the proposed changed will fail to achieve the intended results, because of adverse reactions by contractors, is also discussed in that subsection.

ENSURING THE USEFULNESS OF DATA COLLECTED IN ACCORDANCE WITH THIS PROPOSAL

The reason for changing the contracting process is to provide data for the empirical analysis described in Sec. II. For this analysis to succeed, the data generated by the proposed changes must satisfy three conditions. First, the pairs of targets negotiated at each sharing proportion selected for a procurement must represent the outcome that would have occurred, had that sharing proportion been the only one considered for that procurement. Second, the sharing proportions selected for a procurement, and for each of which a pair of targets is negotiated, must cover as wide a range as possible. Third, aspects of the incentive arrangements other than the sharing proportion itself must be kept uniform for all of the procurements studied in the analysis. These three conditions are discussed in turn.

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†See Preston, op. cit.

The necessity of satisfying the first condition follows directly from the reason for negotiating several pairs of targets. This reason is to measure the effect of different sharing proportions on the establishment of targets; and targets do not serve this purpose if they do not reflect what would have occurred in negotiations at a given sharing proportion, had that proportion been the one to govern contract performance.

To satisfy the first condition, it is necessary to prevent the contracting officer from imposing on the negotiations his or the Government's preconceived notions about a correct relationship among targets negotiated at different sharing proportions. The reason is that such notions are irrelevant in a situation where only one sharing proportion is selected and only one pair of targets is negotiated; such notions must, therefore, be prevented from influencing the negotiations when several pairs of targets are chosen.

In particular, it is undesirable for the Government to expect cost targets at different sharing rates to be equal, on the theory that a cost target is a cost estimate, and, therefore, unaffected by the sharing rate. Rather it must be recognized that the cost target is a parameter in the formula for determining the profit fee on the basis of the allowable cost outcome, and may change as the other parameters of the contract, notably the sharing rate, change.†

It may be possible to achieve the necessary freedom for the contractor to determine the relationship between sharing proportions and targets by instructing the contracting officer to remain neutral in his attempt to bargain for lower targets. It seems more realistic, however, to formalize this neutrality; and, therefore, step 4 is included in the proposal. Its presence means that step 3 is, in effect, a bargain about the overall size of the entire target package, but that the contractor may insert individual pieces of whatever shape he prefers.

For this arrangement to be satisfactory, it is obviously essential the contractor not know, at step 4, what sharing rate the Government

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†The reasons that the targets are dependent on the sharing proportion are discussed on pp. 10-11.

will eventually choose to govern actual contract performance. If the contractor does have some advance information about how the Government makes its choice in step 5, he can raise the targets at sharing proportions likely to be chosen, even though this forces him to make the targets at other sharing proportions less attractive. As an extreme example of this danger, if in advance of step 4 the contractor definitely knows the sharing rate that will actually govern contract performance, he can transfer all target amounts to that sharing rate, and let all of the other targets be zero. This behavior is bad for two reasons: it can be very expensive for the Government; and it fails to reveal the contractor's attitude toward the relationship among targets associated with different sharing proportions.

To ensure that the contractor not have any advance information about the choice of a sharing proportion to govern performance of his contract, it is essential that the procedure used in step 5 be carefully constructed. If the Government uses a single rule for making this selection, it may be possible for the contractors eventually to deduce it from observation of past choices (assuming the rule has not yet been disclosed in some unauthorized manner). It is, therefore, imperative that the Government <u>not</u> apply a single set of criteria uniformly to all contracts to select a sharing proportion governing actual performance. In particular, the Government must occasionally make what seems like a bad choice--a low sharing proportion having a high target associated with it, or a high sharing rate with a target that appears absurdly high (compared to the targets negotiated at other sharing rates for the same procurement). Only by being capricious, at least part of the time, can the Government induce the contractor to negotiate on the basis of his own preferences and not as a strategist trying to outguess his opponent.†

These considerations suggest that the ideal way for the Government to select the one sharing rate that governs actual performance is by random drawing. Random choice has two advantages. First, it eliminates

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†Students of game theory will recognize this argument as an illustration of the principle that one player must use a mixed strategy, involving randomization, in order to force his opponent to adopt the minimax strategy.

the game-theoretic aspects of step 4 in the negotiation process. There is no incentive for the contractor to try to guess the Government's criteria and then associate targets to sharing rates in such a way that the combination he prefers is also preferred by the Government. If the Government uses a random choice process, the contractor knows his manipulation of the pattern of targets cannot possibly have a favorable influence on the Government's choice.

Second, random selection eliminates the danger of systematic bias in matching sharing rates and procurements. This bias might take the form of tending to choose a low sharing rate for a procurement believed to be especially risky or to have especially slack targets. If present, biases such as these will be confounded with the effects of the sharing rate itself on performance, and will thus negate the usefulness of the proposed changes. Although their removal can also be achieved by carefully designed systematic selection methods, random choice is the safest possible method.

In summary, analysis of the first condition suggests that it can best be satisfied if steps 3 and 4 are adopted as stated, and if the Government uses a random device to make the selection in step 5. Systematic methods can also be used in step 5, but only if the criteria they use are carefully designed to prevent bias, and if these criteria can be kept secret from the contractors.

The second condition essential to the success of the proposal is that the sharing proportions selected for negotiation with any procurement cover as wide a range as possible. This condition is necessary so that the contractors perceive definite differences among the sets of contract provisions negotiated, and also so that the Government may observe how large differences in the sharing proportion affect bidding. Negotiations on at least some contracts must consider sharing rates covering the entire range that the Government considers potentially useful in any contract. At the beginning, this range might be from zero percent (no incentives) to a 50-percent sharing rate, although it would not be necessary or even desirable to negotiate targets for both extremes on all or even most procurements. A typical set of negotiations might consider sharing rates of 15, 30, and 50 percent, or 5, 15, and 40 percent.

In choosing a wide range of sharing proportions, it is necessary that all types of work be considered for all sharing rates, in order that suitable experience be generated. Thus, it is important to insist that high sharing proportions be negotiated on at least some developmental contracts, because this is the only way to find out how contractors react to strong incentives on development contracts. Similarly, nominal sharing rates, or even fixed fees, should be tried on some production contracts.†

The third requisite for successful implementation of the proposal is that the total number of different sharing formulas considered for all procurements in the analysis be kept small. This condition provides the proper statistical basis for evaluating the data; and without it the analysis might be impossible. The reason is that a sufficient number of procurements must be negotiated and performed under each of the sharing formulas studied. Only then can it be assumed that the random factors affecting the negotiation and performance of individual contracts tend to cancel out in an averaging procedure.

The problem of restricting the number of sharing formulas arises because the sharing rate itself is not the only parameter defining what may be called the "shape" of the sharing formula. A sharing formula is typically represented as a broken line, or curve, on a graph relating actual profit to allowable cost. If this curve were a straight line, it could be described completely by a combination of the sharing proportion (which would be its slope) and the target cost and target profit (which would be the coordinates of one point on the line). If all sharing formulas were straight lines, the relationship between sharing rate and targets could be studied without the intrusion of other elements.

In actual contracts, however, the formula relating earned profit to allowable cost is not represented by a single straight line. Instead,

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†The suggestion that fixed fees be used on production contracts is not meant to imply that these contracts should be written on a cost, as opposed to price, basis. The Air Force would still contract for delivery of the product, not the performance of specific services, but it would make the profit fee independent of actual cost as negotiated at the termination of the contract.

the curve has kinks or corners in several places. For large cost underruns or overruns, proportional sharing is superseded by a profit ceiling, a price ceiling, or possibly a profit floor. Furthermore, many contracts are now written with different sharing proportions applying to different ranges of cost outcomes.† All of these provisions introduce changes of slope into the curve describing the sharing formula, and their total effect is to define the shape of this curve.

The existence of these additional provisions does not itself invalidate the type of analysis proposed in Sec. II. Variation of these provisions from procurement to procurement does, however, cause a problem. The variations must be treated as changes in the sharing arrangements, and play a role similar to changes in the sharing proportion itself. These changes may affect the relationship between the sharing proportion and the targets, and may also affect the contractors' performance, thus influencing the allowable cost outcomes.

To understand why this is a problem, consider for example the case of a price ceiling. If it is always set at 120 percent of target cost, its presence can be disregarded. It affects all procurements equally, in the sense that whatever slack the contractor requires in the cost target to reduce the risk of butting against the ceiling (and taking an unacceptable loss) is the same from procurement to procurement. Therefore, when comparing allowable cost outcomes to these cost targets, the differences from procurement to procurement do reflect the influence of the sharing proportion, because the slack in the targets is the same for all procurements. However, if on some procurements the price ceiling is 120 percent of the cost target, on others 130 percent, then the contractors with the higher ceiling may accept lower cost targets. In this situation, differences from procurement to procurement in the allowable cost outcome, measured as a percentage of the cost targets, reflect the influence of both the sharing proportion on the cost outcome and the price ceiling on the target. Unless these two

†For some examples, see Preston, op. cit., Chaps. III and IV.

effects can be separated, the analysis is not a valid measure of the impact of the differences in the sharing proportion alone.

There are two ways of coping with this problem. The first is to include explicitly an analysis of price ceilings, profit ceilings, and other variations in the shape of the sharing formula. The difficulty of this approach is that there may not be enough procurements negotiated to provide a statistically adequate sample performed at each possible combination of sharing arrangements. The greater the number of different sharing formulas studied in the entire analysis, the fewer the number of contracts negotiated and performed under each one and, therefore, the less reliable the results of the analysis.

The alternative solution, which is strongly preferred, is to require that all aspects of the sharing arrangements other than one sharing proportion and the two targets be identical in all contracts. A standard sharing formula should be defined now, and applied to all procurements studied in the analysis.†

Until there is further theoretical investigation of the ideal shapes for sharing formulas, it is probably best to keep this standard formula as simple as possible. The focus of attention is the sharing rate, which is allowed to vary from contract to contract because it is the parameter of major significance for constructing cost incentives. A single price ceiling and a single profit ceiling, each defined as a percentage of target cost, may be incorporated into the standard formula; but it is unwise to attempt to study the effects of varying the height of these ceilings from procurement to procurement. The empirical method proposed in this study is yet untried. There can be greater hope for its success if its initial applications are confined to some of the less complicated aspects of the contracting and negotiating process.

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† If in a few procurements it is impossible to agree upon a sharing proportion and targets in accordance with this standard formula, these procurements may be dropped from the analysis and performed under whatever arrangements are acceptable to both parties.

CAN THE PROPOSED POLICY BE SUCCESSFULLY IMPLEMENTED?

This subsection discusses the feasibility of implementing the proposed changes in contracting policy. The cost of extending the scope of the negotiations is considered first. Adverse reactions by contractors, including changes in their responsiveness to differences in the sharing proportion, may endanger the success of the proposal; this possibility is discussed next. Finally, it is necessary to consider the problems caused by the common practice of negotiating adjusted cost targets long after work under the contract has begun.

The cost of negotiating several pairs of cost and profit targets, one pair corresponding to each of several sharing proportions, should be no greater than the present cost of negotiating a single sharing formula. There are two reasons for expecting this to be so. First, the actual negotiations in step 3, requiring agreement between the Government and the contractor, involve in effect only the overall size of the target package; and this is exactly what present negotiations involve. The more difficult job of determining the differences among targets corresponding to different sharing proportions is left to the contractor alone--step 4 does not require the assent of the Government.

Second, there is no need to reach agreement about the nature of the sharing arrangements, because they are fixed beforehand. In step 1, the Government makes a unilateral choice of the sharing proportions to be considered; and all the other provisions--the price and profit ceilings--are determined by the standard sharing formula applied to all contracts.

Precedents for exploring the relationship between the sharing proportion and the targets can be observed in several contract negotiations conducted in the past. These precedents support the belief that it will not be difficult to reach agreement on pairs of targets associated with different sharing proportions.

In the tenth procurement action for the B-52, the Air Force imposed a low cost target, but adopted a correspondingly low sharing proportion that did not penalize the contractor excessively for moderate overruns. Beyond this range of apparently acceptable overruns, the sharing rate

was higher. The outcome of the negotiations suggests that stronger cost incentives would have been possible throughout the range of cost outcomes with a higher--and, therefore, presumably more realistic--target.[†]

The implication that changes in the sharing proportion affect the acceptability of targets, and that these effects enter the negotiating process, is explicit in B-52 procurement number 14. Boeing accepted Air Force demands for a reduced cost target only on condition that there be no penalty for overruns up to 103 percent of target, and a low (10 percent) sharing proportion beyond that point. On the other hand, Boeing's share of possible underruns was set at the high level of 25 percent.[††] The proposal offered in this study suggests nothing more complicated than a formal agreement between Boeing and the Air Force as to how much higher the target would be for Boeing to accept the 75/25 sharing of overruns. In this particular contract negotiation, it appears that such an agreement would have been easy to reach. (This is not to say that the Air Force would have preferred such a contract to the one actually signed.)

These precedents also suggest that contractors will not have strong adverse reactions to the negotiation of target pairs associated with several different sharing proportions. However, even if adverse reactions occur, they are not likely to endanger the success of the proposal. Contractors may, for example, publicly insist that the cost target is actually a cost estimate made independently of the sharing proportion; and they may back up this assertion by not varying the target proposed for a procurement, even when the Government suggests a different sharing rate. Alternatively, they may adopt a rule of thumb for determining the relationship between sharing proportions and targets. Such a relationship might be the one suggested by Secretary Charles: each increase of 10 percent in the sharing proportion be accompanied by an increase in target profit equal to one percent of target cost.[†††]

[†] Ibid., pp. 50-56.

[††] Ibid, pp. 63-64.

[†††] Address by the Honorable R. H. Charles, Assistant Secretary of the Air Force (Installations and Logistics), before AFLC/Industry Management Conference, Dayton, Ohio, 25 June 1964, p. 17.

The fact that contractors adopt such a negotiating pattern does not, however, invalidate the analysis proposed in this Memorandum. It is not even certain that this pattern implies a change in contractor behavior; the observed relationship between targets and sharing proportion may actually represent the field from which the Government has in the past chosen one point for each procurement. Of course, individual contractors have behaved differently in the past, and the common pattern can at best reflect an average of their past behavior. But, this it may do very well. Certainly there is no reason for contractors to adopt as a common bargaining pattern one far removed from what any of them would choose for himself.

Furthermore, even if implementation of the proposal leads to final contracts that differ from those that would have been obtained under current negotiating conditions, the policy changes will still generate information useful for selecting preferred sharing proportions. It must be remembered that the Government is not interested in the relationship between targets and the sharing proportion for its own sake. This relationship is used only to provide a basis for comparing the sizes of contracts negotiated at different sharing rates. The comparisons then make it possible to evaluate the performance of different contractors in controlling allowable cost. Both types of comparison can be made on contracts let after the new policy goes into effect. In fact, adoption by the contractors of a uniform rule of thumb for relating targets to sharing rates merely simplifies the first comparison, because it eliminates the need for studying the averaging procedures discussed in Sec. II.

It is the effect of different sharing proportions on the control of allowable costs, not on contract negotiation, that is of major interest to the Government. What the preceding discussion shows is that information about this effect can be obtained by analyzing contracts let under the proposed policy, even if the proposed changes lead to adverse changes in the negotiating behavior of the contractors.

The only remaining problem is the practice of negotiating adjusted cost targets. Targets are adjusted when the Government wants to modify the specifications and scope of the work under contract. These modifications

naturally involve a change in the amount of work required to perform the contract. The problem is that the change in the amount of work also invalidates the norm calculated when the contract was negotiated. It is therefore necessary to derive a set of adjusted norms that reflect the total amount of work required under different contracts, including changes and modifications.

An obvious and simple way to construct an adjusted norm for a contract is to modify the original norm in proportion to the adjustment of the targets. This method is first described in detail, then its justification is discussed.

The first step in adjusting the norm for a contract is to define the quantity S_r' as

$$S_r' = \frac{(P^*)' + r(C^*)'}{r + .085} , \tag{3}$$

where $(P^*)'$ and $(C^*)'$ are the adjusted profit and cost targets. This definition is exactly analogous to the earlier definition of the standard size, given in the expression on p. 18. The adjusted standard size S_r' is defined, of course, only at the one sharing rate under which the contract is being performed.† It is not a suitable norm for the purposes at hand, because it suffers from the same defect as the single pair of targets negotiated under current contracting procedures--no allowance is made for the sharing proportion itself, which may systematically influence the target size.

The adjusted targets, however, can be combined with the original targets to define an adjusted norm N', as

†It is possible to negotiate several pairs of adjusted cost and profit targets, one pair corresponding to each of several sharing proportions; but these negotiations are meaningless unless the sharing proportion is also chosen anew. The adjustment then becomes a repetition of the entire process for initiating a procurement contract. This complication of contract adjustments is unnecessary and it is therefore not recommended.

$$N' = \frac{S'_r}{S_r} N \quad . \tag{4}$$

In this equation, r is the sharing proportion under which the contract is being performed; S'_r is the adjusted standard size; and S_r is the standard size computed from the single pair of profit and cost targets, P^*_r and C^*_r, corresponding to the sharing proportion r in the original negotiations. Equation (4) defines the adjusted norm. Its ratio to the original norm, $(N' : N)$, is the same as the ratio $(S'_r : S_r)$ of the adjusted standard score to the original score, provided both are derived from targets corresponding to the same sharing proportion.

The question is whether the adjusted norms are as suitable for comparing the amounts of work required under modified contracts as the original norms were for the original contracts. The adjusted norms clearly would be suitable for this purpose, if the adjustment to the norm for each contract were an unbiased estimate of the additional work needed to meet that contract's changed specifications. But the adjustment is unbiased only if the adjusted targets bear the same relation to the work required for meeting the modified specifications that the original targets bore to the original specifications. And this is not a valid assumption to make about the adjusted targets.

The reason for this is that the forces of competition that tend to constrain the original targets are eliminated once the initial contract has been negotiated. Consequently, it seems likely that contractors will attempt to overstate the costs of changes and modifications in order to increase the likelihood of larger underruns and greater profits. The result of this is that the adjusted norms, when considered as estimates of the size of a contract, are presumably unduly inflated. Despite this bias, however, the adjusted norms defined by Eq. (4) are suitable for comparing the sizes of different contracts.

The main point here is that the original norms were never intended to provide unbiased estimates of the work required under individual

contracts. All that is required is that the norms determine the relative sizes of different contracts; this goal is achieved so long as the influence on the adjusted targets is the same from contract to contract. And even this condition is unnecessarily strict; it is only necessary that the average bias in the cost of contract changes and modifications be the same among groups of randomly chosen contracts performed at different sharing rates. In this case the upward bias in the adjusted targets becomes a constant factor that disappears when cost scores of different groups are compared.

There remains only one reservation about the use of Eq. (4): This is that the sharing proportion itself might affect the size of adjusted targets. It is recognized that this may occur, and an attempt is made to remove this effect by making an adjustment that compares the adjusted targets (as used in adjusted standard score S_r') to the original targets negotiated at the same sharing proportion (as used in S_r). This arrangement is clearly better than using the adjusted standard scores themselves as norms, but it may not be good enough. It may fail, however, because the willingness of the contractor to exercise his monopoly power depends upon the sharing proportion. This may be the case because each dollar by which the cost target is inflated is worth r cents of additional profit to the contractor, where r is the sharing proportion. The higher the sharing proportion, the more the contractor gains by exercising his monopoly power to inflate the targets; and the Government's resistance (or disfavor) may not increase as much, because the contracting officer may be motivated to keep the target down to a level that looks reasonable relative to cost (independent of the sharing proportion), rather than down to a level that keeps profit at some reasonable level.

If the sharing proportion does have an independent effect on the size of the adjustment ratio (S_r': S_r), then this effect invalidates the use of norms defined by Eq. (4) for comparison of cost scores between groups of contracts performed at different sharing proportions. The reason for this is that there is no way to separate the effect of the sharing proportion on the adjusted norms (via the adjusted

targets) from the effect of the sharing proportion on the realized level of allowable cost. In short, the validity of Eq. (4) depends upon acceptance of the hypothesis that the adjustment ratio (S_r': S_t)--which does depend upon a variety of the other factors--is independent of the sharing proportion.

This hypothesis can be tested by a cross-section analysis of all contracts let in accordance with the proposal of this Memorandum. Take the average adjustment ratio over all of the contracts studied, and denote it by the letter "K". Now consider the average of the adjustment ratios taken over all contracts with a particular sharing rate, say r = 20 percent. Our hypothesis implies that this group mean, which may be denoted "K_{20}", tends toward the overall average K. This follows because the sharing proportions are assigned at random, at least with respect to factors that may influence the adjustment ratio for any particular contract. Therefore, the fluctuations in these factors tend to cancel out on a number of contracts, and the mean adjustment ratio in each group of contracts (one group for each sharing proportion used in the analysis) tends to be the same as the mean in every other group.

A statistical technique called analysis of variance can be used to test whether the mean adjustment ratios K_r (K_{10}, K_{20}, K_{40}, etc., for r = 10, 20, 40 percent, etc.) in the different groups differ significantly from one another. If they do not, then the hypothesis need not be rejected, and Eq. (4) may be used as originally suggested. If, however, the differences are statistically significant, they provide evidence that the sharing proportion does influence the size of the target adjustment, because the sharing proportion is the only factor that varies systematically from group to group when the contracts are grouped by sharing rate.

In this case, the basis for Eq. (4) is shown to be incorrect, and a modified method must be used to adjust the norms for the contracts studied. Fortunately, the very differences among the group means for the adjustment ratio can themselves be used to estimate the net effect of the sharing proportion alone on these adjustment ratios. At a given sharing proportion r, the fraction K_r/K indicates how much higher (or

lower) the adjustment ratio tends to be at that sharing proportion than for the average of all contracts. The effect of the sharing proportion on the ratio ($S'_r:S_r$) of targets can therefore be removed by dividing this adjustment ratio by K_r/K. The result is that the adjusted norm can be properly defined by

$$N' = \frac{K}{K_r} \cdot \frac{S'_r}{S_r} \cdot N \ . \tag{5}$$

The meaning of this equation can perhaps be clarified by an example. Consider the information given for contract number 3 in Table 3. Suppose the targets are later adjusted to be $(P^*)' = 2907$, $(C^*)' = 32530$. These targets are negotiated only for the sharing proportion r = 10 percent, at which the contract is being performed, and they yield an adjusted standard score $S'_{10} = 33297$. This is a 10.1-percent increase over the original S_{10} (= 30238), and suggests that the adjusted norm be 10.1 percent higher than the original one of 30305. Indeed, if Eq. (4) were applied, this would be the result:

$$N' = \frac{33297}{30238} \cdot 30305 = \frac{110.1}{100} \cdot 30305 = 33366 \ .$$

However, suppose it is also found that the mean adjustment ratio (K_{10}) for contracts negotiated at 10-percent sharing is 108.8 percent (an 8.8 percent increase), whereas the average adjustment ratio (K) over all contracts studied is only 105.6 percent. This information indicates that the sharing proportion (r = 10 percent) alone makes the adjustment ratio for the particular contract under study larger by a factor of 108.8/105.6, or 1.030, than it would be had adjustments been negotiated for all possible sharing proportions. It is therefore necessary to divide the adjustment ratio of 110.1 percent by the factor 1.030 to obtain the corrected adjustment ratio. The complete result is then:

$$N' = \frac{105.6}{108.8} \cdot \frac{33297}{30238} \cdot 30305 = \frac{1}{1.030} \cdot \frac{110.1}{100} \cdot 30305 = 32394 ,$$

as given by Eq. (5).

Once an adjusted norm is calculated for each contract--using Eq. (4) or (5), whichever is appropriate for the complete set of contracts studied--the analysis can proceed along the lines set forth in Sec. II. The final allowable costs are compared to norms to obtain cost scores, and these are averaged within groups corresponding to sharing proportions to find the effect of the sharing proportion on cost performance.

IV. PREFERRED SHARING ARRANGEMENTS

Section II described a method for estimating the effect of the sharing proportion on the levels of allowable cost that contractors achieve. Section III proposed a method for collecting the necessary data. The reason for this proposal is that the information obtained can lead to the determination of a preferred sharing proportion for use in Government contracts. For illustration, it is assumed in this Memorandum that the preferred sharing proportion is the one at which the total procurement price the Government pays is a minimum. The first part of this section shows how the preferred sharing proportion, so defined, is determined. The second part then recapitulates, with respect to this determination, some of the limitations of the analysis proposed here.

The reason for preferring the particular sharing proportion defined as best in this Memorandum is obvious. On the other hand, there may be equally good reasons for preferring other sharing proportions. A few other bases for selecting optimal sharing proportions are considered in the third part of this section. When considering them, it is important to note that the research proposed in this Memorandum not only leads to a determination of the sharing proportion at which the total procurement price is a minimum, but also provides information about the effects on total procurement price of a whole range of different sharing proportions. For this reason, the research proposed here is an essential element in any program for selecting preferred incentive sharing proportions.

Finally, selection of preferred sharing proportions is not the only aspect of procurement policy. The fourth and final part of this section shows how the research proposed in this Memorandum fits into the general framework for studying the weapons acquisition process and establishing procurement policies.

DETERMINING THE PREFERRED SHARING PROPORTION

Consider first the problem of determining the preferred sharing proportion for the Government to choose. The rationale for incentive

sharing arrangements is that they induce the contractor to achieve a lower level of allowable cost than he would without incentives, or than he would if the incentives were weaker. This is what is meant by the effect of incentives on cost performance. A precise definition of this effect is that there is a functional relationship between the sharing proportion for any contract and the cost performance that the contractor can be expected to achieve. It is virtually certain that the higher the sharing proportion, the lower the allowable cost will be but nothing more is known about this functional relationship. Indeed, the preceding two sections have been almost exclusively concerned with an empirical method for measuring it.

If it is true that higher sharing proportions lead to lower levels of allowable cost, then why not insist on incentives that are as strong as possible, in order to minimize costs? One answer is that stronger incentives also lead to higher profits for the contractor, and these profits are included in the total price the Government pays. These profits must therefore be considered when deciding how strong to make incentives. A theoretical analysis of the relationship between the sharing proportion and the contractor's profit is not relevant at this point. All that is necessary is the empirical observation that on contracts that are comparable in other respects, profits are higher when the sharing proportion is higher.†

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†The evidence is clear when CPFF, FPI, and FFP contracts are compared, and there are some indications that profits are directly related to the sharing proportion on FPI contracts. However, a sample of 128 recent contracts, based on information collected by R. E. Johnson of The RAND Corporation, does not reveal this relationship. Part of the difficulty may be that past contracts at different sharing proportions have been systematically noncomparable. In particular, riskier contracts probably have had lower sharing proportions, and the greater inherent risk may have offset the effect of the sharing proportion on profit.

In any case, if the purported empirical observation is not correct, then all contracts should indeed be negotiated with sharing proportions as high as possible--in other words, unity (as FFP contracts). That contractors balk at high sharing rates (and FFP contracts) indicates they are unwilling to perform such contracts at any reasonable profit, and supports the contention that stronger incentives do indeed require higher profits for the contractor.

Stronger incentives can lead to higher profits in three different ways. First, the contractor retains a higher proportion of whatever underrun he achieves (incentive contractors, on the average, have in the past achieved substantial underruns). Second, the underrun tends to be increased because the contractor succeeds in reducing allowable cost. Third, the underrun can be made larger if the target is inflated. Various combinations of these three effects are also possible.†

Fortunately, it is not necessary to know which of these three factors influence contractor profits in order to choose a preferred sharing proportion. Analysis of this choice is quite simple. A $1,000 reduction in allowable cost is desirable for the Government if, and only if, the increase in contractor profit that accompanies it is less than $1,000. This follows because the total cost to the Government is the sum of two components: allowable cost, commonly called "cost" here, as achieved by the contractor; and contractor profit.

To find out whether stronger incentives are desirable, two basic relationships are needed: one between the sharing proportion and the expected cost performance of the contractor; and one between the sharing proportion and the contractor's expected profit. If the cost reduction accompanying a small increase in the sharing proportion exceeds the increment to profit, then that increase is desirable; otherwise it is not desirable. The preferred sharing proportion is the one at which the marginal effect of a change in the sharing proportion on allowable cost is the same as the marginal effect on profit.††

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† Notable among them is one in which decreases in the cost target equal the achieved reductions in allowable cost, with the result that the underrun remains the same. Higher profit then occurs in the first way only--as a larger share of this same underrun. This possibility reveals why the underrun itself is a poor measure of a contractor's cost performance.

†† Neither the second-order condition for a minimum of total cost to the Government nor the problem of obtaining a global, as opposed to local, minimum is discussed here. Since the two relationships will be known over the whole range of possible sharing rates, and since these relationships will be simple (because they will be derived as empirical estimates), neither issue is important at this time. See the Appendix for further discussion of these points.

One of the two relationships needed for determining the preferred sharing proportion--the relationship between the sharing proportion and cost performance--has been the subject of much of this study. The other can be estimated from any historical sample of contracts. It is most appropriately determined for the same contracts used to estimate the effect of incentives on levels of allowable cost. In any case, the data needed to estimate the relationship between the sharing proportion and contractor profit are readily available under any contracting arrangements that might conceivably be adopted, so the problem of measuring this relationship requires no further consideration at this stage, which is concerned primarily with gathering the necessary data.†

LIMITATIONS OF THE ANALYSIS PROPOSED HERE

The method for determining preferred incentive sharing proportions, as proposed here, has a number of limitations; and these must be kept in mind when evaluating and--if that is decided upon--implementing the proposal.

The basic limitation is that the proposed method is one of cross-section analysis. It is first explained that this type of analysis yields results not exactly suited to any particular procurement situation, but only to a mythical "average" procurement. This limitation raises the possibility that intuitive judgments about preferred sharing arrangements may be better for each individual contract than the one set of arrangements preferred for the mythical average. This possibility is then discussed with reference to risk.

Cross-section analysis is limited because all contractors and procurement situations are considered identical, except for those characteristics of each contract that are explicitly recognized as variables, and are subjected to detailed study. In the analyses proposed here, only the sharing arrangements, the levels of allowable cost, the profits

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†A simple regression of profit (expressed as a percentage of the cost target) against the sharing proportion may be sufficient. Further comments about this analysis, and about a suitable shape for the regression, may be found in the Appendix.

achieved, and the contract size--as reflected by cost and profit targets--are studied explicitly. In any single procurement action, many factors excluded from the analysis also affect the behavior of these variables. Among the other relevant factors are: the level of risk inherent in estimating the difficulty of, and then performing, each particular contract; the attitude of each contractor toward variations in the sharing proportion; the responsiveness of each contractor's cost performance toward these variations; and the state of the contractor's business, which may affect the preceding two items. Because these other factors vary from procurement to procurement, the observed relationships among the targets, the sharing proportion, the allowable cost, and the profits achieved, also differ from procurement to procurement. Cross-section analysis yields only the average relationships, taken over the entire set of contracts used to generate the data. Deviations from this average, which occur from procurement to procurement and reflect the varying conditions not included in the analysis, are treated as unexplained random disturbances.

This means that the relationships derived from the study proposed here apply exactly to only a hypothetical "average" procurement; they are but approximations to the conditions found in any real procurement. Since the preferred sharing proportion is derived from the average relationships, it too may be preferred only for the hypothetical "average" procurement. In any single real procurement action, the individual contractor's response to changes in the sharing arrangements may differ from the average of the responses found in all contracts studied. These differences mean that the same sharing proportion may induce different levels of targets and allowable costs in different contracts. The sharing proportion at which the total price is a minimum may, therefore, be different in different procurements.

Since the cross-section analysis proposed here yields only a single preferred sharing proportion that is suitable for the average of the behavior found in all contracts studied, it is clearly not the best result that can be hoped for. One measure of its success or failure is the importance of the variables included in the analysis relative to the importance of the omitted factors. If the sharing proportion and

the contract size go a long way toward explaining the variations in targets and in allowable cost, and if the unexplained variations (attributed to random disturbances) are small, the model used in the analysis is a good one. Inferences about the effect of the sharing proportion on price, and then about the preferred sharing proportion, apply quite well to all contracts, because the circumstances peculiar to each individual contract have comparatively little effect on the variable of interest. On the other hand, if the unexplained disturbances are large, the sharing proportion preferred for the "average" procurement contract may be far from best for most of the actual contracts that are let.

The extent to which the cross-section model presented here is successful cannot be known until the data required to implement it have been gathered, as this Memorandum proposes. However, when deciding whether to adopt this proposal, it may be worthwhile to consider alternative ways of selecting sharing arrangements for particular procurement contracts. Two obvious alternatives may conceivably offer better results than the comparatively simple analysis proposed here.

The first is to refine the model, by including explicitly some of the other factors left out of the present analysis, and known to influence contract behavior. For example, if explicit allowance is made for such factors as the degree of risk[†] and the identity of the contractor, the amount of unexplained variations in the key variables might be reduced. The refined model could then be used to derive different preferred sharing proportions for each contract and each type of procurement action; and these differences would reflect the appropriate conditions peculiar to each contracting situation. There are three reasons why extensive refinements are not suggested in detail here. First, the need for them will become apparent only as data are accumulated and attempts made to fit the model to these data. Second, attempts to estimate the effects of other factors make additional demands on the data. Specifically, the more variables included in the analysis, the more observations needed to estimate their effects.

[†]It could perhaps be measured by the type of contract--development or production.

Since the number of contracts that can be let in the manner proposed here is limited, it may be impossible to gather enough information to make empirical estimates for complex models. Finally, to the extent that available data do justify refinements, they can be introduced into the model by the analyst at the time the empirical procedures suggested here are carried out.

The second alternative is to rely on intuition to select the sharing proportion for each procurement contract. Intuition may be preferable to formal analysis if a multitude of factors affect each contracting situation. The contracting officer, using a priori theoretical understanding of the way these factors presumably affect contractor behavior, and combining this reasoning with a "feel" for the responsiveness of the particular contract he is negotiating, may be in an excellent position to select a good sharing proportion. And if the situation he faces is so complex that the sort of analysis proposed here cannot be very successful, his judgment may fit that particular situation better than the average results obtained through formal analysis. The problem with intuitive methods is that we can never be sure how successful they are, unless we undertake empirical tests of the sort proposed here.

The Problem of Risk

One factor for which the limitations of cross-section analysis may be most important is that of uncertainty. It is widely believed that it is more difficult to estimate in advance the costs on some contracts (say development contracts) than on other contracts (say production contracts). Put differently, this means that random events, such as unforeseen problems (or easy solutions to seemingly difficult problems) have a greater effect on costs for some types of work than for others. Under incentive sharing arrangements, these unforeseen cost variations involve variations in the contractor's profit because he bears a share of the overruns or obtains part of the savings. This unforeseeable variability of profit due to the variability of the risks

is involved in Government contracts. Its magnitude is determined by two factors: the unforeseeable cost variations and the sharing proportion.

The typical response of Government contractors, as of all businessmen, is to accept a greater risk (larger variability of profit) only if the expected average profit (the "best guess") is also larger.

These considerations suggest two ways in which the degree of uncertainty about cost estimates may affect behavior in procurement situations. To understand these two effects and their implications, it is convenient to assume that the procurements are partitioned into a high-uncertainty group, and a low-uncertainty group. The first effect of difference is found by comparing contracts in the two groups that are performed at one sharing proportion. Since, at the same sharing proportion, risks are greater in the high-uncertainty group, it may be expected that the average rate of profit is also greater in that group. Some difference in average profit should appear at each sharing proportion, from the lowest to the highest. The second effect of differing degrees of cost uncertainty concerns the size of the spread between average profitability of contracts in the two groups. One expects this spread to be larger, the higher the sharing proportion. The reason for expecting this pattern is that the risk premium is only one component of the profit. At low sharing proportions, the risks are low in both groups, so differences in the level of risk will lead to comparatively small differences in profit. At higher sharing proportions, the risk premium accounts for a much larger component of profit, and differences in risk can, therefore, cause a greater spread between the profits in the two groups.

These effects exemplify the limitations of cross-section analysis. This suggests that the relationship between the sharing proportion and profit is different for different groups of contracts. This difference suggests that the preferred sharing proportion may be different for the two groups. Cross-section analysis, however, estimates only a single relationship between the sharing proportion and profit--the average of the relationship holding in the two groups. And from it is derived only

a single preference sharing proportion, one that is probably not suited exactly to either group. What can be done about this situation? The answers follow the general line of argument set forth above.

One possibility is to refine the analysis by treating these two groups separately. In practice, this particular refinement may be a substantial contribution to the success of the analysis, but in principle it does very little to eliminate the sources of potential noncomparability among procurements. There remain many shades of uncertainty finer than the two broad categories of "development" versus "production," and there are many factors other than uncertainty that account for differences among contracts. Obviously not all such factors can be included in even a highly refined model. The question is, how much refinement is needed?

One answer is to see what improvement could be achieved by suitably refining the model. Consider the relationship between the sharing proportion and the level of profit, and suppose it is contemplated to divide the procurements studied into two uncertainty groups. The points in Figs. 3 to 5 describe three hypothetical sets of data, showing the profit achieved in each of a number of (hypothetical) contracts. The points are plotted against the sharing proportion at which the contract is performed. The line RR' in Fig. 3 shows the average relationship between the level of profit achieved and the sharing proportion. The success of this relationship in explaining the observed data points may be gauged by comparing RR' to the horizontal line HH', which is derived by assuming that the sharing proportion has no affect on profit. It is obvious that by some measure,† the average distance of the points from line RR' is less than their average distance from HH'. The ratio of these average distances (using mean square measure) is called the correlation coefficient, and it indicates how successful the relationship RR' is in explaining the observed data. If this correlation coefficient is low, it may be raised by adding new explanatory factors to the analysis of profit, and using a new dimension to represent

†Ordinarily one uses a mean square measure, and considers the residual variance.

each. However, the magnitude of the unexplained variation--the average distance of the observed points from RR'--sets an upper limit on further improvement that can be achieved by refining the model. The relationship QQ' of Fig. 5, for example, clearly has less to gain from being refined than RR'.

Fig. 4 illustrates the case where dividing the contracts into two groups is a valuable refinement. Average relationship AA' fits the observed data poorly (about as well as RR'), whereas the use of the two relationships BB' and CC' together accounts for almost all of the profit variability observed in the data. If a factor as important as risk, as illustrated in the hypothetical data of Fig. 4, is omitted from the cross-section analysis, then there is a danger that the one preferred sharing proportion, as it might be determined using AA', may not be suited to any actual procurement.

One can only hope, when proposing a cross-section analysis, that no initially important factor is omitted; but at least the analysis itself yields a measure of its own success.

The alternative is to use intuition. In the example under discussion, this means classifying procurements into uncertainty groups and using lower sharing proportions for the more uncertain procurements. This is presumably the current basis for contracting policy, and it may indeed be a good one. But without a formal analysis of the kind proposed here, there is little hope of improving this policy.

HOW IMPORTANT IS PRICE MINIMIZATION IN SELECTING PREFERRED SHARING PROPORTIONS?

The first part of this section showed how the analysis proposed here leads to the selection of a sharing proportion at which the total price of a hypothetical "average" procurement is minimized. The second part discussed the limitations of dealing with cross-sectional averages. But one may also question the notion that price minimization--even if it can be achieved--is appropriate.

This subsection does little more than set forth a number of other considerations that may be relevant to chosing a desirable sharing proportion. It makes no attempt to determine the extent to which they

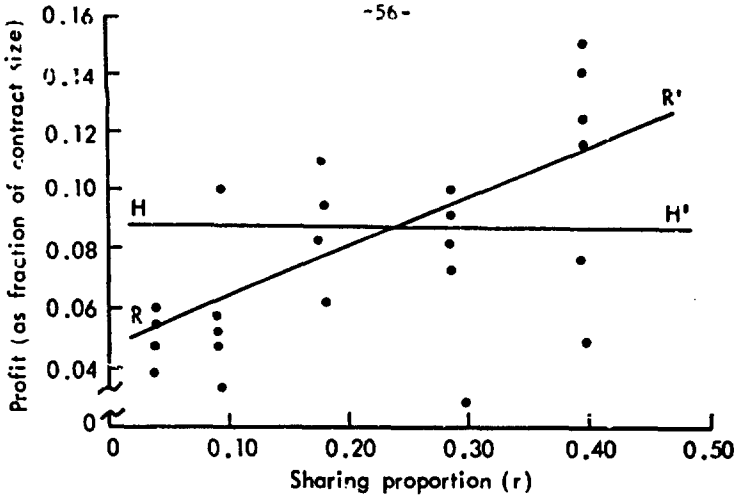

Fig.3

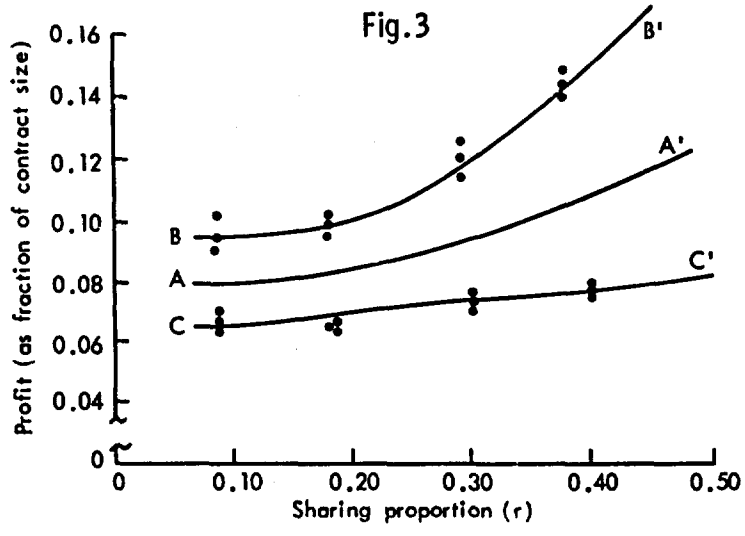

Fig.4

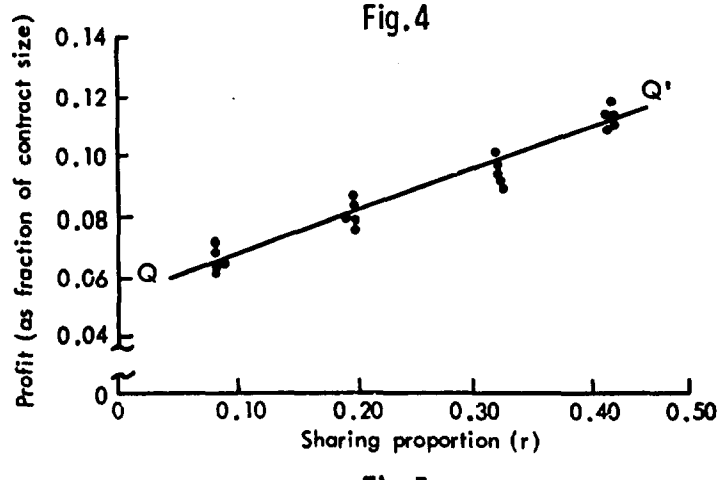

Fig.5

are, or are not, proper concerns of procurement policy. Some considerations, if they are deemed important, lead to simple modifications of the criterion for selecting a preferred sharing proportion; and the modified criterion can then be used in conjunction with the data base that is the essence of the proposal made here. Others relate the selection of the sharing proportions to things we have virtually no empirical information on. In these cases, further empirical work must precede any but an intuitive judgment of their effect on the choice of a sharing proportion.

One consideration that could lead to a simple change in selecting the preferred sharing proportion is the question of whether the Government is indifferent between paying out a dollar of allowable cost and a dollar of profit. If the net effect on the Government budget, rather than the price paid by the Department of Defense, is the desired minimum, then profits should be given less weight than allowable cost, because they are taxed at a higher rate than incomes in general. Minimizing

$$(1 - t_I)C(r) + (1 - t_p)P(r) \quad , \tag{4.1}$$

where t_I and t_p are the tax rates on incomes (of average composition) and corporate profits, will yield a higher sharing proportion (r) than minimizing

$$C(r) + P(r) \quad , \tag{4.2}$$

as suggested at the beginning of this section. It is left for others to decide which of these two objectives, or what combination of them, is in fact proper for Government policy. It should be noted, however, that data gathered by the method proposed here are necessary and appropriate for implementing the decision, whatever it may be.

A second consideration affecting the choice of the sharing proportions is that it may be possible for a company that has more than one Government contract to shift the costs among them. Such shifts are desirable for the company whenever they can be made from a contract with a high sharing proportion to one with a low sharing proportion.

Nothing is known about the possible extent of such practices, but if they are important, that would be a reason for having the sharing arrangements on all contracts (including CPFF and FFP contracts) more similar than they might otherwise be.

A third reason for questioning the desirability of minimizing prices is the possible effect this policy might have on product quality.[†] The contractor has an interest in doing high quality work, but higher quality also means higher costs. In a CPFF situation, the contractor's reputation is best served by providing those aspects of quality that he believes the Government will find worth their cost; and by omitting improvements that increase cost by more than their value to the Government. In this situation, the Government is delegating its decisions to balance quality against cost, and there is no reason to assume that the authority is being exercised by a contractor whose interests conflict with those of the Government.[††] But this concurrence of objectives is achieved only in CPFF contracts where the Government pays the full cost of whatever improvements it gets. When cost incentives are introduced, the contractor must bear part of the cost of whatever improvements he makes in the quality of the product. Then he includes only those aspects of quality that are worth more to him--that is, in terms of good customer relations--than they actually cost him. Since the out-of-pocket cost to the contractor for this quality he provides is directly proportional to the sharing rate,[†††] the higher

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[†]Quality can be varied to the extent that the product is not completely specified in the original contract. Even if the Government must approve all engineering designs in detail, the contractor has considerable discretion about what he submits.

[††]Actually, the contractor may be more interested in quality than cost. This is especially true of developmental work, in which the prospects for follow-on procurement (a production contract) depend upon quality and in which the development costs, once incurred, do not affect the production costs relevant to follow-on procurement decisions. This argument may help explain the persistent tendency toward large overruns on CPFF contracts.

[†††]This argument is correct even if the original cost target includes an estimate for the cost of the aspects of quality in question. Once the target is set, the contractor's profit is 20 cents lower (at 20-percent sharing) for each dollar of cost incurred; and this is as much the case in the range of substantial underruns as it is if other overruns have whittled the profit to near zero.

the sharing proportion, the lower the quality is likely to be. (These considerations are perhaps one of the major reasons for combining cost incentives with performance incentives.) If strong incentives do have an adverse effect on quality, then the sharing proportion should be set lower than it otherwise would be.† Without fully investigating the magnitude of this adverse effect, nothing more specific can be recommended. Again, to reach a correct result it is necessary to balance the adverse effects of cost incentives on quality against their favorable effects on cost; and the empirical estimates proposed here are therefore still essential.

A fourth reason for questioning the policy of seeking price minimization on each procurement action is that this approach focuses undue attention on short-run gains. For a contract in the development stage or the beginning of the production stage, it may be more important to induce behavior that will lead to the lowest costs during the bulk of the production run. Lower production costs can be achieved by designing the end product so that it is cheaper to make (for given performance features), or by improving the production process itself. These achievements may be treated exactly as changes in quality, and the preceding analysis suggests that the sharing proportion be kept low to increase the prospect of obtaining them. On early production contracts, however, a further consideration suggests the opposite result. Even if price minimization is a suitable goal, the Government is not indifferent in the short run between paying a dollar of allowable cost and paying a dollar of profit. Cost savings at the beginning of a series of production contracts will be repeated in later contracts; whereas the additional profit needed to induce them is a one-time expense. Therefore, the Government should be willing to pay somewhat more than one dollar of allowable cost saved, provided that follow-on production is expected. Increasing the weight attached to cost, relative to the weight given profit, leads to the selection of a higher sharing proportion.

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†This argument holds only if the adverse effect is strong enough to cause the omission of aspects of quality the Government is willing to pay for. Incentives may be necessary precisely to impair quality--i.e., to dissuade the contractor from introducing improvements that the Government feels are not worth their cost.

(The result is the same as in the case where profits are weighted less owing to a higher tax rate.) A decision involving this consideration requires: first, further investigation to determine the correct weight assigned to cost savings relative to higher profits; and second, the empirical information that this Memorandum proposes.†

The four considerations discussed above are not an exhaustive list of the relevant factors for selecting a preferred sharing proportion. They do, however, indicate that a variety of things must be considered when making this selection. And in each case, it is also clear that the effect of incentives on cost cannot be disregarded. Whatever objectives are desired, the price of achieving them through cost incentives must be considered when deciding how strongly they be sought.

THE PLACE OF COST INCENTIVES IN THE FRAMEWORK OF PROCUREMENT POLICY

The obvious message of the preceding part is that preferred cost incentives cannot be selected solely for their impact on allowable cost performance; there are other facets of contractor behavior where the effects of cost incentives also appear to be relevant. A better interpretation of this state of affairs is that cost incentives are only one of the instruments needed to guide contractor behavior; and that other instruments must be devised to help shape the actions of contractors.

One class of instruments that is frequently discussed, and sometimes used, comprises performance incentives. Such incentives make the amount of profit paid to a contractor depend upon certain characteristics of the product. An example is an arrangement to increase profit by $2,000 for each mile per hour by which the maximum speed of an aircraft exceeds some target level. The use of performance incentives

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†A suggestion for studying the effect of incentives now (in the current contract) on costs later (in follow-on production), concerns learning curves. Particular attention might be devoted to points on a single learning curve where the sharing proportion changes.

to encourage work of high quality can be combined with the use of cost incentives to encourage control of allowable costs, and helps free the sharing proportion for this latter role, to which it is best suited.

Incentive arrangements of all kinds help control the performance of specific contractors in specific procurement situations. Their purpose is thus to achieve the best possible results on each contract let. This goal, although important, is not the only aspect of procurement policy. A more basic area in which it may be possible to improve the weapons acquisition process is that of deciding what contracts should be let, and to whom they should be let. Two issues arise here.

The first is how to slice the entire acquisition process for one weapon into a sequence of manageable procurement contracts. The role of cost incentives at each stage may depend upon the way this division is accomplished. For example, the Government might carry design competition for a new product up through the construction of a prototype. If the production contract is always given to the successful designer, the Government would find it essential to impose very strong cost incentives to hold down the costs of the prototype development contracts. Each contractor would be likely to accept these incentives, viewing them as rules of a game from which he can withdraw if his plans become more difficult to fulfill than he expected. The situation would be quite different from the present arrangement, in which the contractor is virtually committed to reaching the design objective, whatever its cost; he is therefore unwilling to accept the responsibility of paying a substantial part of that cost, as strong incentives would require him to do.

The second issue is deciding who should receive the procurement slices. In the absence of competitive bidding on a firm-fixed-price basis, choosing a vendor is a difficult proposition. If the product can be precisely defined, the Government presumably wants the lowest cost supplier. But the targets of an incentive contract are a poor indicator of what the final price is likely to be. Indeed, if the sharing proportion is low enough, one can make a strong case that the

apparently high bidder will yield a low final price, and vice versa.[†] The use of cost incentives on each individual contract cannot, therefore, be undertaken without some consideration of their role in the process of choosing a contractor.

Delving deeper into the problems of weapons acquisition policy, we may note that the questions of how to slice and apportion the procurement cake have answers that depend to some extent upon the structure of the defense industry. Policies that alter this structure will change the context in which the two narrower questions are answered, and thus affect the role that cost incentives play in the answers.

Finally, procurement policy as a whole must be formulated with respect to some general notions about the types of weapons that are being acquired.[††] In particular, the desirable way of organizing the defense industry must be based on this consideration. And it should also be noted that information from the more detailed levels of procurement policy must be fed back into the process for selecting weapons, because this information helps to define the alternatives available.

Carrying the analysis of procurement policy back to its foundations makes cost incentives appear as a marginal and not very significant part of the total structure, meaningful only in relation to the particular members supporting them. Indeed they are. But it should also be remembered that considerable effort and time must be spent before the entire structure can be rebuilt. Meanwhile, changes in some of the smaller parts--the only changes that are feasible in the short run--may contribute to the beauty and usefulness of the entire edifice.

[†] For a complete presentation of the argument, see McCall, op. cit.

[††] Bickner, op. cit.

APPENDIX

This Appendix presents a formal mathematical model corresponding to the analysis given in the main parts of the text of the Memorandum. Where the formulation of this model follows the text closely, no attempt is made to repeat the discussion given there. Those aspects of the model that extend the textual formulation, or specify it in greater detail, are treated more fully here.

The model described in Sec. II is presented first. The possibilities for refining this model are then noted. Finally, the treatment of adjusted targets is presented in more detail and with greater precision than was possible in the brief discussion at the end of Sec. III.

Notation is carried over from the text to the Appendix wherever possible. One exception is that subscripts denoting a sharing proportion are now written explicitly as arguments of a function; thus, P^*_r and C^*_{15} become $P^*(r)$ and $C^*(15)$, etc. This change frees the subscript to be an index designating the successive procurement contracts, numbered ($i = 1, 2, \ldots, n$), subject to study. The actual profit fee received on the i^{th} contract (P_i) is related to the targets (P^*_i, C^*_i), the sharing proportion (r_i, a decimal fraction), and the allowable cost outcome (C_i) by the formula

$$P_i = (P^*_i + r_i C^*_i) - r_i C_i. \tag{1}$$

It is next assumed that the profit and cost targets depend upon the sharing proportion. More precisely, the expression $S_i(r)$, the standard observable measure of a contract size, determined from a single pair of cost and profit targets, is taken as an unknown function of: the sharing proportion; the size of the contract--represented by the yet unknown N_i; and possibly other factors denoted by the single variable $\underline{u}$ (which may be considered a vector). This gives

$$\frac{P^*_i(r) + rC^*_i(r)}{r + .085} \equiv S_i(r) = f(N_i, r, u_i). \tag{2}$$

Data that will be obtained under the proposal in the text are sufficient for estimating both the function $f(\cdot)$ and the set of norms N_i $(i = 1, 2, \ldots, n)$. This is possible because two or more target pairs are negotiated (at different sharing proportions) for each procurement. One easy way to estimate $f(\cdot)$ and the norms simultaneously is to specify $f(\cdot)$ as $N_i g(r,u_i)$, and then fit

$$(3) \qquad \log S_i(r) = \log f(N_i,r,u_i) = \log N_i + \log g(r,u_i) \ .$$

If $g(\cdot)$ is specified so that simple regression in the logarithmic form is possible, then the norms are obtained by analysis of covariance. The regression coefficients of $g(\cdot)$ are common to all procurements, but a separate constant (the norm N_i) is fitted for the several sets of targets applying to the i^{th} contract.† More complicated shapes for the function $f(\cdot)$ may be specified, of course, but it is pointless to discuss this function further until some data become available; then empirical analysis will rep a priori theorizing.

Once the set of norms has been obtained, the outcomes of the contracts can be analyzed. It is assumed that the expected profit and allowable cost outcomes, each expressed as a fraction of the norm, are functionally related to the sharing proportion (r_i) at which the contract was performed:

$$(4) \qquad \frac{P_i}{N_i} = h(r_i,u_i) \ ,$$

$$(5) \qquad \frac{C_i}{N_i} = d(r_i,u_i) \ .$$

It is again pointless to speculate about the exact shapes of these functions. However, it must also be noted that the functional forms should not be selected without recognizing the importance of these forms for further analysis.

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†The unnecessary extra degree of freedom is removed by specifying, say, $g(0.20, \bar{u}_i) = 1$, where $\bar{u}_i$ is some average of the values taken on by the $u_i (i = 1, 2, \ldots, n)$.

The functions $h(\cdot)$ and $d(\cdot)$ will be used to determine the sharing proportion at which the expected total price, given by

$$\frac{C_i}{N_i} + \frac{P_i}{N_i} = d(r_i, u_i) + h(r_i, u_i) \quad , \tag{6}$$

is a minimum. If both $d(\cdot)$ and $h(\cdot)$ are linear functions of the sharing proportion, this minimum must occur either at $r = 0$ or at the highest permissible sharing proportion (unless by a freakish accident the coefficients of r are exactly equal in magnitude and opposite in sign, in which case the expected total price is independent of the sharing proportion). This conclusion may indeed be justified by the data--if linear relationships are the best fitting representations of $h(\cdot)$ and $d(\cdot)$--but it is not one that should be blundered into on the generally commendable, but here misapplied, principle that a simple linear relationship is least complicated and therefore best. It is, therefore, strongly suggested that quadratic, logarithmic, or exponential representations of $d(\cdot)$ and/or $h(\cdot)$ be tried at some point in the analysis.†

The model described by Eqs. (1) to (6) corresponds to the presentation in Sec. II of the text. The presence of the term u_i as an argument of the functions $f(\cdot)$, $g(\cdot)$, $h(\cdot)$, and $d(\cdot)$ suggests that refinements are possible. In particular, variables other than the sharing proportion may be included in (4) and (5) as determinants of the expected profit and cost outcomes. Among the other factors that might affect profit or cost expectations are contract size, measured as a fraction of the firm's annual sales volume, and the contractor identity. If data on enough contracts are collected, it may be possible to estimate the effects of these variables. Otherwise, their possible influences must be disregarded.

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†It would also be possible to fit a single relationship

$$\frac{P_i}{N_i} + \frac{C_i}{N_i} \equiv T_i = t(r_i, u_i). \tag{7}$$

This would presumably be nonlinear, and its minimum could be found directly. However, it would not provide the information about effects of the sharing proportion on cost and profit separately.

Finally, consider the method for dealing with adjusted targets. The adjustment process consists essentially of negotiating for each contract ($i = 1, 2, \ldots, n$) a single adjusted standard size S_i', which is applicable at the sharing proportion r_i. Equation (2) or (3) cannot be used to fit both the adjusted norms (N_i') and the shapes of function $f(\cdot)$ or $g(\cdot)$, because the estimation of the constants $N_i (i = 1, 2, \ldots, n)$ uses up all of the degrees of freedom in the data. However, if $f(\cdot)$ or $g(\cdot)$ has been estimated from data obtained by negotiating unadjusted targets, Eq. (2) or (3) can be solved for N_i, giving

$$N_i' = \frac{S_i'}{g(r_i, u_i)} , \tag{8}$$

or some more complicated expression.

Use of (8) to define the adjusted norms disregards differences between the average behavior of all contractors, as described in $g(\cdot)$, and the response of the i^{th} contractor to the sharing proportion. It differs from the criterion

$$\frac{N_i'}{S_i'} = \frac{N_i}{S_i(r_i)} \tag{9}$$

because the right-hand side of Eq. (9) is not exactly equal to $1/g(r_i, u_i)$, owing to the presence of random variation that cannot all be captured in the function $g(\cdot)$. Equation (9) is, therefore, considered a better way to determine adjusted norms.

But it too can be questioned, because it does not take into account the possibility that the sharing proportion, which is already known, may affect the negotiation of adjusted targets. To allow for this possibility we assume that the expected adjustment ratio (S_i'/S_i) is independent of the sharing proportion (r_i). (This is a valid assumption if the sharing proportion (r_i) was originally chosen randomly with respect to all the other interesting characteristics of the procurement.) To verify it, let u take on whatever values (0.10, 0.20, 0.25, etc.) are used as sharing proportions, and define K_u by

$$K_u = \sum_{\{i \mid r_i = u\}} \frac{S_i'}{S_i} . \tag{10}$$

Also define

$$K = \sum_{i=1} \frac{S_i'}{S_i} . \tag{11}$$

Note that K, which is also the (weighted) average of K_u, is the best estimate of the expected adjustment ratio. To test whether the observed adjustments are in fact independent of the sharing proportion, use analysis of variance to see whether the group means (K_u, for u = 0.10, 0.20, etc.) are significantly different from the population mean (K).

If there are significant differences, they are evidence that the sharing proportion itself affects the size of this ratio. In that case, this effect can be removed by dividing the observed adjustment ratio (S_i'/S_i) by the correction factor (K_{r_i}/K) to obtain a normalized adjustment ratio. This modification produces

$$N_i' = N_i \left(\frac{S_i}{S_i(r_i)} \right) \left(\frac{K}{K_{r_i}} \right), \tag{12}$$

which differs from (9) only by the introduction of the normalizing term.†

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†An equivalent, and probably better, result can be obtained by regressing the observed adjustment ratios against the sharing proportion, to obtain a function k(·) defined by

$$\frac{S_i'}{S_i(r_i)} = k(r_i) + \text{error terms.} \tag{13}$$

[This is equivalent to regressing the K_u against u, to obtain a smooth relationship instead of a scattering of group means.] The regression coefficients of k(·) are then tested, presumably by a likelihood ratio test, against the null hypothesis that k(·) is a constant. If k(·) differs significantly from the constant K, then $k(r_i)/K$ is used to correct the observed adjustment ratios in exactly the same way the (K_{r_i}/K) was used in Eq. (12).

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10. ABSTRACT

A proposal that contractor efficiency be studied by explicitly analyzing the effects that cost incentives have on target costs and profit. Also proposed is that data for this analysis be obtained by negotiating several sets of contract provisions for each future procurement action, the sets corresponding to different sharing rates. Actual performance of a contract is naturally to be governed by only one set of provisions, chosen after all the sets have been negotiated. To be meaningful, the analysis based on these data must satisfy three conditions: (1) steps must be taken to ensure that the contract provisions negotiated at each sharing proportion are the outcome that would have occurred had that sharing proportion been the only one negotiated for that procurement; (2) for many procurements, the different sets of contract provisions must encompass a wide range of sharing rates; and (3) aspects of the incentive arrangements other than the sharing proportion itself must be kept uniform for all procurements studied in the analysis.

11. KEY WORDS

Aerospace industry
Air Force
Procurement
Military contracts