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AN EVALUATION OF CONTRACTOR PROJECTED AND ACTUAL COSTS

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16. Abstract

GSFC contractors with cost-plus contracts provide cost estimates for each of the next four quarters on a quarterly basis. Actual expenditures over a two-year period were compared to the estimates, and the data were sorted in different ways to answer several questions and give quantification to observations, such as how much does the accuracy of estimates degrade as they are made further into the future? Are estimates made for small dollar amounts more accurate than for large dollar estimates?

Other government agencies and private companies with cost-plus contracts may be interested in this analysis as potential methods of contract management for their organizations. It provides them with the different methods one organization is beginning to use to control costs.

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AN EVALUATION OF CONTRACTOR PROJECTED AND ACTUAL COSTS

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INTRODUCTION

NASA contracts meeting certain category, dollar, and duration of performance criteria contain a requirement for contractors to submit monthly financial and manpower data. The NASA Form 533 shown in Figure 1 is the means through which these data are obtained.

The contractor reports actual expenditures on a monthly basis, estimates of expenditures for the next four quarters, and the yearly total. These estimates are used at the Goddard Space Flight Center to track the contractor's progress and to calculate the end of year accrued cost position of NASA flight projects. This document reviews the accuracy of these contractor estimates.

For this study accuracy will be measured by the ratio of the actual expenditures in a quarter to the predicted expenditures for that quarter. It is important to understand that inaccuracy does not necessarily mean mismanagement or poor contractor analysis. At any point in time the contractor must estimate future costs based on the existing contract. Even if a contractor knows that the government is considering a major contract change, that change may not be reflected in the estimate until it is formalized. This means that the contractor does not even attempt to predict actual costs, but predicts the costs of the present contract. In an environment where total overruns of 200 percent are frequent, this distinction is more than academic.

Since these estimates are used as part of the Center's resource planning, several questions need to be asked.

- What is the overall accuracy of these estimates?
- Are projections made for the near future more accurate than those made further into the future?
- How accurate are the yearly totals?

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
QUARTERLY CONTRACTOR FINANCIAL MANAGEMENT REPORT

2. REPORT FOR QUARTER BEGINNING (Col. 8a)

TO: *(Enter name of NASA field installation and contracting officer to whom report is submitted)*

FROM: *(Enter full name, address and ZIP Code of contractor and, if applicable, contractor's division performing contract)*

3. CONTRACT VALUE
a. COSTS $ | b. FEE $

1. DESCRIPTION OF CONTRACT
a. TYPE
b. CONTRACT NO. AND LATEST DEFINITIZED AMENDMENT NO.
4. FUND LIMITATION $
c. SCOPE OF WORK
d. SIGNATURE OF AUTHORIZED CONTRACTOR REPRESENTATIVE | DATE
5. BILLING
a. INVOICE AMTS BILLED $ | b. TOTAL PYTS REC'D $

6. REPORTING CATEGORY	7. COSTS INCURRED / HOURS WORKED			8. ESTIMATED COST / HOURS TO COMPLETE										9. ESTIMATED FINAL COST / HOURS		10. ESTIMATED COMPLETION DATE	11. UNFILLED ORDERS OUTSTANDING
	CUMULATIVE ACTUAL THRU PRIOR MONTH a.	CURRENT MONTH ESTIMATE b.	CUMULATIVE ESTIMATE TO DATE c.	MONTH d.	MONTH e.	MONTH f.	QUARTER g.	QUARTER h.	QUARTER i.	BALANCE OF FY- j.	NEXT FY- k.	BALANCE OF CONTRACT l.	TOTAL TO COMPLETE m.	CONTRACTOR ESTIMATE n.	CONTRACT VALUE		

Figure 1. Quarterly contractor financial management report form.

- Is the accuracy of estimates made on service-, spacecraft-, or experiment-type contracts different?
- Are projections made for smaller dollar amounts more accurate than those made for larger dollar amounts?
- Is there any difference in the accuracy of estimates made for newer and for older projects?
- Is there any difference in the accuracy of estimates made for application projects and for science projects?

DATA ANALYSIS

The contractor data in Goddard's automated 533 system have been analyzed for the fiscal years 1971 and 1972. There were a total of 204 contracts included in the data base and these represented 86 contractors.

The approach used for this analysis was to compute the overrun ratio by dividing the quarterly projected cost into the quarterly actual cost. A ratio of 1.00 means the projection was accurate; a ratio less than 1.00 means that actual costs were less than estimated; and a ratio greater than 1.00 means that actual costs were more than estimated. The statistics of these overrun ratios were then studied by plotting their distribution functions. For example, Figure 2 is the distribution of the quarterly overrun ratios for all projects; it should be read as follows: Ten percent of the whole sample had overrun ratios less than 0.5, that is, they underran by a factor of 2 or more. Fifty percent of the sample either accurately estimated the quarterly projection or underran it, and 90 percent of the sample had overrun ratios less than 2.5.

Another way to look at the situation is this: There is a 10 percent chance that the actual costs will be half or less than the estimated cost; there is a 50 percent chance that the actual cost will be equal to or less than the estimated cost; and there is a 90 percent chance that the actual cost will be less than 2.5 times the estimated cost. Since graphs are often difficult to read, the Appendix contains the distribution functions in tabular form.

LIMITATIONS OF THE STUDY

In later sections, conclusions will be drawn from the distribution functions for various subsets of the data. These conclusions should be considered tentative because the data is limited to a 2-yr period in one center's history. This may or may not be typical enough to justify generalizing the conclusions.

Furthermore, these statistics can only be used to adjust contractor estimates in the absence of specific information. If, for example, the life span of a 40-yr old adult male were to be estimated, the statistics in standard mortality tables might suffice. But if it were also known that he smoked 10 packs of cigarettes a day and had a family history of

cancer, it would be unwise to use the mortality tables. Judgement of the relevance of the additional facts would make the statistics inappropriate.

THE EFFECTS OF TIME

To decide if projections made for the near future are more accurate than those made for the more distant future, the ratios were grouped into five categories:

- Estimates made 3 months ahead (nearest quarter)
- Estimates made 6 months ahead (second nearest quarter)
- Estimates made 9 months ahead (third nearest quarter)
- Estimates made 12 months ahead (fourth nearest quarter)
- Estimates made for the year's total

These distribution functions are plotted in Figure 3. The data show that the quarterly estimates become more accurate as they get closer in time, and that the contractor is better able to estimate and control annual expenditures than quarterly expenditures.

Next it must be determined if these differences are statistically significant or if they are just due to chance. The Pearson chi-square test* was used to determine statistical significance for the differences of ratios among the various groupings. The result of this test had to be significant at the 0.05 level to be acceptable, meaning that there was a 95 percent chance that ratios for a specific group were significantly different from the ratios of the total sample. In this case there is indeed a significant difference at the 0.05 confidence level, between each of the four quarterly estimates and the yearly total.

The graph shown in Figure 3 could be used to adjust a specific contractor estimate if its time range were known. Consider, for example, a 9-month estimate of $500K. Ninety percent of the time, the actual expenditure will not exceed $500K X 3.5 or $1750K.

TYPE OF CONTRACT

Contracts fell into three main categories: spacecraft, experiments, and service. The ratios of all 204 contracts were grouped into these three broad categories. The chi-square test was applied to each of the groupings and there was a significant difference at the 0.05 confidence level. The distribution functions are shown in Figure 4. Differences are small but the lowest overrun ratios were found among the service contracts and the largest overrun ratios among the experiment contracts. Service contracts tend to be more definable, therefore less apt to change, so that costs can be more accurately estimated. On the other hand, experiments are probably the least definable of the three contract types, and are subject to the most change, resulting in the largest variance between actual costs and estimated costs.

*Fisz, Marek, *Probability Theory and Mathematical Statistics*, John Wiley & Sons Inc., N. Y., 1963.

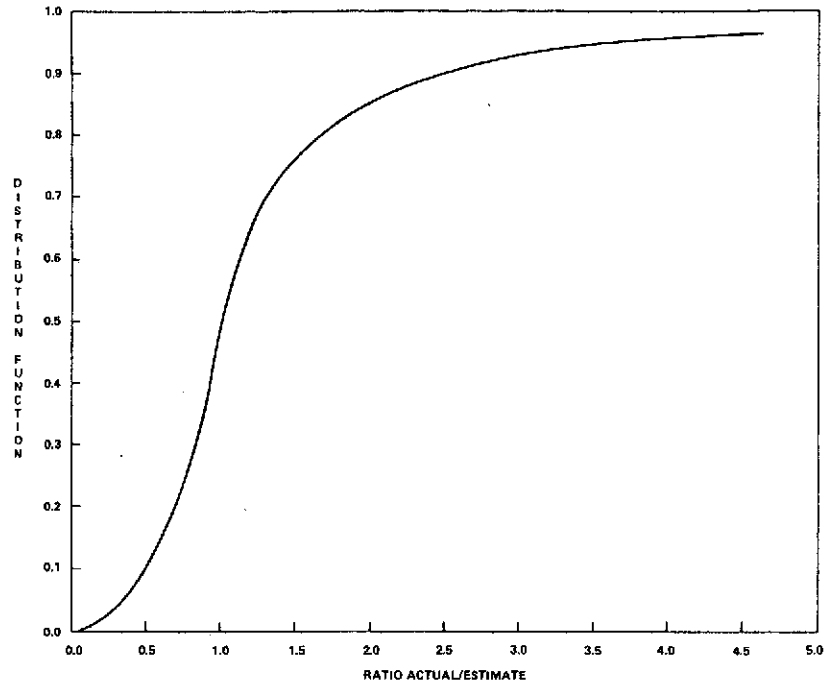

Figure 2. Fiscal year 71-72 data total sample.

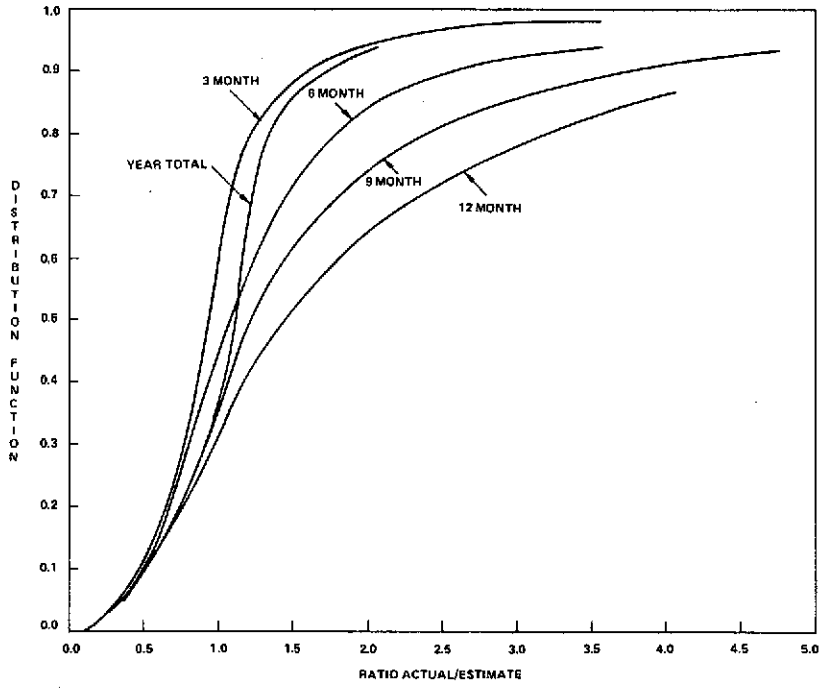

Figure 3. Fiscal year 71-72 533 estimates by time.

DOLLAR EFFECTS

To determine if projections made for smaller dollar amounts are more accurate than those made for larger dollar amounts, all 204 contracts were grouped into one of four categories:

- Quarterly expenditures under $100K
- Quarterly expenditures $100K but less than $500K
- Quarterly expenditures $500K but less than $1,000K
- Quarterly expenditures $1,000K and over

The overrun ratios were computed, the chi-square test was applied to each group, and the resulting distribution function is shown in Figure 5. The test showed that there is a statistically significant difference between the cost ratios for the four groups of dollar values.

Smaller contracts overran a little less than larger contracts, but between $100K and $1 million seemed essentially the same. Prediction accuracy does not appear to be influenced greatly by the size of the contract. However, more absolute dollars are involved in larger contracts, so one hesitates to conclude where better management is exercised.

PROJECT AGE EFFECTS

The next question is to decide if there is any difference in the accuracy of estimates made for newer and for older projects.

Of the 204 contracts, 115 were identified with a specific project and the other 89 were identified with a functional Goddard organization. The projects were classified as older or newer based on when Goddard manpower charges first appeared; projects with manpower charges prior to FY 1967 were considered older. Their ratios were computed and compared to the total sample via the chi-square test; the distribution functions are shown in Figure 6.

There is no significant difference at the 0.5 confidence level between cost ratios of older projects and cost ratios of newer projects so the answer to the question appears to be no.

PROGRAM AREA

The final problem is to determine if there is any difference in the accuracy of estimates made for applications and science projects.

Of the 204 contracts in the total sample, the 115 contracts that were identified with specific projects were grouped by application or science projects. The ratios were computed and compared to the total sample via the chi-square test, and the distribution functions are shown in Figure 7. There is a significant difference at the 0.05 confidence level between

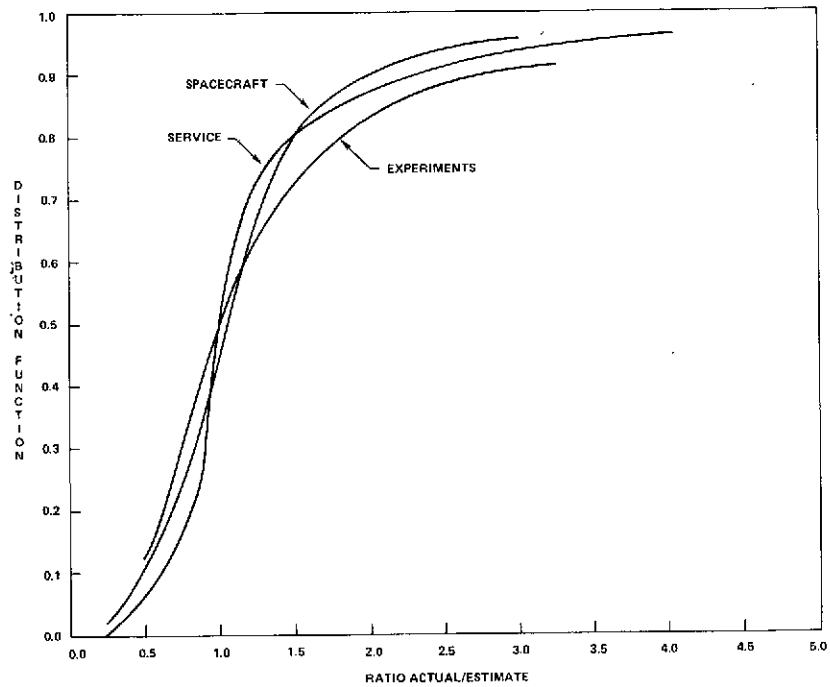

Figure 4. Fiscal year 71-72 533 data by type of contract.

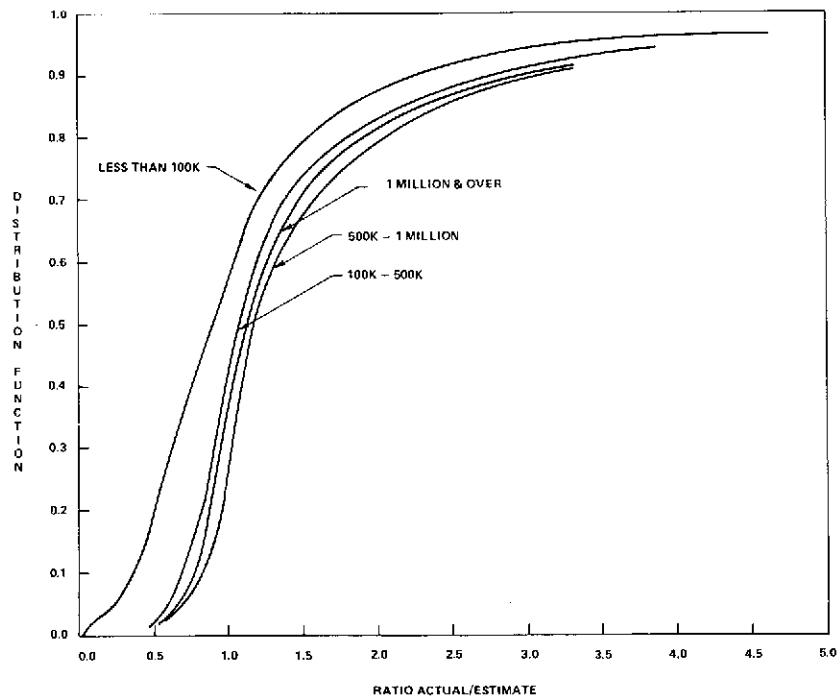

Figure 5. Fiscal year 71-72 533 data by quarterly dollar amount.

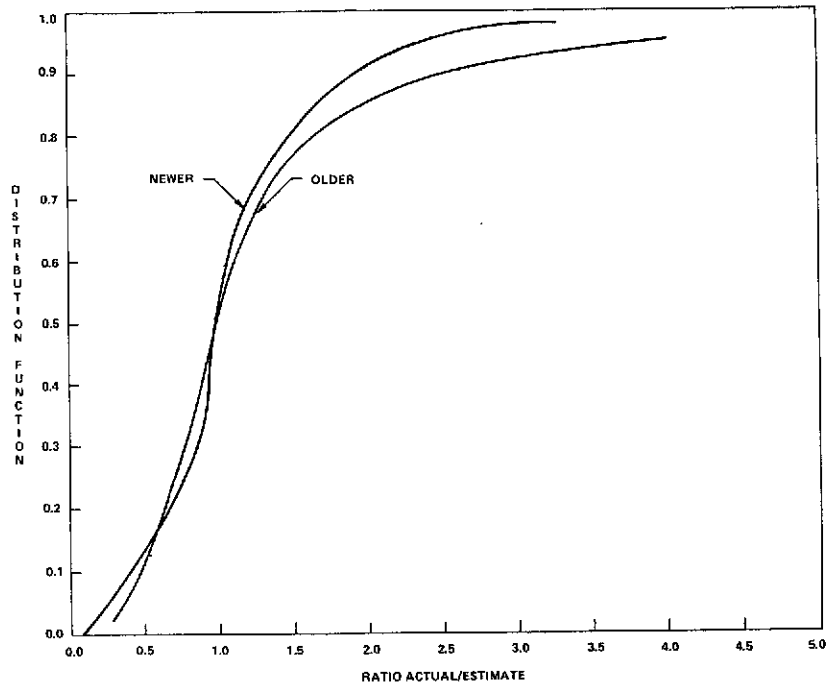

Figure 6. Fiscal year 71-72 533 data, newer and older projects.

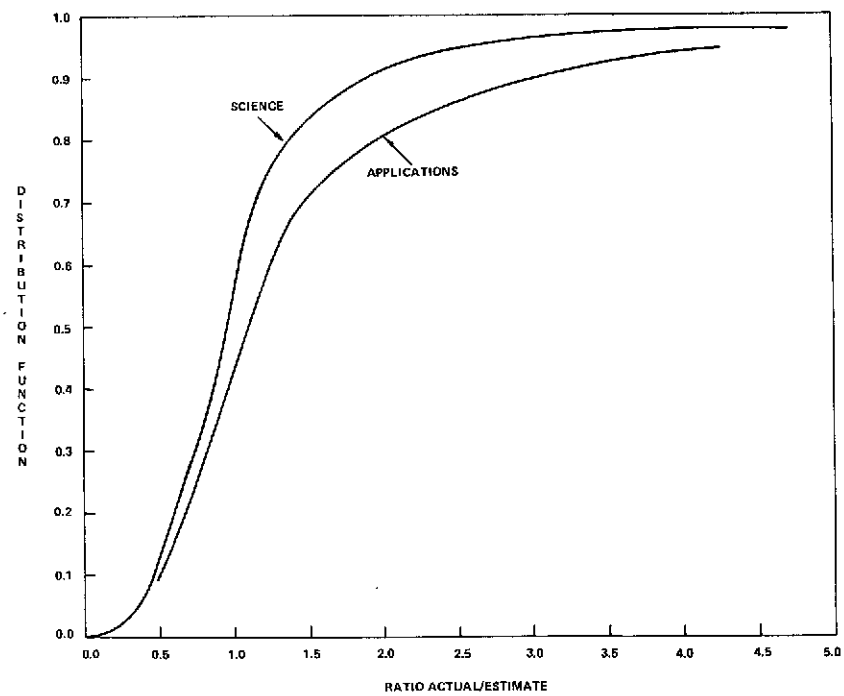

Figure 7. Fiscal year 71-72 533 data, science and applications projects.

the overrun ratios of application projects and the cost ratios of science projects. One reason for the higher rates for application projects might be that during the sample period there was a push on the application projects because of tight launch schedules that may have resulted in less detailed definition. Science projects developed at a slower rate and therefore were capable of more detailed definition.

CONCLUSIONS

The analysis of contractor 533 reports showed that the overruns of projected costs are:

- Smallest for the nearest quarter projected and larger for projections further into the future
- Smallest for service and largest for experiment contracts
- Smallest for expenditures under $100K in a quarter
- Not significantly different for newer projects as compared to older projects
- Smaller for science projects than application projects

Goddard Space Flight Center
National Aeronautics and Space Administration
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039-03-43-13-51

APPENDIX
DISTRIBUTION TABLES

This Appendix contains the distribution functions in tabular form for contractor data in Goddard's automated 533 system for the fiscal years 1971 and 1972.

Table 1

Ratios for Total Data Base
by Nearness of Projection.

Percent	Time Periods				Total
	3 Months	6 Months	9 Months	12 Months	
100.	99.33	43.72	65.00	35.31	99.33
90	1.61	2.53	3.73	4.65	2.51
80	1.22	1.80	2.28	3.20	1.69
70	1.07	1.45	1.77	2.34	1.33
60	0.99	1.24	1.43	1.79	1.13
50	0.93	1.08	1.20	1.37	1.00
40	0.85	0.95	1.08	1.15	0.92
30	0.75	0.85	0.94	1.00	0.82
20	0.64	0.68	0.79	0.79	0.68
10	0.45	0.50	0.54	0.50	0.49
0	0.02	0.03	0.03	0.03	0.02
Sample Size	1015	562	376	239	2197

Table 2

Ratios for Service Contracts
by Nearness of Projection.

Percent	Time Periods				Total
	3 Months	6 Months	9 Months	12 Months	
100	16.08	43.72	46.62	35.31	46.62
90	1.66	2.02	2.49	4.88	2.30
80	1.26	1.39	2.00	3.09	1.55
70	1.10	1.20	1.60	2.35	1.20
60	1.02	1.05	1.25	2.12	1.07
50	0.98	0.95	1.14	1.31	1.00
40	0.95	0.91	1.04	1.19	0.95
30	0.89	0.87	0.95	0.96	0.90
20	0.79	0.74	0.90	0.77	0.79
10	0.65	0.52	0.63	0.61	0.62
0	0.06	0.10	0.26	0.26	0.06
Sample Size	353	134	83	49	619

Table 3

Ratio for Spacecraft Contracts
by Nearness of Projection.

Percent	Time Periods				Total
	3 Months	6 Months	9 Months	12 Months	
100	99.33	7.80	3.73	13.02	99.33
90	1.34	2.00	1.99	2.59	1.91
80	1.12	1.51	1.56	1.84	1.50
70	1.01	1.39	1.44	1.57	1.31
60	0.97	1.29	1.30	1.36	1.18
50	0.90	1.14	1.15	1.23	1.05
40	0.77	1.01	1.10	1.18	0.96
30	0.71	0.88	0.96	1.05	0.83
20	0.63	0.74	0.77	0.83	0.69
10	0.42	0.49	0.59	0.55	0.53
0	0.15	0.05	0.29	0.28	0.05
Sample Size	82	65	50	37	234

Table 4

Ratios for Experiments Contracts
by Nearness of Projection.

Percent	Time Periods				Total
	3 Months	6 Months	9 Months	12 Months	
100	8.00	43.00	65.00	31.50	65.00
90	1.54	2.88	4.51	4.66	2.81
80	1.21	1.94	2.73	3.50	1.81
70	1.06	1.61	2.00	2.54	1.41
60	0.96	1.33	1.51	2.01	1.16
50	0.87	1.14	1.22	1.47	1.00
40	0.78	0.99	1.08	1.11	0.89
30	0.69	0.84	0.90	0.97	0.77
20	0.56	0.63	0.70	0.79	0.61
10	0.40	0.47	0.50	0.46	0.45
0	0.02	0.03	0.03	0.03	0.02
Sample Size	580	363	243	153	1339

Table 5

Ratios for Contracts with Less Than $100K Expenditures
in Any One Quarter by Nearness of Projection.

Percent	Time Periods				Total
	3 Months	6 Months	9 Months	12 Months	
100	8.00	31.50	31.50	31.50	31.50
90	1.60	2.49	3.50	3.55	2.25
80	1.21	1.64	2.22	2.41	1.52
70	1.06	1.32	1.50	2.15	1.20
60	0.96	1.09	1.22	1.41	1.03
50	0.85	0.90	1.08	1.05	0.91
40	0.75	0.73	0.89	0.94	0.76
30	0.64	0.61	0.66	0.65	0.63
20	0.50	0.47	0.51	0.50	0.50
10	0.34	0.35	0.37	0.28	0.35
0	0.02	0.03	0.03	0.03	0.02
Sample Size	514	249	160	101	1024

Table 6

Ratios For Contracts With $100- to $500-K Expenditures
in Any One Quarter by Nearness of Projection.

Percent	Time Periods				Total
	3 Months	6 Months	9 Months	12 Months	
100	99.33	43.00	65.00	22.33	99.33
90	1.61	2.81	3.84	4.02	2.76
80	1.20	1.89	2.25	2.81	1.78
70	1.06	1.51	1.75	2.28	1.37
60	1.00	1.33	1.45	1.81	1.16
50	0.96	1.14	1.21	1.44	1.04
40	0.90	1.03	1.09	1.20	0.97
30	0.83	0.94	1.01	1.06	0.90
20	0.75	0.87	0.89	0.88	0.81
10	0.60	0.72	0.78	0.78	0.67
0	0.21	0.48	0.41	0.39	0.21
Sample Size	332	207	137	82	758

Table 7

Ratios for Contracts with $500- to $1,000-K Expenditures
in Any One Quarter by Nearness of Projection.

Percent	Time Periods				Total
	3 Months	6 Months	9 Months	12 Months	
100	4.02	2.82			13.02
90	2.05	1.97			3.03
80	1.31	1.69			1.98
70	1.13	1.51			1.64
60	1.08	1.42			1.28
50	1.00	1.29			1.16
40	0.99	1.22			1.04
30	0.94	1.02			1.00
20	0.89	0.88			0.94
10	0.71	0.72			0.80
0	0.55	0.67			0.55
Sample Size	37	13	8	5	63

Table 8

Ratios for Contracts with $1,000K Plus Expenditures in Any One Quarter by Nearness of Projection.

Percent	Time Periods				Total
	3 Months	6 Months	9 Months	12 Months	
100	13.89	43.72	46.62	35.31	46.62
90	1.42	2.24	3.26	5.07	3.02
80	1.21	1.86	2.49	3.95	1.90
70	1.04	1.51	1.97	2.90	1.45
60	0.99	1.33	1.65	1.95	1.26
50	0.97	1.19	1.44	1.64	1.12
40	0.92	1.05	1.23	1.32	1.00
30	0.86	0.94	1.10	1.21	0.94
20	0.78	0.89	0.96	1.05	0.88
10	0.66	0.84	0.89	0.91	0.77
0	0.50	0.56	0.59	0.60	0.50
Sample Size	132	93	71	51	347

Table 9

Ratios for Contracts Associated with Newer and Older Projects.

Percent	Newer Projects	Older Projects
100	7.03	99.33
90	1.97	2.48
80	1.44	1.62
70	1.21	1.30
60	1.03	1.11
50	0.96	1.00
40	0.90	0.88
30	0.78	0.77
20	0.66	0.61
10	0.45	0.45
0	0.10	0.02
Sample Size	108	1286

Table 10

Ratios for Contracts Associated with Science and Application Projects.

Percent	Science Projects	Application Projects
100	22.33	99.33
90	1.88	3.02
80	1.38	2.00
70	1.16	1.48
60	1.04	1.24
50	0.95	1.04
40	0.85	0.93
30	0.73	0.80
20	0.57	0.69
10	0.44	0.50
0	0.02	0.02
Sample Size	735	659