APPENDIX A

AN OVERVIEW OF REGULATIONS GOVERNING COST CALCULATIONS

This appendix will provide a very brief description of the regulations governing the way that defense contractors calculate the cost of their products. Readers desiring more detail might refer to two excellent nontechnical overviews by Grenough [1984] and Grenough and Shapiro [1983].

There are basically two bodies of regulations governing the way that defense contractors calculate the cost of their products. These are, first, the *Federal Acquisition Regulations (FAR)* and the *Defense Federal Acquisition Regulations (DFAR)* and, second, the *Cost Accounting Standards (CAS)*. The *FAR* and *DFAR* are designed to be a complete description of all regulations governing the procurement process. The *CAS* specifically addresses the cost allocation methods used by defense firms.

Prior to 1984 the various branches of the federal government each had completely separate sets of regulations governing their procurement processes. In 1984 the *FAR* was published as a general set of regulations governing the procurement process of all government agencies. These are published as Chapter 1 of Title 48 of the *Code of Federal Regulations*. Each government agency also publishes a supplementary set of regulations which are consistent with the *FAR* but describe aspects of procurement of particular interest to that agency in more detail. The DoD supplement is called the *DFAR*. It is published as chapter 2 of Title 48 of the *Code of Federal Regulations*. The general regulations contained in the *FAR* are extremely detailed and a very large fraction of the DoD's procurement process is in fact determined by the *FAR*. It should also be noted that the *FAR* and *DFAR* perform two functions. First, they specify the required behavior of contractors. However, second, and just as important, they specify the required behavior of the DoD.

In 1970, the DoD's procurement practices were still governed by the predecessor to the *FAR* and *DFAR* called the *Armed Services Procurement Regulations*. The *ASPR* contained essentially no regulations governing the way that contractors allocated costs. Congressional hearings were held where a series of examples were presented showing how contractors manipulated their allocation methods to increase government contract costs. For example, contractors would charge a cost direct when incurred for a government contract but charge the same type of cost to overhead when it was incurred for a commercial contract. Congress's response was to create the Cost Accounting Standards Board (CASB) in 1970 whose purpose was to create a set of regulations designed to prevent the types of manipulations described above.

The CASB issued 19 standards on different aspects of the allocation process. They are published in Title 4 of the *Code of Federal Regulations* and are usually referred to as standards 401 through 420 since this is the numbering used for them in the *Code of Federal Regulations*. (There are only 19 standards. Number 419 was left unfilled.) These standards have the force of law through the enacting legislation and are not merely administrative regulations. The standards do not attempt to define a single cost accounting system which must be used by all firms. Instead, they describe fairly general principles designed to prevent fraudulent sorts of manipulations. For example, CAS 402 prevents the manipulation described above by requiring that like costs in like circumstances be allocated the same way. A fairly accurate description of the *CAS* is that its goal is to force contractors to use the same type of allocation methods that they would use if they were purely commercial and their prices were not cost based.

The CASB's recent history has been somewhat tumultuous. In 1981 the board ceased to exist because Congress did not appropriate funds for it. However, the *CAS* continued to exist and have the force of law. In 1990 the CASB was reconstituted and it will presumably now continue to revise existing standards and/or issue new ones.

Note that the *CAS* was originally created to fill a void in the general set of regulations now called the *FAR/DFAR*. However, at the time, the DoD could certainly have issued regulations governing firms' allocation practices if it wished. After creation of the CASB there was therefore a possibility of conflicting regulations. Courts soon resolved this potential conflict by deciding that the *CAS* controlled *allocability* while the *FAR/DFAR* controlled *allowability*. Allocability is defined as procedures determining how costs will be allocated between contracts. Allowability is defined to be rules determining whether costs will be considered as legitimate or not by the DoD for purposes of costing. The practical impact of this is that the DoD can still wield a sort of "veto power." If the DoD does not like the way that the *CAS* allows a particular cost to be allocated then it can simply make the cost unallowable. This type of behavior has been fairly typical. For example, the *CAS* has been interpreted as allowing commercial advertising expenses to be included in G&A and allocated over all contracts. DoD's response was to make these costs largely unallowable. This has the same impact as regulations requiring them to be allocated to commercial contracts.

APPENDIX B

THE PURE WASTE MODEL

The first order conditions for (4.6)-(4.7) are

(B.1) $$\frac{\partial \Gamma}{\partial L_i}(L^*) = 0 \text{ and } L_i^* \geq L_i^F \quad .$$

(B.2) $$\frac{\partial \Gamma}{\partial L_i}(L^*) < 0 \text{ and } L_i^* = L_i^F \quad .$$

From (3.6) rewrite $\partial\Gamma/\partial L_i$ as

(B.3) $$\frac{\partial \Gamma}{\partial L_i}(L^*) = (1+R)\phi_i'(C_i^*) - (1+RA) \quad .$$

In particular, then, the terms

(B.4) $$\left\{\frac{\partial \Gamma}{\partial L_i}(L^*)\right\}$$

and

(B.5) $$\left\{\phi_i'(C_i^*)\right\}$$

are ranked in the same order. Proposition 3 follows immediately from this.

Now consider Proposition 4. Suppose (for contradiction) that

(B.6) $$L_i^* > L_i^F$$

for every i. Then by (B.1),

(B.7) $$\frac{\partial \Gamma}{\partial L_i}(L^*) = 0$$

for every i. Therefore $\phi_i'(C_i^*)$ must be equal for every i. Call this common value x. Substitution into (B.3) yields

(B.8) $$\frac{\partial \Gamma}{\partial L_i}(L^*) = x - 1 \quad .$$

Since (B.8) must equal zero then x=1. This contradicts (4.3).

Now consider Proposition 5. It is obviously sufficient to prove that

(B.9) $$\phi_i'(C_i^*) < 1$$

for every i. Suppose (for contradiction) that

(B.10) $$\phi_k'(C_k^*) = 1$$

for some k. Then (B.1)-(B.3) imply that

(B.11) $$\phi_i'(C_i^*) = 1$$

for every i, contradicting (4.3).

APPENDIX C
THE INPUT SUBSTITUTION MODEL

First two lemmas will be stated which more clearly define what needs to be proven. Since the proofs of the lemmas are straightforward, they will not be given.

Lemma 1 states that if the labor choice is too large (too small) relative to both second best criteria, then the labor choice is also too large (too small) relative to the first best criterion.

<u>Lemma 1</u>

Consider a vector of inputs (L_i, M_i, Z_i) which satisfies

(C.1) $$L_i = f^i(M_i, Z_i) \quad .$$

Suppose that

(C.2) $$L_i \ > \ (= \ ; \ <) \ L_i^s \ (M_i)$$

and

(C.3) $$L_i \ > \ (= \ ; \ <) \ L_i^s \ (Z_i) \quad .$$

Then

(C.4) $$L_i \ > \ (= \ ; \ <) \ L_i^F \quad .$$

The significance of this lemma is that it means that Proposition 6 follows directly from Proposition 7. Therefore it is sufficient to prove

Proposition 7. Note that the only role of assumption (g) in the proof is to guarantee that Lemma 1 is true.

Lemma 2 now establishes conditions which determine whether L^i is too large or too small relative to the second best criteria.

Lemma 2

Consider a vector of inputs satisfying (C.1). Then

$$L_i \gtreqless L_i^s(M_i) \Leftrightarrow f_M^i(M_i, Z_i) \lesseqgtr -1 \quad . \tag{C.5}$$

$$L_i \gtreqless L_i^s(Z_i) \Leftrightarrow f_Z^i(M_i, Z_i) \lesseqgtr -1 \quad . \tag{C.6}$$

Therefore, it is sufficient to prove the following two statements

$$\phi_i'(C_i^*) \gtreqless A^* \Leftrightarrow f_M^i(M_i^*, Z_i^*) \lesseqgtr -1 \quad . \tag{C.7}$$

$$\phi_i'(C_i^*) \gtreqless A^* \Leftrightarrow f_Z^i(M_i^*, Z_i^*) \lesseqgtr -1 \quad . \tag{C.8}$$

Substitute (4.12) into $\Gamma(L,M,Z)$ so that profits are a function of M and Z. Denote this function as G(M,Z). The first-order conditions for the firm's optimization problem are then

$$\frac{\partial G}{\partial M_i}(M^*, Z^*) = 0 \tag{C.9}$$

and

$$\frac{\partial G}{\partial Z_i}(M^*, Z^*) = 0 \quad . \tag{C.10}$$

It will now be shown that (C.9) implies (C.7) and (C.10) implies (C.8).

First consider (C.7) and (C.9). Rewrite (C.9) as[48]

$$\text{(C.11)} \qquad \frac{f_M^i\left[\sum_{k=1}^{n} Z_k^{*} + J\right]}{\sum_{k=1}^{n} f^k}\left\{\phi_i'(C_i^{*}) - A^{*}\right\} + (f_M^i + 1)\left\{\phi_i'(C_i^{*}) - 1\right\} = 0 \quad .$$

By assumption f_M^i is negative and $\left(\phi_i'(C_i^{*}) - 1\right)$ is nonpositive. Therefore, there are two cases to consider. First suppose that

$$\text{(C.12)} \qquad \phi_j'(C_j^{*}) = 1 \quad ,$$

for some j. Then, by (C.11)

$$\text{(C.13)} \qquad A^{*} = 1 \quad .$$

Since the average value of the derivatives is 1 and no derivative can be greater than 1, this implies that all derivatives equal 1. That is,

$$\text{(C.14)} \qquad \phi_i'(C_i^{*}) = 1$$

for every i. This contradicts (4.3). Therefore, the first case cannot occur.

In the second case

$$\text{(C.15)} \qquad \phi_i'(C_i^{*}) < 1$$

for every i. In this case (C.11) immediately implies (C.7).

Now consider (C.8) and (C.10). Rewrite (C.10) as

$$\text{(C.16)} \qquad \left\{ \frac{f_Z^i \left[\sum_{k=1}^{n} Z_k^* + J \right]}{\sum_{k=1}^{n} f^k} - 1 \right\} \left\{ \phi_i'(C_i^*) - A^* \right\} + (f_Z^i + 1) \left\{ \phi_i'(C_i^*) - 1 \right\} = 0 \; .$$

Since f_Z^i is negative, the entire term

$$\text{(C.17)} \qquad \frac{f_Z^i \left[\sum_{k=1}^{n} Z_k^* + J \right]}{\sum_{k=1}^{n} f^k} - 1$$

is negative. The proof that (C.17) implies (C.8) now parallels the proof that (C.11) implies (C.7).

QED

APPENDIX D
THE SUBCONTRACTING MODEL

First note that because the cost function (4.31) is single peaked, the question of whether labor usage is greater or smaller than the first best can be investigated by determining the derivative of the cost function. That is,

$$L_i \gtreqless L_i^F \Leftrightarrow 1 + g_i'(L_i) + h_i'(L_i) \gtreqless 0 \quad . \tag{D.1}$$

Recall that $\pi(L)$ denotes the value of $\Gamma(L,M,Z)$ when (4.35) and (4.36) are substituted into Γ. Therefore, the first-order conditions are

$$\frac{\partial \pi}{\partial L_i}(L^*) = 0 \quad . \tag{D.2}$$

From (3.15) this is given by

$$\left[R^* - g_i'(L_i*)\right]\left[\phi_i'(C_i^*) - A\right] + \left[1 + h_i'(L_i*) + g_i'(L_i^*)\right]\left[\phi_i'(C_i^*) - 1\right] = 0 \quad . \tag{D.3}$$

Now consider case (i) of Proposition 8. Assume that

$$R^* - g_i'(L_i^*) > 0 \quad . \tag{D.4}$$

Just as in appendix B, it must be that

$$\phi_i'(C_i^*) < 1 \quad . \tag{D.5}$$

(If $\phi_i'(C_i^*) = 1$ for some i, then $\phi_i'(C_i^*) = 1$ for every i which contradicts (4.3).) The result now follows from (D.3) and (D.1). The proofs of (ii) and (iii) are very similar.

APPENDIX E

DERIVATION OF TABLE 5.2

Table E.1 presents the raw data on cost pools obtained from McCullough and Balut [1990]. These are the total dollar figures summed across all four firms for the year 1987.[49] Direct labor and overhead are obtained from table 3, page 10.[50] The figure for total cost (which is called the total business base) is obtained from table 2. Then material is determined as a residual. Note that material includes the cost of all subcontracts and, as well, any direct charges which are not material or direct labor. These are usually called "other direct charges" (ODCs). The largest ODC is directly charged computer costs. For the purposes of this paper there is no need to separate material and ODCs. Therefore, they are all simply included under the category labelled direct material.

The derivation of the totals for the various components of overhead is slightly more complicated. In table 14, overhead is broken into the four categories of engineering, manufacturing, material, and G&A. Summing manufacturing and engineering (M&E) together yields the three categories reported in table E.1. However, one further correction must be made. The direct labor and direct material figures in table E.1 include direct labor and material charged to IR&D/B&P. However, the M&E overhead pool reported in table 14 also includes these figures. Therefore they must be subtracted from one or the other to avoid double counting. In table E.1 they have been subtracted from M&E Overhead. The direct IR&D/B&P charges total 199,117.[51]

Table E.1
Raw Data

Direct labor	1.897,060
Direct material	5,786,010
Overhead	3,509,127
G&A	650,006
Material	281,157
M&E	2,577,964
Total	11,192,197

The data in table E.1 is not suitable for the purposes of this paper for a number of separate reasons. It will now be transformed in six steps into a suitable form. Each step will be explained individually.

Step #1: Fully Loaded IR&D/B&P. IR&D/B&P stands for independent research and development and bid and proposal costs. Government regulations[52] specifically require the following accounting treatment of such costs. Direct labor and material are charged to individual IR&D or B&P projects as though they were a contract. Then all overhead pools *except* G&A are allocated over contracts and IR&D/B&P projects. Finally, these "fully loaded" IR&D/B&P costs are allocated to contracts using the same allocation base as G&A.

For purposes of this paper, the important figure to calculate is the value of "fully loaded" IR&D/B&P costs. These will then be viewed as a separate element of overhead allocated using the same base as G&A.[53] In table E.1, the direct labor and direct material charged to IR&D/B&P is included in direct labor and material. In a personnel communication, J. McCullough stated that the total IR&D/B&P direct charges of $119,117 were approximately 80 percent direct labor and 20 percent material or ODCs. This yields values of $159,294 for direct labor and $39,823 for direct material.

The material overhead rate is .0486 (281,157 ÷ 5,786,010). The labor overhead rate is 1.3589 (2,577,964 ÷ 1,897,060). Applying these overhead rates to the IR&D/B&P direct material and direct labor yields "full loaded" IR&D/B&P costs of $417,517. This is reported in table E.2. The overhead and direct charges assigned to IR&D/B&P have been subtracted from the relevant pools.

Table E.2
The Result of Step #1

Direct labor	1,737,766
Direct material	5,746,187
Overhead	3,708,244
G&A	650,006
IR&D/B&P	417,517
Material	279,222
M&E	2,361,499
Total	11,192,197

Step #2: Allowable IR&D/B&P. An additional complication also exists with regard to IR&D/B&P expenses. This is that the DoD only accepts a certain amount of IR&D/B&P expenses as "allowable" for the purposes of generating costs which it will recognize for the purposes of pricing defense contracts. All large firms negotiate a dollar value ceiling with the DoD each year. IR&D/B&P expenses up to the ceiling are then allowable for the purposes of defense contract costing. Furthermore, the ceiling almost always is binding, i.e., total IR&D/B&P expenditures are almost always greater than the ceiling. Note that the ceiling applies to total IR&D/B&P expenses and not to the DoD's share. For example, suppose a firm spends $1.5 million on IR&D/B&P, its negotiated ceiling is $1 million, and 75 percent of its business is with DoD.

Then $1 million will be allocated to all contracts and the DoD's share will be $750,000.

For the purposes of this paper, only IR&D/B&P expenses up to the ceiling levels ought to be included in the overhead pool. This is because, overceiling IR&D/B&P is ignored for the purposes of defense contract costing.

The IR&D/B&P figure in table E.2 includes *all* IR&D/B&P. McCullough and Balut [1990] do not break this down into underceiling and overceiling amounts. Alexander, Hillard, and Bodilly [1989] present this breakdown for the group of all major defense contractors.[54] They report that in 1985 the ceiling level equalled 69.52 percent of the total level. This proportion will be used in this paper. Thus it will be assumed that 30.48 percent of the IR&D/B&P expenses in table E.2 or $127,280 are unallowable. Table E.3 displays the resulting figures when this amount is subtracted.

Table E.3
The Result of Step #2

Direct labor	1,737,766
Direct material	5,746,187
Overhead	3,580,964
G&A	650,006
IR&D/B&P	290,237
Material	279,222
M&E	2,361,499
Total	11,064,917

Step #3 Facilities Capital Profit. As explained in the paper, DoD regulations break "economic cost" into two components. The first component is labelled "cost" and basically corresponds to items an accountant would think of as costs. The second component is labelled "profit" and includes compensation for working capital, facilities capital, and risk bearing.[55]

Table E.3 only includes items from the first component. For all items of profit except that for facilities capital, this exclusion is of no great consequence. This is because the profit for each contract is directly calculated and no other costs are allocated based on these charges. Thus they can be viewed as direct charges which do not receive any overhead allocation. Since they are not allocated themselves and do not affect the allocation process, they are irrelevant to the issues being analyzed in this paper. Therefore they will simply be ignored.

The one exception to this is profit for facilities capital. It is allocated across contracts using a base of direct labor and thus should be included as an overhead cost for purposes of calculating the magnitude of incentive effects. To explain this, it will be useful to provide a little more general background information on the process by which defense firms recognize facilities capital costs.

There are two issues. The first is how the costs of facilities are allocated to contracts. The second is how the costs of facilities are calculated. These will each be considered in turn.

First, regarding the method of allocation, the practice of most defense firms is to include all facilities capital costs as part of manufacturing overhead and allocate them according to direct labor usage along with all other manufacturing overhead.

Second, regarding the method for calculating facilities capital costs, three separate components are calculated. The first component is depreciation. This is called a "cost" by the regulatory system and is included in table E.3 as part of M&E overhead. The second component is called the "cost of money." This is the one major departure of government accounting conventions from commercial accounting conventions. A return to facilities capital is calculated by multiplying an interest rate called the Treasury Rate by the net book value of all assets. The Treasury Rate is an interest rate issued twice yearly by the Treasury Department. Its historic average is about 10 percent.[56] This cost is formally labelled as a "cost" by government procurement regulations. However, it is not included in table E.3 as part of M&E overhead. The third component is called "facilities capital profit." Just as for "cost of money" it is calculated by applying an interest rate to net book value. It is labelled as a "profit" instead of a "cost" and it is not included in table E.3. This is no good reason for the separate existence of the second and third components and why one is labelled a cost and one is labelled a profit. This separation exists simply as a historical artifact determined by a series of separate legislative interventions.

From this paper's perspective, the important point is that the second and third components are allocated according to direct labor. Thus they are an overhead charge that firms can attempt to shift through manipulating direct labor. That is, conceptually, they are no different than any other element of M&E overhead. Therefore, they will be added to this overhead pool.

In order to do this, the typical or average value of these two components must be calculated. As reported above, the typical value for the Treasury Rate used to calculate the cost of money is 10 percent. Table E.4 summarizes the regulations which determine the interest rates used to calculate the facilities capital profit. Capital is broken down into three categories--land, buildings, and equipment. The regulations specify an allowable range and a normal value for the interest rate to be applied to each category. (As for cost of money, the interest rate is applied to net book value.)

Table E.4
Interest Rates Used For Calculating Facilities Capital Profit

Asset Type	Normal Value	Allowable Range
Land	0%	0% to 0%
Buildings	15%	10% to 20%
Equipment	35%	20% to 50%

McCullough and Balut [1990] report that in 1987 the net book value of assets for the four aerospace firms was $2,205,500.[57] Unfortunately they do not break this total down into the desired three categories. However, the last major DoD study of the defense industry, the *DFAIR* [DoD, 1985], provided such a breakdown for an extremely large sample of defense firms. Table E.5 reports the net book value of assets by each category as a percent of the total net book value for 1983 which was the most current year of data contained in the *DFAIR* study. It will be assumed that the asset breakdown in table E.5 applies to the four aerospace firms under consideration.

Table E.5
Net Book Value of Assets By Category As a Percentage of Total Net Book Value of Assets*

Asset Type	Percentage
Land	6.83%
Buildings	35.33%
Equipment	57.84%

*This is 1983 data for all DFAIR firms. The data is from the DFAIR [DoD 1985], Appendix 1, Volume II.

The value of the third component can now be calculated by multiplying a weighted average interest rate by the net book value of facilities capital where the weighted average is constructed by averaging interest rates from table E.4 using the weights in table E.5. The only question regards which interest rates to use from table E.4. The natural candidates are the "normal" values in the first column of E.4. However, based on discussions with industry participants, it seems likely that (at least currently) the typical values used for calculations are lower than these normal values. The reason for this may be that prior to the last change in the regulations governing profit calculations in 1988, the interest rates applied to facilities capital were much lower. It seems that many contracting officers have not yet "accepted" the changes and tend to allow facilities capital profit somewhere between the value which would have existed under the old regulations and that which would occur under the new regulations.

This paper will adopt the conservative approach of using the lower bounds of the allowable ranges to calculate the typical facilities capital profit. This results in a lower value of facilities capital profit than would occur if the normal values were used. This in turn means that the overhead rate is smaller and that the magnitude of the incentive effects is smaller. This is why it can be interpreted as a conservative approach.

The resulting weighted average interest rate is 15.1 percent.[58] Adding 10 percent for the cost of money component yields an interest rate of 25.1 percent.[59] Applying this to the net book value of $2,205,500 yields a return of $553,581. Table E.6 adjusts table E.3 by adding this amount to M&E overhead.

Table E.6
The Result of Step #3

Direct labor	1,737,766
Direct material	5,746,187
Overhead	4,134,545
G&A	650,006
IR&D/B&P	290,237
Material	279,222
M&E	2,915,080
Total	11,618,498

STEP #4: FRINGE BENEFITS. Fringe benefits for all employees, both direct and indirect, are classified as an indirect cost by the four aerospace firms. (This is typical industry practice.) All fringe benefits are part of the M&E overhead pool in table E.6.

For purposes of this paper's calculations, however, the fringe benefit costs of direct employees should be removed from the overhead pool and reclassified as direct. This is because fringe benefits are a *linked cost* in the sense that expenditure of one more dollar on direct labor necessitates a certain additional expenditure on fringes as well.

McCullough and Balut [1990] do not report fringe costs for direct employees separately. However, they give direct labor cost, indirect labor cost, and total fringe benefit cost. The approach that will be followed here is to assume that the fringe benefit costs are incurred for each employee group in proportion to the direct salary costs. This yields an imputed fringe benefit cost for direct labor of $596,228. Table E.7 adjusts table E.6 to reflect this by adding $596,228 to direct labor and subtracting $596,228 from M&E overhead.

Table E.7
The Result of Step #4

Direct labor	2,333,994
Direct material	5,746,187
Overhead	3,538,317
G&A	650,006
IR&D/B&P	290,237
Material	279,222
M&E	2,318,852
Total	11,618,498

Step #5: Material Overhead. The material overhead pool is sufficiently small relative to its base of all direct material that it can safely be ignored without having any major effect. This produces a somewhat simpler set of formulas which are easier to interpret. Therefore, the material overhead will simply be viewed as part of direct material.

Step #6: IR&D/B&P. Finally since IR&D/B&P is allocated on the same base as G&A it is mathematically equivalent to G&A for the purposes of this paper's calculations. Therefore it will be grouped as part of G&A. Table E.8 presents the results of Steps #5 and #6.

Table E.8
The Result of Steps #5 and #6

Direct labor	2,333,994
Direct material	6,025,409
Overhead	3,259,095
G&A	940,243
M&E	2,318,852
Total	11,618,498

APPENDIX F

DERIVATION OF TABLE 5.4

This appendix derives overhead rates using data from Meyers et al. [1985] on the cost data initially proposed by contractors at the beginning of negotiations. The advantage of this data is that it is (presumably) drawn from many more firms than is the McCullough and Balut [1990] data. However, it has two major problems. First, the data is from contractors' proposals and is not actual *ex post* incurred cost data as is true for the McCullough and Balut [1990] data. Second, the summary of the cost breakdowns in Meyers et al. [1985] is not complete enough to perform all of the desired adjustments that were performed in appendix E. Furthermore, there are some ambiguities in the description of the data which reduce the reliability of the estimates. Nonetheless it is still of some value to show that the overhead rates calculated using this data are reasonably close to those calculated using the McCullough and Balut [1990] data.

Table F.1 presents the raw data from table 2-4 of Meyers et al. [1985]. Two points should be noted. First, this is the data for manufacturing contracts. Data was presented for three separate groups of contracts--manufacturing, R&D, and service contracts--but not for the entire group and not enough data was presented to allow construction of a weighted average. Second, 8.3 percent of the costs were labelled as "other costs" and it is not clear what these are. They were interpreted to be direct charges of some sort other than direct labor. Thus, mathematically, they are equivalent to direct material charges for the purposes of this paper and they are included as part of direct material in table F.1. This is, of course, a conservative procedure since it minimizes the overhead rates. Third, material overhead is also included in direct labor.

Table F.1
Raw Data

Cost Pool	% of Total
Direct labor	19.8
Direct material	41.2
Overhead	38.9
G&A	12.7
M&E	26.2
Total	100.0

Step #1: Fringe Benefits. The most important adjustment which must be made is to reclassify fringe benefits for direct labor as a direct cost. No data is supplied on the magnitude of these costs. Therefore it will be assumed that the ratio of fringe benefits to salary costs is the same as for the McCullough and Balut [1990] data. For the McCullough and Balut [1990] data, fringes equalled 34.31 percent of salary costs. This means that 6.8 (.3431 x 19.8) percentage points should be moved from M&E overhead to direct labor. Table F.2 presents the result of this calculation.

Step #2: Facilities Capital Profit. Just as for the McCullough and Balut [1990] data, the data in table F.2 does not include the cost of money or facilities capital profit. Meyers et al. [1985] reports that the net book value of facilities capital equalled 10.4 percent of the total costs. Applying the same weighted average interest rate as used in appendix E of 25.1

Table F.2
The Result of Step #1

Cost Pool	% of Total
Direct labor	26.6
Direct material	41.2
Overhead	34.4
G&A	12.7
M&E	19.4
Total	100.0

percent thus yields a return to facilities capital of 2.6 percent (25.1% x .104) of total cost. Adding 2.6 percentage points to the M&E pool and recalculating all percentages so the total still sums to 100 yields table F.3. The overhead rates in table 5.4 are calculated from table F.3.

Table F.3
The Result of Step #2

Cost Pool	% of Total
Direct labor	26.0
Direct material	40.2
Overhead	33.9
G&A	12.4
M&E	21.5
Total	100.0

APPENDIX G

DERIVATION OF TABLE 7.1

Table G.1 presents the raw data from McCullough and Balut [1990] which breaks total overhead down into a number of separate components. As usual all of the data is in thousands of 1987 dollars. The data will now be transformed in five steps. The rationale for most of these steps was described in appendix E and will not be repeated here. Only new considerations which did not arise in appendix E will be discussed.

STEP #1: FULLY LOADED IR&D/B&P. Appendix E calculates that $218,399 of M&E overhead is allocated to IR&D/B&P. The raw data in table G.1 does not distinguish between M&E overhead and G&A overhead. Corporate office allocations are entirely in G&A. All other categories contain both G&A and M&E overhead. In the absence of any better method, it will be assumed that the $218,399 of overhead is drawn proportionately from all of the cost categories except corporate office allocation. Subtracting the calculated amounts from each of the categories and adding $218,399 to IR&D/B&P yields table G.2.

Table G.1
Raw Data

Indirect labor	926,212
Fringe benefits	968,643
Facilities related	610,841
Data Processing	396,679
Corporate office allocation	163,186
IR&D/B&P	199,118
Others	443,565
Total	3,708,244

Table G.2
The Result of Step #1

Indirect labor	865,756
Fringe benefits	905,417
Facilities related	570,970
Data Processing	370,787
Corporate office allocation	163,186
IR&D/B&P	417,517
Others	414,611
Total	3,708,244

Step #2: Allowable IR&D/B&P. As calculated in appendix E, $127,280 of IR&D/B&P expenses are unallowable and must, therefore, be subtracted.

Step #3: Return to Facilities Capital. As calculated in appendix E, a return to capital of $553,581 must be added to the facilities related costs.

Step #4: Fringe Benefits. As calculated in appendix E, $596,228 of fringe benefits apply to direct labor and thus should be removed from overhead. The remaining fringes apply to indirect labor and will be considered part of indirect labor. Table G.3 presents the results of steps #2-#4.

Table G.3
The Result of Steps #2-#4

Indirect labor	1,174,945
Facilities related	1,124,551
Data Processing	370,787
Corporate office allocation	163,186
IR&D/B&P	290,237
Others	414,611
Total	3,538,317

Step #5. The data in table G.3 includes M&E, G&A, IR&D/B&P, and material handling overhead. The IR&D/B&P is separately identified and can be subtracted. From appendix E, G&A expenses total $650,006 and material handling overhead expenses total $279,222. It is clear that the corporate office allocation of $163,186 is part of G&A. This leaves net expenses of $486,820 which must be subtracted from table G.3 to yield M&E overhead. In the absence of actual data on the cost breakdown of G&A and material handling, it will be assumed that these pools are drawn proportionately from all cost categories except facilities related. (Most facilities are probably part of M&E overhead.)

Prorating $486,820 over the cost categories and subtracting the resulting values, subtracting the corporate office allocation, and subtracting IR&D/B&P yields the result presented in table G.4.

Table G.4
The Result of Step #5

Indirect labor	715,812
Facilities related	1,124,551
Data Processing	225,895
Others	252,594
Total	2,318,852

NOTES

1. This certification is required by the Truth-in-Negotiations Act. See Oyer and Mateer [1987].

2. Appendix A gives a brief overview of the nature of these regulations.

3. Interpret C_i as being *all* economic costs, including the cost of risk-bearing and capital.

4. Scherer [1964] stresses the importance of competition between different weapons systems. See chapter 2. See Stubbing [1986] pages 39-42 for a discussion of the air-lift/ship substitution question.

5. See Weitzman [1980]. Also see Baron [1989] for a survey of much of the more technical literature.

6. An intuitive explanation for this precise equivalence between the sign of $\partial R^M/\partial L_i$ and the nature of the distortion in the firm's labor choice can be seen by considering the case where subcontracting has no effect on the overhead rate. That is, decreased subcontracting on product i raises L_i but also raises Z_i so that R^M is unchanged. The important point to note is that this means that the amount of overhead assigned to all other products stays absolutely constant. (Overhead assigned to some other product j depends on product j's direct labor use and the overhead rate. Neither of these change.) Therefore subcontracting has no overhead reallocation effect. Therefore the basic intuition of this paper yields the desired result. Since subcontracting has no affect on overhead allocation, the firm chooses the first-best level of inputs.

7. See DoD [1986], chapter 6, for a statement to this effect in the DoD's standard procurement text. See McCullough and Balut [1990] for an empirical analysis.

8. Formal demonstration of this type of result is beyond the scope of this paper because it would require formally modelling uncertainty and multiple production periods where some inputs are fixed.

9. Technically, this assumption plays the following role in the various proofs. In most cases the first order conditions will be satisfied if $\phi_i'(C_i) = 1$ for every i. In such a case the firm is indifferent between all cost allocations and, in general, anything could be true. Assumption (4.3) rules out this possibility. Then the first order conditions generally imply a great deal of structure for the resulting equilibrium.

10. On a technical level this generalization is relatively trivial. It will be assumed that Z_i and M_i are strong substitutes for L_i in the sense that the cost-minimizing choices of Z_i and M_i both go down when L_i goes up. Under this assumption it is in fact sufficient to demonstrate the distortions in the two smaller problems. It is then immediate that the distortions also occur in the general problem. This will be explained in full detail below.

11. In fact the method of proof is to first prove Proposition 7. Then Proposition 6 follows immediately because of Assumption (g) that all the inputs are strong substitutes.

12. Substitution of (3.37) and (5.16) into (5.22) yields (5.24).

13. I am particularly indebted to Jim McCullough for answering many questions regarding the interpretation of their data.

14. For those unfamiliar with this term, IR&D/B&P expenditures are discussed further in appendix D and in chapter 7.

15. There are two reasons why the data from McCullough and Balut [1990] was used instead of that from Meyers et. al. [1985]. First, the McCullough and Balut data was much more detailed and contained, for example, data on IR&D/B&P expenditures and fringe benefits which allowed precise adjustments to be made. Second, the McCullough and Balut data is actual incurred cost data. The Meyers et. al. data is taken from the forms firms must fill out when they submit cost estimates prior to negotiations for a new contract. Thus it is not necessarily equal to actual costs. Because of these two problems it was felt that the McCullough and Balut data was preferable even though it was based on fewer firms. Nonetheless it is reassuring that one can derive relatively similar overhead rates using the Meyers et. al. data.

16. See, for example, Horngren and Foster [1987], chapters 6 and 7.

17. See McCullough and Balut [1990] for details. The results reported in McCullough and Balut [1990] are actually attributed to another IDA researcher, Tom Frazier. No separate publication of these results is cited.

18. Actually direct labor *hours* were used. This should not have any effect.

19. Furthermore it is not that important since only the subcontracting case uses it.

20. These figures are from *DFAIR* [DoD 1985] for the year 1983 which was the most recent year in the study. It reports that on average 17.2 percent of operating costs were allocated to commercial contracts. Since the allocation is almost entirely based on direct labor, this is a reasonable approximation to use for the fraction of direct labor assigned to commercial contracts. Note that if firm A performed a subcontract for firm B as part of a government contract that firm B was performing, then the subcontract would be labelled as noncommercial for the purposes of classifying firm A's business. Thus the 17.2 percent is truly commercial work. Finally, note that the *DFAIR* analysis

was on the profit center level. That is, it considered individual segments of a company that separately accumulated cost and profit. This is the correct procedure for the purposes of this paper.

21. This is true even for the pure waste case because the second term of the formula, $\phi_i'(C_i) - 1$, equals zero when $\phi_i'(C_i) = 1$.

22. Table 4, page 13b.

23. See DoD [1985], chapter VI, for a good summary of various government policy studies drawing this conclusion. Also, see Gansler [1980], pages 57-58.

24. See table 5.5.

25. The calculation reported below is conservative because this value is selected from the low end of the plausible range of 39 percent to 82 percent.

26. See *FAR* 15.7 for regulations describing this monitoring process.

27. See Peck and Scherer [1962], pages 386-391 and Gansler [1980], pages 132-137.

28. Gansler [1980], page 133.

29. See Rasor [1985], chapter 5, for a fairly complete description of a number of these cases. Also see Fitzgerald [1989], chapter 12.

30. Fitzgerald [1989], page 215.

31. Rasor [1985], page 157.

32. Page 165.

33. In addition $56 of profit was paid to yield the price of $436.

34. I particularly benefitted from discussions with Jim Dertuzos in preparing this section.

35. See Pilling [1989] for an empirical analysis and references to other empirical studies. See Drewes [1987] for a fascinating description of a particular procurement where dual sourcing was used. See Anton and Yao [1987a,b; 1988] for a theoretical analysis.

36. See the discussion in section B of this chapter.

37. The answers to (i) and (ii) may differ because not all DoD products may be perfectly cost-sensitive.

38. See Johnson and Kaplan [1987], Berliner and Brimson [1988], and Cloos and McCullough [1989].

39. Recall that the *FAR/DFAR* and *CAS* are described in more detail in appendix A.

40. See Johnson and Kaplan [1987], Berliner and Brimson [1988], and Cloos and McCullough [1989] for a more complete discussion and further references.

41. The same methodology is used to calculate these costs. See appendix G for a complete discussion.

42. In previous chapters of this paper IR&D/B&P expenditures were viewed as a subcomponent of G&A expenditures since for purposes of calculating overhead rates, they were the same. In this chapter it will be useful to separately distinguish these costs since different issues arise when contemplating directly paying for them. Thus the term G&A will be interpreted as not including IR&D/B&P.

43. See Alexander, Hill, and Bodilly [1989] for a much more detailed description of the institutions.

44. Page 29.

45. See Alexander, Hill and Bodilly [1989]; Brock [1990]; and Lichtenberg [1990].

46. DoD [1985].

47. See Johnson and Kaplan [1987].

48. The function f^i and its derivative are evaluated at (M_i^*, Z_i^*). That is, f^i denotes $f^i(M_i^*, Z_i^*)$, f_M^i denotes $f_M^i(M_i^*, Z_i^*)$, etc. This convention will be used throughout the appendix.

49. All dollar figures in this appendix are in 000s of 1987 dollars.

50. In this appendix, tables with arabic numerals (e.g., table 3, table 4, etc.) are from McCullough and Balut [1990].

51. This figure is from table 10. I am grateful to J. McCullough for explaining the required correction to me.

52. *CAS* 420.

53. This treatment will ignore one technical point which has no substantive effect on the calculations. In reality, if direct labor use changes on any contract, then this changes the overhead rate and thus also changes the value of "fully loaded" IR&D/B&P. However, this effect is extremely small so will

be ignored, i.e., the value of "fully loaded" IR&D/B&P will be viewed as a constant not affected by direct labor usage.

54. Alexander, Hillard, and Bodilly [1989], page 43.

55. See Rogerson [1989a] for a thorough description. The regulations governing profit calculations are in the *DFAR* 215.9 and *CAS* 414.

56. See Rogerson [1989a].

57. Table 7, page 19.

58. The corresponding interest rate is 25.5 percent using the normal values and 36.0 percent using the maximum values.

59. The corresponding interest rate is 35.5 percent using the normal values and 46.0 percent using the maximum values.

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