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REPORT TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

with respect to Grant NsG-342,

covering the period March 15, 1967 to

September 15, 1967

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REGIONAL IMPACT STUDIES

Study 1. The NASA Subcontract Program

The basic results of this study were furnished to NASA in July 1967, as Working Paper 6708, An Economic Analysis of Research and Development Procurement: The NASA Subcontract Program, by John T. Burgess. The highlights of this study are reproduced at the end of this progress report.

Study 2. Impact of Defense/Space Programs on Income Distribution

Research continues on the study. No results are yet available.

NATIONAL IMPACT STUDIES

Study 3. Role of Defense/Space Programs in the National Economy

Work continues in this area. Working Paper 6709, Prospects for the American Economy During the Post-Vietnam Period, by Murray L. Weidenbaum, was furnished to NASA in July 1967. Two reports previously furnished to NASA were reprinted by The Joint Economic Committee of the U.S. Congress in its volume on The Military Impact on the American Economy: Now and After Vietnam (Volume II of the Committee's hearings on The Economic Effect of Vietnam Spending). The two papers reprinted were Edward Greenberg, "Employment Impacts of Defense Expenditures and Obligations," and Maw Lin Lee, "The Relationship of New Orders to Shipments of Defense Products".

Study 4. Measures of Impact of Defense/Space Programs

No additional work was performed in this area during the progress report period.

Study 5. Impact of Changing Defense/Space Programs on the Federal Budget

The study, Program Budgeting and the Space Program, previously furnished to NASA, was published in the American Astronautical Society's book, The Management of Aerospace Programs, Volume 12 of the AAS Science and Technology Series.

R & D AND MANPOWER STUDIES

Study 6. International Labor Market for Scientists and Engineers

Professor Irvin Sobel is writing up the results of his field work and data analysis on the subject of the "brain drain".

Study 7. Economics of Technical Change

Professor Frederic Raines continues to analyze the results of his work on the "spillover" effects of space and other government R & D expenditures. Working Paper 6705, Methods of Government Assistance to Research and Development, by Murray L. Weidenbaum, was furnished to NASA in June 1967. Working Paper 6707, Relationships Between R & D Contracts and Production Contracts, by Edward Greenberg, was also furnished to NASA in June 1967.

INDUSTRIAL IMPACT STUDIES

Study 8. Structure of the Defense-Space Market

Professors Marshall Hall and Murray Weidenbaum are continuing their research in this area. Working Paper 6704, Strategies for Diversification of Defense/Space Companies, by Murray L. Weidenbaum, was furnished to NASA in June 1967. The results of this research were presented at an international meeting of the American Marketing Association in June. An earlier report which was an input to this study, Working Paper 6701, The Role of Economics in Long-Range Planning for an Aerospace Company, was furnished to NASA in January 1967.

Study 9. Impact of Personnel Practices of Space Companies

Professor Richard Goodman is continuing work on his analysis of selected personnel practices of leading NASA contractors.

Study 10. Economics of International Space Telecommunications

Edward Heiden completed his analysis of COMSAT rate structures and related economic problems. The results were transmitted to NASA as Working Paper 6711, Some Economic Problems of Space Telecommunications, August 1967 (two volumes).

AN ECONOMIC ANALYSIS OF RESEARCH AND DEVELOPMENT PROCUREMENT: THE NASA SUBCONTRACT PROGRAM

by

John T. Burgess
Department of Economics
Washington University
Working Paper 6708
July 1967

SUMMARY

This research was supported by National Aeronautics and Space Administration Grant NsG-342 to Washington University.

PREFACE

This study is intended to provide new insights into the economic factors affecting the size and geographic distribution of R & D subcontract procurement, with special reference to the NASA program. Major achievements over previous studies include:

(a) Extending economic analysis to the 2nd tier subcontract level. Previous studies have only speculated as to the size, technical and industrial characteristics, and geographic distribution of 2nd tier procurement.

(b) Recognizing the dollar importance of subsystem and non-subsystem 1st tier procurement and the different technical and industrial characteristics of each. These differences are offered as the primary determinants of the size and geographic distribution of subcontract procurement in general, and

(c) Recognizing the presence of stable subcontract relationships for prime contractors engaged in similar activities. These relationships provided a basis for forecasting subcontract size and geographic distribution on an individual prime contract basis.

By virtue of the four and one half year time period of this study, it has been possible to provide additional insight into the stability of the relationships discussed. Short time periods of available data and inconsistent subcontract samples have prevented similar efforts in previous studies.

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Acknowledgement is made to Professors Edward Greenberg and Murray L. Weidenbaum, who served as advisers to this research.

Additional acknowledgement is also in order to the Project Services Branch, Computation Center, Washington University (National Science Foundation Grant G-22296) for their programming efforts.

This research was supported by National Aeronautics and Space Administration Grant NsG-342 to Washington University.

CHAPTER I

INTRODUCTION

Since the early 1950's, expenditures for R & D have played an increasingly important role in the total pattern of Federal procurement. Although estimates of fiscal 1966 and 1967 R & D expenditures showed a slight decline, there is every reason to believe that as the resource priorities of the Viet Nam war decrease, these R & D expenditures will return to their pre-war levels and may well increase at an even faster rate.

The most dramatic change within total R & D procurement has been the increased share accruing to NASA. NASA R & D and R & D plant procurement has increased from 97.3 million dollars in fiscal 1958 to an estimated 5,505.7 million dollars in fiscal 1966.[1/] In terms of total Federal R & D and R & D plant procurement, this change represents an increase from 2.0% in fiscal 1958 to 32.2% in fiscal 1966.[2/]

The increased significance of NASA R & D expenditures raises questions as to the size, nature, and geographic distribution of the economic impact. One has only to read the works of Bolton, Park, Tiebout and Weidenbaum to know that there are significant regional economic impacts involved in Federal procurement programs, and that these impacts play an important role in the economic

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[1/] National Science Foundation, Federal Funds for Research, Development and Other Scientific Activities, Volume XV, July 1966, pp. 154 and 155.

[2/] Ibid, pp. 154 and 155.

development of the affected regions.[3/] Because of these regional growth implications, much public attention has been given to the so-called "fair share" controversy. Interested parties in what may be referred to as the "have-not" areas contend that a "fair" or "just" distribution of R & D funds has not been accomplished. On the basis of their share of total United States population, Federal income tax payments, or general manufacturing capability, these areas argue that they should have received a larger ("fairer" - i.e. in proportion to their share of total population, etc.) portion of total R & D procurement.

A. Statement of Purpose

In an effort to provide a basis for discussing public policy issues such as those just mentioned, the present study has undertaken a presentation and analysis of the geographic distribution of NASA 1st and 2nd tier subcontract activity, and has explored the extent to which the resulting geographic distribution can be objectively explained on economic grounds. More specifically, the purposes of this paper are as follows:

1. To examine the size and distribution of 1st tier subcontract procurement over an extended (4 1/2 year) period of time, thereby limiting certain time phasing problems present in previous studies.
2. To extend this examination to the hitherto unresearched level of 2nd tier subcontract procurement.

[3/] Roger E. Bolton, Defense Purchases and Regional Growth, Washington, D.C., Brookings Institution, 1966; Se-Hark Park, Urban Employment Multipliers and Their Application to the Aerospace Industry in St. Louis, Washington University, St. Louis, Mo., June, 1965; R. S. Peterson and C. M. Tiebout, "Measuring the Impact of Regional Defense-Space Expenditures," Review of Economics and Statistics, Volume XLVI, November, 1964; Murray L. Weidenbaum, "Measurement of the Impact of Defense and Space Programs," American Journal of Economics and Sociology, October 1966, Vol. 25, No. 4.

3. To define the basic factors affecting the size and geographic distribution of NASA subcontract procurement, and in particular, to explore the relationship between subcontract size and distribution and the industrial and technical nature of contract activities.

4. To assist policy decision-making by providing a basis for first approximation forecasts of the size and goegraphic distribution of 1st and 2nd tier subcontract.

B. Organization of the Study

To accomplish these purposes the study has been organized in the following manner. Chapter II provides a discussion of the prime and subcontract data. The primary purpose is to qualify the NASA "postcard" subcontract data as representative enough of the subcontract universe to permit generalizations for the entire NASA subcontract program. Of special significance is the presence of all major NASA space systems in the prime sample and the relative insignificance of the subcontract awards from those primes not included.

Chapter III provides the empirical basis upon which the conclusions of succeeding chapters will be based. The size (subcontract ratios) and geographic distribution (by state and region) of NASA 1st and 2nd tier subcontract procurement is presented, and appropriate implications for regional economic analysis are suggested. Of special concern is the role of home area procurement and distance in determining the geographic distribution of awards, and the importance of R & D "complexes" as centers of NASA procurement activities. The difference in geographic emphasis between 1st and 2nd tier procurement is noted and the industrial and technical requirements of subcontract activities are offered as possible explanations.

Chapter IV pursues this possibility by categorizing subcontract activities as subsystem and non-subsystem and examines the relationship between this differentiation and the subsequent differences in subcontract firms, industrial emphasis and geographic distribution of procurement. The dual nature of 1st tier subcontract activities provides a basis for discussing these differences. The industrial and technical requirements of 2nd tier procurement offer additional support and further implications for non-subsystem activities.

Chapter V utilizes previous conclusions to develop a forecasting model which is designed to provide first approximations of the geographic distribution of subcontract awards. Two approaches are considered. The first involves developing multiple regression equations on the basis of each state's share of 1st and 2nd tier subcontract awards (dependent variable) and its corresponding share of total (United States) technical personnel and "key" industry employment (independent variables). The second is a regional approach based on differences in technical and industrial emphasis of subcontract procurement resulting from different prime activities. By categorizing prime contracts on the basis of their contract activities, fairly stable 1st tier subcontract distribution patterns to the Northeast, Pacific and East North Central regions are developed.

Chapter VI is a summary of the major conclusions reached in the study. Additional areas of research and various data needs are discussed.

Before moving on, one final issue should be discussed. This is the decision to concentrate on subcontract procurement. This decision was motivated by two factors. At the time this study was begun, little reliable information existed regarding the geographic distribution of subcontract awards. Earlier studies recognized the importance of subcontract programs and attempts were made

to account for them.[4/] In most cases the geographic distribution of subcontract awards was assumed to be closely associated with the geographic distribution of employment or wages paid in certain defense or space-related industries. However, direct (via subcontract data) empirical support for these assumptions was not available. Secondly, no attempt had been made to organize and analyze from a purely economic point of view the fairly extensive 1st and 2nd tier subcontract data collected under NASA's "postcard" reporting system.

C. A Brief Survey of the Literature

From 1964 on, and particularly in 1965 and 1966, various studies involving both NASA and the Department of Defense have explored the geographic relationships and economic implications of R & D prime procurement. At the time the present study was begun, only the first of a three part series of Stanford Research Institute (SRI) studies was published.[5/] However, since that time a C-E-I-R study and two additional SRI studies of DOD subcontracting and the Bohm and Hoffenberg studies of NASA subcontracting have been published.[6/] In an effort

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[4/] See footnote 3 for a list of earlier studies.

[5/] A. Shapero, R. P. Howell, J. R. Tombaugh, An Exploratory Study of the Structure and Dynamics of the R & D Industry, Stanford Research Institute, Menlo Park, California, June, 1964.

[6/] C-E-I-R Inc., Economic Impact Analysis of Subcontracting Procurement Patterns of Major Defense Contractors, Bethesda, Md., September, 1966; A. Shapero, R. P. Howell, J. R. Tombaugh, The Structure and Dynamics of the Defense R & D Industry: The Los Angeles and Boston Complexes, Stanford Research Institute, Menlo Park, California, November, 1965; R. P. Howell, W. N. Breswick, E. D. Wenrick, The Economic Impact of Defense R & D Expenditures: In Terms of Value Added and Employment Generated, Stanford Research Institute, Menlo Park, California, February, 1966. R. A. Bohm, Empirical Evidence on the Geographic and Industrial Distribution of Aerospace Expenditures, Washington University, St. Louis, Mo., April, 1966; and M. Hoffenberg, Analysis of NASA Postcard Subcontract Data, University of California, Los Angeles, California, December, 1966.

to place the present study in the proper context of existing knowledge regarding subcontract activities, a brief survey of the earlier studies is in order.

Although R & D primes from two different Federal agencies were considered in these studies, the descriptive aspects of the size and geographic distribution of 1st tier awards were very similar. The most obvious and important similarity is the role of the Northeastern and Pacific regions as major centers of both prime and 1st tier subcontract activities. Because of different prime samples, the combined share of total 1st tier subcontract awards to these regions differed. However, the figures fluctuated within a fairly narrow range of 60% to 70%. The Northeastern and Pacific region share in the 1965 SRI study was 81% primarily because all sample primes were located in these regions. As a result, the home procurement share, which would not have been included if the primes were located in other regions, was added in.

In addition to recognizing the dominant position of the Northeastern and Pacific regions, the C-E-I-R study pointed out that the flow of net 1st tier awards was from the West and South Census regions to the Northeast and North Central regions. However, no attempt was made to correlate these flows with the industrial and technical nature of subcontract activities. The 1st tier "From - To" figures in the Hoffenberg study suggest the same net flow. However, it was not specifically mentioned.

A similarity of establishments engaged in prime and subcontract activities was noted in the C-E-I-R and Hoffenberg studies. The similarity was concluded to be indicative of a limited network of firms and areas capable of performing the more sophisticated subcontract activities. As a result, both NASA and DOD 1st tier procurement is characterized by considerable substitution of supply sources in one area for those in another. A similar conclusion was reached in the three SRI studies, although appropriate figures were not provided.

All but the Bohm study considered the subcontract to prime contract award relationship (subcontract ratio). It was generally concluded that between 26% and 46% of cumulative prime awards in each study was subcontracted. The different ratios were primarily due to two factors: (a) on the average, DOD primes subcontracted more than NASA primes, and (b) subcontract data examined in the C-E-I-R and SRI studies was "contaminated" in the sense that R & D and non-R & D primes were included. Since R & D activities are generally performed "in-house", the subcontract ratio for R & D primes tends to be lower than for non-R & D.

The C-E-I-R and Hoffenberg studies also pointed out that on the basis of individual prime contracts there was considerable variation in the subcontract ratio. The C-E-I-R figures ranged from 10.3% to 62.0% (these figures are very similar to those of the present study). Differences in program stages, prime contractor current capacity and "in-house" capability, and differences in subcontract time lags were offered as possible explanations. However, no consideration was given to the possibility of different levels of subcontract ratio stability or associating subcontract ratios with particular prime activities.

One of the major purposes of descriptive analysis is to provide a basis for explaining the particular relationships which emerge and, if possible, develop methods of prediction. It is at this point that the conclusions of earlier studies as well as those of the present one differ the most.

The SRI studies of 1964 and 1965 concentrated on the dominant position of the Northeast and West (primarily California) Census regions as centers of subcontract activity. In explaining this situation, it was concluded that the greatest portion (85%) of NASA 1st tier procurement involved products and services

which were referred to as "high technology".[7] The primary sources of technical and research capability required by these "high technology" subcontracts were concluded to be concentrated in the Northeast and West regions, and specifically in their major "R & D complexes". As a result, the following subcontract patterns were observed:

1. Prime contractors in either the Northeast or West region subcontract 70% in the home region and 15% in the other.
2. Prime contractors outside the Northeast and West regions procured 20% in the home region (mostly non-technical) and divided the remainder between the Northeast and West regions roughly according to the distance from them.

Thus a general forecasting model was established on the basis of subcontract technical requirements and the prime contractor's place of performance relative to the Northeast and West Coast complexes.

However, the major emphasis in the SRI model is on the distance relationship. This was apparently the result of two factors: (a) a tautological interpretation of the subcontract data (see the Bohm study), and (b) the short time period of subcontract data used for differentiating "high technology" and non-technical activities. NASA 1st tier subcontract reports for the period January 1, 1962 to April 30, 1963, provided the basis for classifying subcontract activities. The early time phasing of awards for large subsystem projects by primes 9-150 (Apollo) and 9-170 (Gemini) gave these reports a "high technology" bias. Consequently, the extent of "high technology" activity discussed in the 1964 SRI study

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[7] High technology refers to products and services that have a relatively high input of technical professional labor per unit.

is overstated and the amount of non-technical procurement has a greater influence on subcontract location than is implied. Therefore, the share of awards received by R & D complexes from primes in non-complex areas may fall short of the SRI predictions.

The Bohm study recognized this shortcoming and attempted to provide a basis for more clearly differentiating technical and non-technical procurement. The subcontract expenditures (as opposed to obligations) for the Gemini project in St. Louis were classified by three digit SIC codes and then viewed in relation to their geographic distribution. The following observations were made:

1. The highly technical and more refined Gemini inputs were concentrated in the electronic, aircraft and instruments industries and were procured outside the area most economically connected with St. Louis (500 mile radius). Northeastern and Pacific region complexes were the major recipients.
2. The non-technical or low value inputs were concentrated in the materials (metal and chemical),machinery,and metal products industries and were heavily concentrated in the surrounding region (500 mile radius). As the Bohm study concluded, these relationships make it possible to more accurately predict the geographic distribution of subcontract procurement given the prime location and the industrial breakdown of subcontract activities.

The Bohm study did not pursue the industry relationship as far as it might have. It did not recognize that the geographic distribution of subcontract awards is not only a function of the degree of technical sophistication (as measured by their industrial classification) but also the concentration of productive capability in those industries most involved with NASA procurement. In other words, (a) the share of subcontract awards to the home region as opposed

to the complexes is determined by the degree of technical sophistication (i.e. industrial classification of subcontract activities), and (b) the subsequent distribution of awards within the home region or between the complexes is a function of each area's respective concentration of productive capability in the industries involved.

The Hoffenberg study did recognize this differentiation, and thereby suggested that a blend of industrial and technical factors is responsible for the geographic distribution of subcontract procurement. The Hoffenberg study agrees with the SRI studies by concluding that the major portion of 1st tier procurement is concentrated in highly technical activities (subsystems). As a result, the Northeast and Pacific Coast complexes are the focal points of subcontract activity. However, the Hoffenberg study goes on to conclude that the share to each is primarily a function of the industrial nature of the awards rather than the distance of the prime contract from the complex. It is pointed out that the Boston centered complex is characterized by specialized capability in the electronics industry, while the California complexes are more likely to receive awards for aircraft-related activities, particularly those involving large diameter motor effort. Distance was concluded to have some significance for those primes located in or very near an R & D complex.

Although the present study generally agrees with the conclusions of the Hoffenberg study, certain shortcomings should be noted. Briefly they are as follows:

1. Comparative data are not provided for the industrial characteristics of subsystem activities and their geographic place of performance. The conclusion that subsystem procurement gravitates to areas of specialized industrial capability is merely implied from the inter-regional flow of awards and the fact that certain centers of subcontract activity are

centers of electronic and aircraft production.

2. The significance of "high technology" or subsystem procurement is overemphasized. Only passing reference is made to less technical 1st tier activities and the industrial and technical nature of 2nd tier procurement is only speculated. As a result, the role of the East North Central region as a source of less technical subcontract activities is not examined.

3. Observations and conclusions regarding the factors affecting subcontract distribution are confined to total 1st tier procurement. The relationship between prime contract activity and the industrial and technical characteristics of resulting subcontracts (and therefore the geographic distribution of awards) is not explored.

Only the C-E-I-R study differentiated subcontract distributions on an individual prime contract basis. It concluded that there was an inverse relationship between the size of cumulative prime awards and the geographic concentration of subcontract activities. In light of the geographic concentration of subcontract awards from NASA primes 1-3800, 7-100 and SNP-1 (see Chapter 5), this observation has limited applicability for NASA procurement. The 1966 SRI study suggested that the size of cumulative prime awards and the type of prime institution may provide more meaningful predictions of subcontract distributions than those based solely on the prime to complex distance relationship. However, no attempt was made to intergrate this conclusion into the distance model.

CHAPTER V

FORECASTING THE GEOGRAPHIC DISTRIBUTION OF NASA SUBCONTRACT PROCUREMENT

The most difficult problem involved in developing a regression equation of the sort suggested in Chapter 4 is choosing independent variables which are both representative of the factors affecting subcontract location and for which adequate data are available. In the present study the following procedures were undertaken.

A. Selection of Appropriate Variables

Selecting the appropriate industries to be considered was accomplished by two methods: (a) The top 50 firms at each subcontract level were classified on the basis of a three digit industry code. As discussed in Chapter 4, the appropriate SIC code was assigned on the basis of the firm's industrial classification in the SEC Directory of Companies. Whenever possible, 4 digit classifications were made. However, the lack of adequate data on a 4 digit industry basis limited the extent to which this was useful in the present study. The disclosure problem of Census data was particularly troublesome in light of the need for data by state. This is unfortunate, for the amount of aggregation at the 3 digit level in industries 361, 366 and 367 reduced their effectiveness as explanatory variables. This was especially true for industry 366 (communication equipment) which received a large share of both subsystem and non-subsystem awards, yet had R^2 values of .26 and .08 for 1st and 2nd tier procurement respectively. (b) The industries selected under the preceding process were compared to those concluded by other studies to be most involved in NASA procurement. In particular, the conclusions of the Bohn study for the Gemini project were compared and found to be quite similar.[63]

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[63] Robert Bohm, op. cit., p. 8.

Additional industries suggested by this and other studies were included (see Table 21 for a completed list).

Relative shares of total U. S. employment in these industries were selected as one measure of a state's ability to compete for subcontract awards. The two rationales for this choice are that the greater the concentration of the work force (a) the greater the number of firms. With more firms the state has a better opportunity to receive a share of awards, and (b) the more likely it is that the state possesses one or more large firms which woudl be able to offer a more diverse capability. To avoid the problem of space awards being the cause rather than the result of an area's industrial capability, employment figures for 1958 have been chosen. 64/

In an effort to recognize the role of R & D and technical capability in determining the distribution of subcontract awards, the technical occupational groups in Table 21 were selected as additional variables. The choice of which engineers to include was based on the large share of awards received by firms in the aircraft, electronics and metal products industries (see Chapter IV). The mathenaticians and physicists are associated with less applied and more pure research activities in the physical problems of space travel. The figures for each occupation category were also taken from the 1958 Census of Manufactures.

Two additional variables were introduced as proxies for factors which were concluded to be significant in determining subcontract distribution, but could not be statistically measured. The 1st tier subcontract distribution was used as a distance proxy for 2nd tier multiple regression analysis, and the total NASA prime distribution is used in 1st tier calculations to account for the similarity of prime and subsystem firms and geographic distributions. In effect, the

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64/ All employment data, with the exception of the Missile industry, were taken from the 1958 Census of Manufactures. Missile employment figures were taken from Manpower in Missiles and Aircraft, Department of Labor, Bureau of Employment Security, 1959. The years 1958 and 1959 precede the major space system awards by 1 to 2 years.

TABLE 21

LIST OF INDEPENDENT VARIABLES TO BE INCLUDED IN MULTIPLE REGRESSION ANALYSIS

Variable Category (1)	VARIABLE DESCRIPTION (2)	SIC CODE (3) (where appropriate)
Industry Variables		
	Miscellaneous Plastics Products	307
	Rolling, Drawing & Extruding of Nonferrous Metals	335
	Fabricated Structural Metal Products	344
	General Industrial Machinery & Equipment	356
	Computing and Accounting Machines	3571
	Electric Transmission & Distribution Equipment	361
	Communication Equipment	366
	Electric Components & Accessories	367
	Miscell. Electric Machinery, Equipment & Supplies	369
	Electric Equipment for Internal Combustion Engines	3694
	Aircraft & Parts	372
	Engineering, Laboratory & Scientific Research Instruments & Associated Equipment	381
	Measuring Instruments (Physical Characteristics)	382
	Research, Development & Testing Labs	7391
Occupation Variables		Missiles
	Mathematicians	
	Physicists	
	Electronic Technicians	
	Aeronautical Engineers	

TABLE 21 contd.

Occupation Variables contd.	
	Electrical Engineers
	Mechanical Engineers
	Metallurgical Engineers
Other Variables	
	Distribution of All NASA Prime Contract Awards
	Distribution of 1st Tier Subcontract Awards

prime contract distribution and occupational variables were intended to account for the distribution of "key" R & D firms associated with subsystem procurement. The sample prime contract distribution was also tried, but consistently provided less significant results. This is primarily due to the disproportionately large share of awards to California and the correspondingly less representative share to the New England and East North Central regions.

Separate scatter diagrams were constructed for each independent variable with the 1st and 2nd tier distributions. On the basis of these diagrams, it was concluded that for 1st and 2nd tier distributions, California is consistently an extreme or an outlying observation. As a result, it was decided to eliminate California from all statistical analysis. The elimination of California resulted in a substantial reduction of the explanatory power of the aircraft and and missile industry variables and to a lesser extent those associated with technical and electronics occupations (see the comparative figures in Table 22). The magnitude of the change in R^2 values merely points up the extent of California's extreme position. At the 2nd tier level it was further concluded that the share of total procurement to New York was also extreme. Consequently, New York is also deleted from all 2nd tier regression analysis.

B. Multiple Regression Analysis

All possible combinations of the variables in Table 21 were tested by means of the least squares method of multiple regression analysis. The basic criteria for assessing the significance of a given regression equation were:

(a) The size of the R^2

(b) The sign of the regression coefficients. All should be positive. The implication of a negative coefficient is not consistent with the general principles of regional economics. When pursued to its logical conclusion, a negative coefficient means that by reducing

Table 22

INDEPENDENT VARIABLE R^2 VALUES WITH AND WITHOUT CALIFORNIA 1/

Industry Variables (SIC Code)	1st Tier Procurement With Cal.	1st Tier Procurement Without Cal.	2nd Tier Procurement With Cal.	2nd Tier Procurement Without Cal.
307	.15	.41	.24	.36
335	.06	.37	.12	.43
344	.27	.42	.40	.62
356	.11	.37	.22	.60
3571	.16	.39	.27	.14
361	.29	.45	.34	.51
366	.19	.26	.25	.08
367	.25	.57	.32	.53
369	.05	.23	.15	.40
3694	.01	.15	.08	.33
372	.76	.13	.78	.17
381	.21	.30	.28	.10
382	.31	.62	.39	.68
7391	.46	.18	.52	.02
Missiles	.92	.29	.88	.09
Occupation Variables				
Mathematicians	.73	.38	.74	.18
Physicists	.68	.45	.75	.35
Electronic Technicians	.75	.70	.85	.63
Aeronautical Engineers	.84	.15	.84	.15
Electrical Engineers	.63	.57	.76	.51
Mechanical Engineers	.46	.36	.60	.51
Metallurgical Engineers	.19	.38	.29	.68

Table 22 continued

Other Variables	1st Tier Procurement With Cal.	1st Tier Procurement Without Cal.	2nd Tier Procurement With Cal.	2nd Tier Procurement Without Cal.
Prime Distribution	.92	.27	.87	.07
1st Tier Distribution			.94	.64

1/ The result of simple regression analysis using the least squares approach. 1st and 2nd tier subcontract distributions by state were used as dependent variables and the industry employment and occupation distributions by states were separately introduced as independent variables (source: Census of Manufactures, 1958). Missile employment figures by state were taken from Manpower in Missiles and Aircraft, Department of Labor, Bureau of Employment Security, 1959. See Table 2, column 3 for the distribution of prime awards by state.

its share of employment in space-related industries or its share of total technical personnel, a state can increase its share of subcontract dollar awards.

(c) The significance of the beta coefficients for each variable, as measured by the T value. A .025 level of significance was adopted as a cut-off.

On the basis of these criteria and the resulting 1st tier multiple regression equations, it is concluded that the role of "key" R & D firms in determining the geographic distribution of procurement limits the possibility of developing a meaningful forecasting equation. Attempts to account for the role of "key" R & D firms (by means of the distribution of prime and technical occupation groups) were hampered by the proportionately low share of 1st tier awards to the East North Central region and the disproportionate share of prime awards to Missouri, Louisiana and Alabama. As revealed by the scatter diagrams for each variable, the East North Central states (particularly Illinois, Ohio and Michigan) consistently receive a smaller share of 1st tier awards than their corresponding share of people in the various occupation groups.

On the other hand, the prime contract distribution variable was consistent with the East North Central state shares of 1st tier procurement. However, the large cumulative awards to spacecraft and rocket vehicle projects in Missouri, Louisiana and Alabama tended to overstate their role and understate that of other states (Iowa, Minnesota, Connecticut and Massachusetts) relative to their actual shares of total 1st tier procurement.

The most significant variable combinations are listed in Table 23. As is revealed, the highest R^2 value, (.79) was obtained from a combination of employment in industry 382 and the number of Electronic Technicians. Attempts to increase the significance of this combination by the addition of variables listed in other regressions or those variables not included in Table 23 were to no avail. The

TABLE 23

KEY INDEPENDENT VARIABLE COMBINATIONS FOR FIRST AND SECOND TIER MULTIPLE REGRESSION EQUATIONS

1st Tier Distributions

Independent Variable Combinations	R^2	T Values		Partial r^2	
Industry 382 + Electronic Technicians	.79	4.40	6.05	.30	.44
Prime Distribution + Industry 382	.75	4.82	9.34	.34	.66
Industry 382 + Missile Employment	.71	8.16	3.74	.60	.24
Electronic Technicians	.70	10.45			
Industry 382 + Industry 3571	.69	3.05	6.61	.17	.49
Industry 367 + Missile Employment	.67	7.16	3.67	.53	.23
Prime Distribution + Industry 367	.67	3.65	7.32	.23	.54

2nd Tier Distribution

Independent Variable Combinations	R^2	T Values			Partial r^2		
1st Tier Distribution + Industry 3694 + Metallurgical Engineers	.86	7.48	3.21	4.11	.56	.19	.28
1st Tier Distribution + Industry 3694 + Industry 344	.85	7.68	3.59	3.34	.58	.23	.20
1st Tier Distribution + Industry 356 + Industry 344	.84	6.44	3.11	2.54	.49	.18	.13
1st Tier Distribution + Metallurgical Engineers	.83	6.30	7.04		.47	.53	
1st Tier Distribution + Industry 356	.81	7.19	6.48		.54	.49	
1st Tier Distribution + Industry 344	.80	6.13	6.05		.47	.45	

Source: Multiple regression analysis using the least squares approach. First and second tier distributions by state were taken from NASA subcontract reports for the period January 1, 1962, to June 30, 1966. See footnote 1 in Table 22 for the source of independent variables other than the first tier subcontract distribution.

high degree of multicollinearity between the variables resulted in negative variable coefficients and insignificant beta coefficients. 65/

Although the variable combinations in Table 23 are of questionable value for purposes of forecasting subcontract distributions, the conclusions of Chapter 4 regarding the industrial emphasis of 1st tier procurement are generally supported. Note that the variables in each of the equations have an aircraft and electronic emphasis. The fact that missile employment is more important than aircraft is important, for it reflects the common emphasis of space effort on projects which involve complex rocket propulsion and electronic subsystems. In other words, the technical and research capability of missile work is more directly transferable to space activities than is aircraft capability in general. This accounts for the concentration of prime and to some extent subsystem awards in a few "key" firms. By virtue of the close correlation of missile work and prime contract location, the two variables are coveriant and therefore may be used interchangeably for 1st tier forecasting.

The importance of electronic capability is most dramatically revealed by the fact that the Electronic Technicians variable alone accounts for 70% of the variation in 1st tier subcontract distribution (see Table 23). The presence of industry 367 in two of the most significant regressions lends additional support. Two other industries which appear among the top 50 1st tier firms are also included in the most significant regression equations. They are industries 382 and 3571. Industry 3571 is especially significant in light of the role played by IBM, Control Data and Sperry Rand in both subsystem and non-subsystem procurement.

65/ Of particular importance is the multicollinearity or covariance present within the electronics and metal products and machinery variables. Industries 361, 366, 367 and the electrical engineers and technicians demonstrate considerable multicollinearity as do industries 344, 356, 382 and the mechanical and metallurgical engineers.

The greater significance of 2nd tier regression equations is primarily the result of the non-subsystem nature of procurement. By being less tied to the location of "key" R & D firms, the 2nd tier awards were freer to move in response to an area'a general capability in a given industry. This is most clearly demonstrated by the increased share of awards to the states of the East North Central region. As discussed above, the less than proportionate (to their share of employment and occupation variables) share of 1st tier awards to these states is primarily responsible for the low R^2 values of the multiple regression equations.

Table 23 provides the variable combinations of the most significant 2nd tier regression equations. Once again, the presence of multicollinearity between the included and excluded variables prevented further improvement in the "forecasting powers" of these variable combinations. This is particularly true for the electronics variables which are not present in any of the equations. The reason for their absence is simply that they are highly correlated with the 1st tier subcontract distribution, which is now included as a separate independent variable. The electronics industries and occupations continue to be instrumental in explaining the geographic distribution of subcontract awards. However, their significance is indirectly evidenced vis-à-vis the 1st tier procurement variable. It was felt that the need to account for the distance variable outweighed the desirability of explicitly representing the electronics industries and occupations. In all cases, the resulting R^2 was larger when the 1st tier variable was used in place of the electronics variables.

Although the elctronics variables remain important, it is noted that the conclusions of Chapter 4 regarding the increased importance of the metal products and machinery and equipment industries is clearly indicated by the presence of industries 344, 356 and 3694 (see Table 23). It should be pointed out that the increased importance of these industries is not the result of the elimination of the electronics industries (i. e. the presence of the 1st tier variable). This

is made clear by the following industry variable combinations which exclude the influence of 1st tier procurement.

Industry Variables (SIC Code)	Electronics Alone R^2	Both Variables R^2	Both Variables Partial r^2
356 and 367	.53	.70	.36, .25
344 and 367	.53	.72	.25, .41
344 and 382	.68	.74	.30, .19
3694 and 382	.68	.75	.23, .63

For 1st tier regression analysis, none of the significant industry combinations included 344, 356 or 3694. Note too the change in occupation emphasis from Electronic Technicians to Metallurgical Engineers (see Table 23). Once again, the presence of the 1st tier variable accounts for the role of Electronic Technicians. However, the change in emphasis is evidenced by re-examining the individual R^2 values in Table 22. The R^2 values for scientific and electronic occupations fell and those for Metallurgical and Mechanical Engineers increased as 1st and 2nd tier distributions respectively are considered.

Although the 2nd tier regression equations are more accurate "predictors" than their 1st tier counterparts, the best R^2 value (.86) is not as large as would be desired. As indicated, 14% of the variation in 2nd tier procurement remains unexplained. The primary reasons for this are as follows:

(a) The geographic concentration of subsystem awards in the Pacific and Northwestern regions. In Chapter 3 it was concluded that 2nd tier subcontracts are more prone to concentration in the local region. It was further concluded in Chapter 4 that subsystem projects are the primary sources of 2nd tier awards. As a result of these two factors, a greater (than 1st tier) share of 2nd tier procurement is concentrated in the Pacific, New England and Middle Atlantic regions. Since the share of awards to the East North Central region also increases, the states in the remaining regions must nec-

essarily receive proportionately smaller shares than at the 1st tier level of procurement.

(b) The previously discussed aggregation problems associated with a three digit industry classification. Perhaps most illustrative of the need for a more detailed classification of space-oriented industries is the greater significance of industry 3694 (for 2nd tier multiple regression analysis) as opposed to the more general industrial category 369. Note that industry 3694 is included in two of the six regression equations in Table 25, while 369 appears in none.

In light of the shortcomings of regression analysis on a state basis, it may be possible to achieve more reliable results through aggregation. For example, by using the Census division as a separate observation, it is possible to average out the disproportionately high and low subcontract shares of the individual states. Unfortunately, in the present study the short time period of available data ($4\frac{1}{2}$ years) and the limited number of observaticns per time period (9) make it impossible to develop a meaningful regression equation on any basis other than by state. However, an alternative approach by region is available, and for purposes of regional analysis and policy it provides more meaningful results.

C. An Alternative Approach: Regional Forecasting by Prime Contract

Regression equations are meaningful for regional analysis and policy decisions so long as the general subcontract distribution they describe is applicable to all prime contracts. In other words, there is an implicit assumption that the subcontract pattern of each prime contract is the same, and therefore, a given state or region will receive a constant share of total awards. For 1st tier subcontracts, which can vary from a $10,000 award for engineering services or transitors

to a $291 million award for the Surveyor Spacecraft, it is unrealistic to make an assumption of this kind. As was demonstrated in Chapter 4, subsystem and non-subsytem awards to some extent involve different industries and contract place of performance. As long as the mix of prime awards remains constant, the regression equation is useful for a first approximation of the share of total 1st tier awards received by a given area. However, the subcontract pattern of a particular prime may not conform to the total subcontract pattern. Yet it is the procurement pattern of an individual prime which is important in determining the economic impact of a new space system award or the cutback in an old one.

In response to these shortcomings, an effort was made to determine a consistent relationship between prime contract activity and the size and geographic distribution of its procurement. To accomplish this purpose, only those primes in the present study which received cumulative awards of 100 million dollars or more, or let 50 or more subcontracts were examined. The cumulative award and subcontract cut-offs were chosen in order to include only those primes which were large enough to provide a comprehensive subcontract pattern. On the basis of the project descriptions of this group, six distinct prime categories were determined. Briefly, they are as follows:

A. Major Space System

These involve the largest most technically advanced hardware items associated with the primary goals of NASA. At the present time the major emphasis is on the Manned Lunar Landing project. Therefore, the prime projects included in this category are the Gemini Spacecraft (9-170), Lunar Excursion Module (9-1100), Apollo Spacecraft (9-150), Lunar Orbitor Spacecraft (1-3800) and Unmanned Exploration of Space (Surveyor Spacecraft) (7-100). The NERVA project (SNP-1) involves developing a nuclear powered rocket and is the only Major Space System prime which is geared for space projects beyond the lunar landing. However, the need for extensive technological break-throughs in

this area required an early beginning.

B. Rocket Vehicles and Engines

The rocket vehicle provides the housing, fuel and exhaust systems and guidance system for the variuos rocket stages. The rocket engines are the separate power sources.

C. Feasibility Studies

These include the initial research, design, development and prototype fabrication for the more complex and technically advanced hardware items. The "follow-on" projects which are more concerned with fabrication, are included in one of the other categories.

D. Unmanned Craft

These are the data gathering spacecraft projects associated with atmospheric analysis. Examples include the Orbiting Astronomical Observatory and the Tiros and Nimbus weather satellites. Although these satellites involve sophisticated electronic capability, they do not require the same amount of research effort and subsystem procurement as other unmanned craft such as the Lunar Orbitor and Surveyor. For this reason, a separate category was created.

E. Subsystems

In some cases various major subsystem projects are procured under separate prime contract rather than through the space system contractor. For instance, the guidance system, ground computer system and instrument package for the Saturn V rocket were procured under separate prime. The same is true for the Apollo space suit and life support system, guidance system and certain rocket motors.

F. Support Work and Facility Construction

These projects range from engineering services and test stand construction to the complete integration and checkout system for Apollo.

The scope and complexity of the prime contract activity vary with each category. As a result, the size and nature of subcontract procurement also vary. The more encompassing and technically complex the prime project, the greater the emphasis on subsystem procurement and the larger the subcontract ratio. The different emphasis on subsystem and non-subsystem awards is associated with the differences in geographic distribution which we have discussed in Chapter 4.

In an effort to more clearly differentiate the specific implications for subcontract distribution, only the prime activities of the first three categories will be discussed. There are three reasons for this: (a) The subsontract relationships in the Subsystem and Support Work categories are not stable. The subcontract ratios and geographic distributions fluctuate within too wide a range to permit conclusions which are consistent enough to serve as forecasting tools. (b) In the case of the Unmanned Craft category, there are too few prime contracts with large enough subcontract sample to provide a comprehensive sub pattern and ratio. (c) The first three categories involve the major portion of prime and subcontract activities. In the present study, they receive 72% of all prime awards between fiscal 1963 and 1966 and subsequently let 82% of the total 1st tier awards for the same time period. The comparative subcontract figures for the prime contracts in these three categories are found in Table 24. Their implications for forecasting the size and distribution of 1st tier procurement may be summarized as follows:

A. Major Space Systems

As was pointed out in Chapter 4, the scope and complexity of the major space system projects is such that the prime contractor is unable to perform all of the associated subsystem activities. Consequently, the total subcontract awards of these primes are dominated by subsystem procurement. Whereas, subsystem awards were responsible for approximately $\frac{1}{2}$ of total 1st tier procurement, the share rises to between 61% - 91% for the Major Space System

Table 24

REGIONAL DISTRIBUTION OF FIRST TIER AWARDS BY PRIME CATEGORY AND PRIME CONTRACT

Prime Contract Category	Prime Contract No.	Prime Contractor	Prime State	Prime Project
Major Space Syst.				
	9-170	McDonnell	Mo.	Gemini Spacecraft
	9-1100	Grumman Acft.	N.Y.	L. E. M.
	9-150	No. Amer. Aviat.	Cal.	Apollo Spacecraft
	7-100	Cal. Inst. of Tech.	Cal.	Unmanned Expl. ofSpace
	SNP-1	Aerojet-Gen.	Cal.	Nuclear Power Rocket
	1-3800	Boeing	Wash.	Lunar Orbitor
Rocket Vehicles and Engines				
	8-5608	Boeing	La.	Saturn IC Vehicle
	8-4016	Chrysler	La.	Saturn I&IB Vehicles
	7-101	Douglas Acft.	Cal.	Saturn IV&IVB Stages
	3-3232	Gen. Dynamics	Cal.	Centaur Vehicle
	7-200	N. Amer. Aviat.	Cal.	Saturn 11 Stage
	3-2555	Aerojet-Gen.	Cal.	M-1 Rkt. Engine
	8-5603	N. Amer. Aviat.	Cal.	J-2 Rkt. Engine
	8-5604	N. Amer. Aviat.	Cal.	F-1 Rkt. Engine
	7-162	N. Amer. Aviat.	Cal.	H-1 Rkt. Engine
	8-5607	United Acft.	Fla.	RL-10/A3 Rkt. Engine
	8-2690	United Acft.	Fla.	RL-115/A3 Rkt. Engine
Feasibility Studies				
	7-1	Douglas Acft.	Cal.	Saturn IV&IVB Stages
	W-16	N. Amer. Aviat.	Cal.	F-1 Rocket Engine
	8-19	N. Amer. Aviat.	Cal.	J-2 Rocket Engine
	8-2577	Boeing Acft.	La.	Saturn IC Vehicle
	8-5623	United Acft.	Fla.	Centaur Vehicle

Source: NASA 1st tier subcontract reports for the period January 1, 1962, to June 30, 1966.

Table 24 continued

Subcontract Ratio (%)	Share to New England Region (%)	Share to Middle Atlantic Region (%)	Share to East North Central Region (%)	Share to Pacific Region (%)
54.5	9.84	12.14	3.76	40.72
56.7	24.98	25.51	3.69	39.56
37.3	14.52	9.79	6.11	37.36
60.3	2.05	3.82	.87	85.26
56.7	2.66	88.10	1.71	5.65
50.0	0	93.53	.15	4.13
15.5	6.30	4.70	12.41	34.62
17.3	.93	7.47	9.26	31.91
11.5	3.01	5.25	17.26	47.54
15.8	1.08	12.10	19.62	17.14
15.9	5.53	3.59	3.90	65.46
28.6	6.18	3.79	22.10	61.09
17.0	2.26	7.11	6.22	75.33
21.4	7.03	2.05	10.56	77.54
14.4	.74	3.67	21.39	70.04
16.5	21.79	48.82	13.49	10.87
7.0	16.47	31.69	23.03	13.02
3.2	3.85	30.23	2.87	54.81
9.0	2.71	4.22	6.29	83.53
8.6	1.52	4.63	3.72	81.82
4.5	0	4.83	20.80	7.33
3.3	0	29.05	16.64	12.55

category. Only the Centaur Vehicle prime (3-3232) in the second category falls into this range (72% of total subcontracts involve subsystem projects). This exception is primarily due to (a) the fact that the Centaur guidance system was procured by subcontract, while that for the Saturn V Vehicle (of which the other vehicle primes are a part) was procured under a separate prime contract, and (b) the Centaur prime covered the entire Centaur Vehicle, whereas the Saturn V Vehicle is divided into four separate prime contracts.

The subsystem emphasis on research, design and development efforts plus the greater size of the project means that larger dollar commitments are necessary. As a result, the primes in this category are characterized by subcontract ratios which are considerably above that for all primes combined (34%). The ratios for all but 9-150 (Apollo) range between 50% and 60%, with three of the six at the 55% level. However, as indicated by 9-150, these figures cannot be viewed as constants. They must be considered on a project by project basis and adjusted to account for additional factors such as a difference in prime contractor capability (given the nature of the project) and the extent to which the subsystems are procured under separate prime contracts. Within the time constraints of the present study, it is not possible to undertake a comprehensive analysis of the differential "in-house" capabilities of the prime contractors involved in Major Space System projects. However, the fact that North American Aviation participates in all three major prime categories, while the other five firms do not, provides at least a rough indication of its diversified capabilities.

Although the difference in "in-house" capability plays some role, it is doubtful that the extent of the role is enough to entirely account for the gap between the Apollo sub ratio and all others. Instead it is felt that the most significant variable is the fact that a number of the Apollo sub-

systems were procured under separate prime contract. As a result, a larger percent of the prime award is spent on internal work (principally research, development and coordination activities).[66]

The subsystem emphasis on sophisticated technical and research capabilities in the aircraft, electronics and communications industries is consistent with the concentration of 80-95% of all 1st tier procurement in those divisions which contain one or more of the major space complexes (New England, Middle Atlantic, South Atlantic, and Pacific). Once again, the exception is the Apollo project. However, the reason is not inherent in the project or the prime contractor. It is merely that the necessary electronic and communications capability is also present in other areas.

For purposes of determining a more specific subcontract distribution by region, it is necessary to separate the Major System primes into two groups. The first includes 7-100, SNP-1 and 3-3232 and is characterized by the procurement of one very large (relative to total procurement) subsystem project. In the case of these three prime contracts the single subsystem project received 48%, 85% and 45% respectively of total 1st tier dollar awards. The place of performance of the subsystem is a direct function of the industry involved. The scope, technical complexity and research efforts of these projects (particularly 7-100 and SNP-1) are even greater than for other subsystems. Consequently, their performance is limited to only a few more qualified firms. For the aircraft (7-100) and electronic (SNP-1 and 3-3232) projects, California and the Northeastern states respectively are the most likely places of performance.

66/ In an effort to demonstrate the effect of separate subsystem procurement, the cumulative awards for the Apollo subsystem primes were added to the cumulative awards of the 9-150 prime and the 9-150 1st tier subcontracts. The subsystem projects included: the Apollo space suit and life support system and integration checkout system. The result was to raise the sub ratio from 37% to 50%.

The unique nature of the manned spacecraft projects makes them the basis for the second subgroup. No other projects involve the procurement of life support, escape, voice communications, manuel control and sophisticated recovery systems. This wide variety of subsystems means that no one subsystem is dominant. In the case of 9-150, 9-170 and 9-1100 the largest single subsystem received 92 million dollars compared to 291 million and 157 million for 7-100 and SNP-1 respectively. The geographic distribution of awards for the second subgroup involves the following relationship (see Table 24 for comparative figures).

(1) Subsystem awards account for approximately 75% of total 1st tier procurement (range between 71%-85%).

(2) Subsystem procurement demonstrates a consistent breakdown of 50% for aircraft and 45% for electronics and communication (the exact ranges are 44-57% and 39-53% respectively).

(3) Approximately 95% (93-98% of all aircraft industry awards go to the Pacific (California) and Northeastern complex areas. The aircraft specialization of the Pacific complexes is responsible for a 75% - 20% division of aircraft awards between the Pacific and Northeast. The greater the emphasis on rocket motors and engines the larger the share to the Pacific.

(4) Due to the greater geographic spread of capability in the electronics and communications industries, the geographic distribution of these awards is less stable. However, for all practical purposes, the Pacific region does not participate at the subsystem level. The Northeastern states receive 45% of the total procurement for all three primes. However, for each prime the share ranges between 25% and 80%

(5) The distribution of non-subsystem procurement (amounting to approximately 25% of the total 1st tier procurement) is primarily determined

by the industrial emphasis relative to the home area capability in those industries. The primes located in either the Pacific or Northeastern "complexes" procured 55% in the home region, while the corresponding "non-complex" (Missouri) figure is approximately 20%. The Pacific and Northeastern states also received 23% and 15% respectively of non-subsystem procurement from sources outside their home areas.

(6) Because of common overflow fabrication and metal product needs, the East North Central division receives a stable 5% share of total 1st tier procurement (ranged between 4% and 6%).

The conclusions for manned spacecraft primes can be summarized in numerical (% share) terms. Let: P = the cumulative prime awards for all manned spacecraft projects; P_H = the cumulative manned spacecraft prime awards in the home area (Census division or region depending on the dependent variable) ; Po = the cumulative manned spacecraft prime awards in areas outside the home area ($Po = P - P_H$). Given these definitions the conclusions regarding subcontract distribution may be summarized as follows:

(1) Total 1st tier procurement to the Pacific division = .141 (P) + .125 (P_H) + .031 (Po)

(2) Total 1st tier procurement to the Northeast region = .080 to .173 (P) + .125 (P_H) + .019 (Po). The different coefficients for (P) depend on the share of total electronic and communication subsystem Procurement received by the Northeast. The two figures are associated with the extremes previously discussed (25% and 80% respectively).

(3) Total 1st tier procurement to the East North Central division = .025 (P).

Note that a (P) = share of total subsystem procurement and b (P_H) + c (Po) = share of total non-subsystem procurement. One through three above are based on a 50% subcontract ratio and a 75% - 25% split between subsystem and non-subsystem

procurement respectively.

B. Rocket Vehicles and Engines

The primary difference between this category and the previous one is the complexity of the prime activity. Although the main function of the prime contractor in both categories is R &D, coordination, and fabrication, the component parts of the vehicles and rocket engines are smaller and significantly less complex. Whereas the Major System primes involved subsystem projects which were beyond their "in-house" capabilities, the major share of vehicle and engine procurement is for what has been referred to as non-subsystem activities. Some subsystems are necessary for the vehicle projects, but these generally account for a relatively small share of total 1st tier awards (Range from 13.7% to 22.5%. The Center Vehicle 72.1% share has already been discussed). The fabrication of ducting, heat shields, fuel storage tanks, connect and disconnect assemblies, control valves, fuel feed and exhaust systems are characteristic of the larger overflow and part fabrication projects. The emphasis on non-subsystem items such as these provides the rationale for the following subcontract patterns.

(1) Since the majority of fabrication work is done "in-house" and the subcontract projects are smaller and less complex, the subcontract ratio is significantly lower than in the previous category. In the present study, between 15% and 20% of the vehicle or engine prime award is subcontracted (ranges between extremes of 7.1% and 28.6%).

(2) As suggested by the previous examples of procurement, the metal fabrication and metal products industries are noticeably more important. This results in a greater subcontract distribution to the states in the East North Central region. The East North Central combined share of total awards is approximately 10-20%. The actual figures range from a low of 3.9% to a high of 23.0%. However, there

is considerable stability in the 10-20% range (see Table 24).

(3) The home procurement share resembles that of the non-subsystem procurement in the Major System category. Whereas, the previous conclusion was 55% and 20% for complex and non-complex areas respectively, the present category is characterized by a slightly higher complex figure (65%), particularly for the California engine primes. This is primarily the result of a greater participation by local producers via the less demanding technical and research requirements of the subcontracted projects.

(4) With the exception of the Florida primes, the share of awards to the Northeastern states is consistently in the 10-15% range. There is no apparent explanation for the extremely heavy procurement by Florida. The distance factor accounts for some of the difference, but not nearly enough. One additional explanation for prime contract 8-2690 is the phasing of awards for its larger component parts. The prime contract was in operation one and a half years before the reporting system was initiated. Consequently, the reported subcontracts measure only the latter stages of the project. For all practical purposes, the prime was completed as of 1/1/64 (no new NASA obligations reported after that date). This also accounts for the lower subcontract ratio. Given the one and a half year time lag, it is entirely possible that a large portion of the subcontracting was completed before the postcard reporting system was under way.

(5) The share of total 1st tier awards to the Pacific region (California) bears a close relationship to distance. As the source of 1st tier awards moves from Florida to Louisiana to California, the Pacific region's share of total procurement increases from 10-15% (1/8) to 33% (1/3) to approximately 65% (2/3). However, there is further evidence that distance

is not the only important factor. Vehicle projects 7-101 (Saturn IV and IVB Stages) and 3-3232 (centaur Vehicle) procured certain subsystem and large part items which were more tied to the location of key plants in other areas.[67] Consequently, their home procurement shares fell below that suggested by the majority of California primes.

Once again it is clear that the distribution figures are not able to provide "to-the-dollar" predictions. They are merely designed to give first approximations which must be adjusted for those factors which are not explicitly accounted for (the presence of subsystem projects, different "in-house" capability and separate prime procurement of subsystem and large parts).

C. Feasibility Studies

As the name suggests, the prime contracts emphasize research, design and development as opposed to "follow-on" fabrication. Consequently, the most significant differences between this category and the other two are a greater role of "in-house" activities and a subsequent lower subcontract ratio. Subcontracts account for 5-10% of the cumulative prime awards (ranges between 3.2% and 9.0%).

The subcontracting that occurs has the following distribution characteristics:

(1) The size of home procurement is greater than any other category. This is consistent with the nature of the items procured. By virtue of the R & D emphasis, the subcontracts involve related items such as testing services and equipment, construction of facilities (testing and laboratory) and engineering services. These items are

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[67] Examples of these items are: the Centaur guidance system, a computer data reduction system, a hydraulic pump and various control motors and engines.

more likely to be suppled at the local level than are the more complex subsystem and large part projects associated with the fabricationstage. However, it must be pointed out that, although the Feasibility Study awards are characterized by greater procurement in the home region, the extent of procurement under a particular prime contract is determined by the type of subcontract items contracted for. If subsystem or large component part projects occur (7-1, 8-2577 and 8-5623), there is a play-off between home procurement and the "complexes". Comparative figures demonstrating the magnitude of this play-off are only available for California. In this case the home procurement share dropped from approximately 80% to 55%, or a loss of 25% of total procurement (see Table 24). At the same time, the share of awards to the Northeast "complexes" rose from approximately 5% to 35%.

(2) The distribution of awards beyond the home area follows essentially the same pattern as the "follow-on" project, with the exception of a somewhat smaller share of awards to the East North Central and the complexes (see Table 25). Again, this is consistent with the relatively minor emphasis on fabrication (ie, there is less need for the electronic and metal component parts supplied by the firms in these areas).

D. Criticisms of the Alternative Approach

The value of the conclusions reached in A. through C. above is open to question on the grounds that in the future one of two factors may lead to a change in the geographic distribution of subcontract awards: (a) The present prime contractors may be replaced by new ones who subcontract differently (in a geographic sense) even though engaged in the same prime activities. (b) The present

TABLE 25

COMPARATIVE DISTRIBUTION FIGURES FOR

FEASIBILITY STUDIES AND FOLLOW-ON CONTRACTS

Prime Type and Contract Number		Subcontract Ratio (%)	Share to East North Central Region (%)	Share to Complexes Outside Home Region (%)	Share to Home Region (%)
Feasibility Study	(W-16)	9.0	6.3	4.9	83.5
Follow-on	(8-5604)	21.0	10.6	8.6	77.5
Feasibility Study	(8-19)	8.6	3.7	5.1	81.8
Follow-on	(8-5603)	17.0	6.2	8.6	75.3
Feasibility Study	(7-1)	3.2	2.9	36.2	54.8
Follow-on	(7-101)	11.5	17.3	12.3	49.0
Feasibility Study	(8-2577)	4.5	20.8	13.5	20.6
Follow-on	(8-5608)	15.5	12.4	45.6	13.9
Feasibility Study	(8-5623)	3.3	16.6	41.6	35.1
Follow-on	(3-3232)	15.8	20.7	57.5	17.4

Source: NASA first tier subcontract reports for the period January 1, 1962, to June 30, 1966.

prime contractors may subcontract differently.

There is no way to say for sure that either or both of these situations will not occur. Nor would the present study deny that to some extent each prime contract is unique and therefore, can be expected to subcontract in a slightly different manner from all the rest. However, on the basis of available subcontract data, it is felt that enough stability exists within each prime category to allow certain generalizations regarding the expected size and distribution of 1st tier procurement. As pointed out earlier, these generalizations will not allow perfectly accurate predictions, but it is felt that they do provide a more detailed insight into the factors affecting sub-distribution than presently exists. In defense of this position, the following observations are made:

A. In carrying out its space efforts, NASA has consistently relied on single large prime contracts for procuring the major space systems (Mercury, Gemini, Apollo, LEM and the Saturn V vehicle stages). As a result, the qualifying firms are limited to those few with the proper balance of technical, research and management capability and experience to undertake the design, development and coordination of a complete space system. In addition, the nature of these space systems is such that they are best suited to the existing technologies of the aircraft and electronics industries (see the discussion of prime firms and functions in Chapter 4). In light of these observations, it is not surprising to find that the top ten prime contractors are among the largest firms in both industries. The same firms have been included in the top 12 prime contractors since fiscal 1962.[68/] Barring a sudden change in NASA policy (regarding the use of total space system procurement) and assuming that rocket boosters, manned and unmanned space-

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68/ See the Annual Procurement Reports of the National Aeronautics and Space Administration, fiscal years 1961 through 1966.

craft continue to be the major hardware items, it is very likely that the same "key" aircraft and electronics firms will serve as the top prime contractors. This is especially so in view of the significant barriers to entry in either industry, particularly at the level necessary to carry out large scale space system projects.

B. The subcontract data in Table 24 suggest that in the event different firms do participate at the prime level, their subcontract patterns would generally conform to those of the other firms performing the same tasks. Note the change in subcontract ratio and geographic distribution of awards for North American Aviation as it performs in all three prime categories. Within a given category its subcontract ratio and geographic distribution of awards are very similar to those of other prime contractors. The same is true for Boeing and Aerojet-General. On the basis of these examples, it does not seem reasonable that a change in subcontract distribution would necessarily accompany a change in prime contractor. For example, all liquid propellent rocket engines have common component needs. The component specifications may differ, but the product is basically the same. Therefore, unless there is a significant relocation of firms, these common needs will be met in the same geographic locations as now.

C. The figures in Table 24 also indicate that the present prime contractors will more than likely subcontract the same way in the future. Unfortunately, the limited time period of available data prevents a time series approach to this issue. However, a cross section of different rocket engine primes performed by North American Aviation indicates that within a prime category, a contractor's subcontract pattern will not vary to any great extent as the hardware item changes. 69/ The amount of variation

69/ The appropriate prime contracts are: 8-5603 (J-2 rocket engine), 8-5604 (F-1 rocket engine) and 7-162 (H-1 rocket engine).

from contract to contract is minimal:

(1) Subcontract ratio = 14.4% to 21.4%

(2) Home division procurement = 70.0% to 77.5%

(3) Complex area procurement = 74.4% to 86.1%

E. Second Tier Predictions By Region

Thus far the attempts to forecast subcontractdistribution have been confined to 1st tier procurement. Unfortunately, the project classification approach used in predicting 1st tier distributions is not applicable at the 2nd tier level. As discussed in Chapter 2, there is no way to correctly associate a given 2nd tier subcontract award to a particular 1st tier project. It is possible to associate 1st and 2nd tier contractors, by means of their contract number, but many 1st tier contractors perform more than one project in the same geographic location.

In an effort to approximate the industrial nature of 2nd tier procurement from a given area, it will be assumed that all awards originate in the subsystem projects performed in that area (recall that the major source of 2nd tier awards is the subsystem projects). For instance, it is reasonably accurate to assume that the 2nd tier awards from the West North Central, South Atlantic (Florida) and Mountain regions would have an electronics orientation. In each case, the total 1st tier awards received were dominated by a few large subsystem projects in the elctronics and communications industries. Using the 1st tier subsystem awards as a basis, the industrial emphasis of each region's 2nd tier procurement may be classified as follows:

A. New England and Middle Atlantic - Each region received subsystem awards in the three major industry categories (electronics, communications and aircraft). As a result, their 2nd tier awards may be classified as both electronic and non-electronic, with a bias in the direction of the former

category.

B. East North Central - non-electronics (metal fabrication and metal products)

C. West North Central - electronics

D. South Atlantic - electronics

E. Pacific - both, with a bias in the direction of non-electronics (aircraft related).

The conclusions to follow will concern the share of 2nd tier procurement received by the Northeast and Pacific regions. The reason is simply that these areas are the main centers of 2nd tier subcontract activity. On the basis of the 2nd tier procurement patterns in Table 8, the following distribution relationships are revealed:

A. Home procurement for the Northeast and Pacific areas is 2/3 and 3/4 respectively.

B. Together, they receive 75-80% of all 2nd tier dollar awards let outside the borders of the other regions. The exact shares are as follows:

East North Central	=	77.4%
West North Central	=	77.8%
South Atlantic	=	74.6%
Mountain	=	83.1%

C. Their share of 2nd tier procurement received from other divisions can be stated more exactly according to the industrial nature of the awards:

(1) The Northeast and Pacific regions receive 25% and 35-50% respectively of the larger more technical awards and particularly those with an electronics emphasis (see the procurement patterns of the West North Central, South Atlantic and Mountain regions).

(2) Each receives approximately 10% of non-electric awards (see the East North Central procurement), and a like share of all awards from each other.

CHAPTER VI

SUMMARY AND CONCLUSIONS

On the basis of the prime and subcontract data for the period January 1, 1962 through June 30, 1966, it is concluded that the 1st and 2nd tier subcontract programs provide a wider and less concentrated distribution of NASA dollars, particularly at the state level. However, the extent of the redistribution (as reflected by the total net distribution of prime awards) is only of marginal significance at the more aggregate regional level.

Since the major sources of subcontract procurement are concentrated in relatively few states (California, New York, Louisiana, and Missouri let 88.2% of all 1st tier awards in the present study), it is not surprising to find that on a state basis the subcontract program provides a significant geographic redistribution of funds. However, it should be recognized that part of the reason for this is the fact that states such as Connecticut, Massachusetts, Pennsylvania, Ohio, and Michigan did not receive a share of prime awards (in the present study) comparable to their share of all NASA primes. Consequently, these states become net "importers" of subcontract awards to a greater extent than if their normal "export" share would have been included.

The magnitude of the redistribution of funds on a state basis did not carry over to the region. In most cases the effect of subcontracting amounted to a change of 1% or less in the regional share of total NASA dollars received. The net "export" position of one state in a given region was matched to a large extent by the net "import" position of another. The notable exceptions are the Pacific and New England regions, where the 3.8% (of NASA prime awards) net loss of the Pacific is accompanied by a 3.0% net gain for New England. However, the effect of the change in net shares is minimal when the New England, Middle Atlantic and Pacific regions are considered together. The three regions received 72% of all

prime awards and were the source of 76% of all 1st tier procurement. Yet their combined net loss through subcontracting amounted to only 1.25% of their original prime awards. It would appear that just as the loss of one state in a region tends to be matched by the gain in another, the loss by one of the major centers of space activity (Pacific) is matched by the gain of another (New England). As a result, approximately 3/4 of all NASA procurement is confined to a three region (6 state) geographic area.

One of the factors responsible for the limited geographical redistribution of NASA funds is the relatively small share of total prime contract awards spent outside the firm. The subcontract ratio for total prime contract procurement in this study amounted to 34%. That is, 66% or approximately 2/3 of all prime awards remained "in-house". One reason for this situation is that the majority of space hardware items require designs, parts, materials, and occasionally technological break-through in areas which are not often involved in commercial production. For example, the experience in providing strategic aircraft and missile systems for the Department of Defense has given the large aircraft firms an edge in competing for those space systems involving similar hardware items such as rocket vehicles, rocket engines and spacecraft. However, the need for greater compactness, adaptations for extreme temperature changes, the integration of more subsystems, nuclear and solar energy propulsion systems, plus other modifications means that even for the most directly adaptable industries and firms, space work necessitates substantial outlays for research, design, development and testing activities. Since most of these activities are associated with planning and fabrication of the final hardware item, they generally are performed by the prime contractor's staff. In fact, the size and capability of these staffs (technical, research, and managerial) are key factors which are weighed in selecting among alternative contractors.

The emphasis on R & D efforts is not the only reason for the low 1st tier subcontract ratio. The prime and 1st tier contract data examined in the present study indicate that the extent of subcontracting varies with the particular prime project. Consequently, the 34% subcontract ratio is not the result of a stable prime - sub relationship for all space systems. Actually, a 34% subcontract ratio is consistent with only one of the major prime contracts, the Apollo spacecraft. It is the single largest project, but does not dominate the total subcontract pattern. Apollo accounts for 21% of total 1st tier procurement. Clusters of subcontract ratios exist at extremes on either side of the 34% figure. The 22 prime contracts discussed in Chapter 5 (which let 82% of all 1st tier dollar awards) were characterized by stable subcontract ratios in the 5-20% and 50-60% ranges. It was further concluded that the presence of these extremes was the result of a difference in project emphasis regarding the number and size of major component parts. To reduce the errors associated with a subjective classification of subcontract activities, only two categories were considered, subsystem and non-subsystem.

Basically, subsystem activities are characterized by large, highly complex projects which, by virtue of their complexity, require much the same degree of research, design and development as prime contract projects. As a result, they necessitate large scale funding over extended periods of time. The subsystems included in the present study received cumulative awards ranging from approximately $10 million to $291 million. The non-subsystem activities are associated with the opposite situation. The items procured are reduced in scope and generally are accomplished with minimal preliminary R & D efforts. As a result, less of a dollar outlay is necessary. In the present study, only one project received cumulative awards in the 10 million dollar range. The majority received two million dollars or less. The comparative effect of subsystem and non-

subsystem activities on the size of the subcontract ratio is commensurate with their dollar outlays. The major space system prime contracts, which were most subject to subsystem procurement, consistently had subcontract ratios in the 50-60% range, while the rocket vehicle and engine projects rarely exceeded 20%.

The size and number of subsystem projects must be considered in relation to two other factors, namely the "in-house" capability of the contractor and the extent to which the subsystems are provided under separate prime contracts. For example, North American Aviation (Apollo), Grumman Aircraft (LEM) and McDonnell (Gemini) received prime contracts for manned spacecraft hardware which involved essentially the same emphasis on subsystem activities (life support, voice communication, escape and survival, and landing and recovery). However, the broader space responsibility of North American (vis-à-vis rocket engine and vehicle work) during the period covered by this study, and the separate prime contracts for certain Apollo subsystems (life support, guidance and checkout) led to a 37% subcontract ratio compared to 56% and 54% for the Grumman and McDonnell projects respectively. When the value of the separately procured Apollo subsystems was added to the prime and subcontract awards, the subcontract ratio rose to a more representative 50% level.

The 34% subcontract ratio for 1st tier procurement dropped to 20% at the 2nd tier level. The less complete 2nd tier contract reporting and, more importantly, the absence of subsystem procurement are responsible. The implication for regional impact analysis is quite clear. If a region is unable to participate at the prime and 1st tier levels, the chances of receiving sizeable awards at succeeding levels of procurement become substantially less. For all practical purposes, the major economic impact of space activities is at the prime and 1st tier procurement levels.

Although the extent of "in-house" activities is a major factor contributing to the absence of a significant redistribution of prime contract procurement, it does not explain why the 34% which was subcontracted did not involve a greater geographical distribution. The answer to this question goes to the heart of the problem concerning this study, namely, what factors determine the geographic distribution of subcontract procurement. In answer to this question it is concluded that three primary forces shape the geographic distribution of subcontract awards: (a) the industries in which the subcontracts are performed, (b) the geographic distribution of production capability in these industries, and (c) the degree of technical, research and scientific sophistication required to perform the subcontract activities (the subsystem and non-subsystem nature of the awards).

The relationship between the industrial orientation of subcontract activities and their geographic distribution is fundamental. Those states or regions which possess a concentration of productive capacity in a particular industry are able to compete more effectively for the subcontracts involving that industry (via a greater number of firms and/or the presence of the larger firms with more diversified capability). Examples of areas of specialized capability in the industries most relevant to space work include: (a) California, with general capability in most relevant industries (electronics, communications, instruments and research labs), and especially ability to handle aircraft-related projects such as thrust chambers, landing and recovery systems, propellent tanks, fuel feed and exhaust assemblies, motors and engines, (b) Connecticut, with similar, though less complete, aircraft-related capability, (c) Massachusetts, with electronics strength, (d) the Middle Atlantic region, with electronics, communications, measuring instruments (physical and research), and computer firms, and (e) the East North Central region and Pennsylvania, with metal, fabricated metal products, and industrial machinery companies.

The subsystem emphasis on large, complex projects requiring extensive R & D efforts has a definite impact on the distribution of these awards as well as total 1st tier procurement. The major characteristics of that impact are as follows:

A. Because of its size (in terms of cumulative awards), subsystem procurement plays a major role in determining the level and distribution of total 1st tier procurement. The six prime contracts in the major space system category subcontracted 68% of the total 1st tier awards, and between 61 and 91% of their procurement involved subsystem activities. As a result, subsystem procurement accounted for 51% of all 1st tier awards included in the present study. The distribution of 1st tier awards is therefore heavily influenced by the subcontracting decisions of a few space system prime contractors, and the geographic distribution of their subsystem activities. However, because the subsystem share of total 1st tier procurement is limited to 51%, its importance in determining the total 1st tier distribution is not as great as is implied in earlier studies.

B. The concentration of prime contract awards in the aircraft, electronics, and communication industries (16 of the top 20 prime contractors are in these industries) carries over to their subsystem activities. In the present study, 94% of all subsystem procurement was performed in these three industries. The aircraft, electronics, and communications industries respectively received 53%, 30%, and 11% of total subsystem dollar outlays.

C. The similarity of industry and function between prime and subsystem activities is associated with a similarity of firms. All but 4 of the top 20 subsystem firms (which received 91% of all subsystem awards) were included among the top 50 prime contractors.

The concentration of prime contract awards in the aircraft industry and the approximately even split of subsystem awards between aircraft and electronics plus communications meant that most of the firms functioned primarily as subcontractors. In other words, they received larger cumulative dollar awards from subsystem activities. However, of perhaps greater importance is the fact that the bulk of all prime and subsystem activities are performed by a close network of firms.

This has two implications for regional impact analysis: (1) The geographic distribution of subsystem awards appears to be much more heavily influenced by the quality (as measured by the presence of firms with extensive R & D capability and experience) than by the sheer amount of industrial capability. This distinction helps to explain why the West North Central region (with 3.5% and 3.8% of total United States employment in the electronics and communications industries respectively) was able to attract 11.0% of total subsystem procurement while the East North Central region (with 20.2% and 26.8% of electronics and communications employment) received only 1.8%. Collins Radio in Iowa and Honeywell in Minnesota possess strong technical and research capability for producing space subsystems. (2) The similarity of prime and subsystem firms results in a common geographic distribution of awards. The New England, Middle Atlantic and Pacific regions together, which received 70% of the sample prime awards, obtain an even larger share (79%) of the resulting subsystem procurement. Consequently, those regions which are unable to participate in a substantial way at the prime contract level seem to have even less success in participating in subsystem procurement.

D. Because subsystem procurement is tied to the plant location of a few key firms, the distance variable is of no particular significance. The need

for sophisticated research capability outweighs the advantages of reduced transportation costs and nearness to market. Subsystem awards move freely from coast to coast in response to the location of the "key" R & D firms. In the present study, 75% of all aircraft-related subsystem dollar awards are performed in California even though 52% originated in Missouri and New York. The same is true for the New England and Middle Atlantic regions. The two received 46% of all electronics and communications subsystem procurement, with 54% of that amount originating in other regions. Since distance is of only marginal significance, the importance of home procurement is relevant only to the extent that the home region possesses one or more of the "key" R & D firms.

The "off-the-shelf" nature of non-subsystem procurement is characterized by smaller and less research-oriented activities. The uniqueness of space hardware needs requires product adaptation and redesign, but extended periods of research and development are not required for non-subsystem activities. The emphasis on component parts, materials, and services is associated with the following implications for the geographic distribution of awards:

A. The non-subsystem activities are less tied to the specialized R & D capabilities of a few "key" firms. Consequently, a larger number of firms in a wider geographic distribution are able to participate. The top 25 non-subsystem firms received 33% of total dollar awards compared to 70% and 96% for the top 25 prime and subsystem firms respectively. This does not mean that a difference in firms necessarily accompanies the change in function. Of the top 50 non-subsystem firms, 20 were among the top 50 prime firms and 17 among the top 25 subsystem. However, the extent (dollar share of total non-subsystem awards) of their participation is smaller than in the case of prime or subsystem procurement.

Since more firms can effectively compete, the resulting geographic distribution of awards is less concentrated. This is reflected in the comparative figures for those regions which did not participate, to any great extent, in subsystem procurement. The combined share of the East North Central, East South Central and West South Central regions is .9% of subsystem and 19.8% of non-subsystem procurement. It is clear that the non-subsystem procurement is primarily responsible for the greater geographic spread of subcontract procurement. The preceding (subsystem) and succeeding (2nd tier) subcontracting is more concentrated.

It must be recognized that some of the overflow fabrication and part projects are large and complex enough to be limited to the more specialized or larger capacity firms. However, these awards do not dominate total non-subsystem procurement.

B. Because non-subsystem projects involve more standard production activities, the advantages of nearness to market and the role of transportation costs (i.e. the importance of distance from the prime contractor) become more influential indetermining thegeographic distribution of awards. Consequently, the local or home region producer has a competitive advantage via lower transportation costs and reduced delivery time, particularly for materials, services, and smaller component parts. The home region share of procurement for the major sources of 1st tier subcontracts increased significantly as the influence of subsystem procurement was removed.

C. Although the role of distance is considerably more important, the need for some product adaptation and specialization means that a region's relative industrial capability remains a major factor in determining its share of procurement. The ability of the New England, Middle Atlantic, and Pacific regions to continue to receive sizeable shares of non-subsystem awards

(37% from Missouri and 42% from Louisiana) reflects the fact that the aircraft and electronic parts, electronic equipment, and testing services were more readily supplied by these areas of specialization. The three regions received 66% of all non-subsystem awards. However, some shift in industrial emphasis is evident. Since parts and materials are more associated with the fabrication stage, the non-subsystem activities have a greater tendency to involve metal materials, fabricated metal products, instruments, gages, and industrial machinery. By virtue of its specialization in these industries, a larger share of non-subsystem awards flowed to the East North Central region (.9% of subsystem compared to 9.0% of non-subsystem procurement).

In the present study, 2nd tier subcontract procurement was found to be entirely of a non-subsystem nature. As a result, the previous conclusions regarding the importance of distance, the role of home region procurement and the larger share of awards to the East North Central are equally applicable. However, the following additional observations were made:

A. The primary sources of 2nd tier procurement are 1st tier subsystem projects. Because of data limitations, it is not possible to directly associate 2nd tier procurement with a given 1st tier project. However, each of the primary sources (states) of 2nd tier awards was a recipient of one or more large subsystem contracts. The combination of this and the increased role of home procurement is partly responsible for the greater 2nd tier regional concentration. This is particularly true for the Middle Atlantic and Pacific regions which let 26% and 37% of all 2nd tier dollar awards and procured 66% and 78% in their home region.

B. The large net "import" positions of the East North Central and Pacific regions and net "export" position of the West North Central region suggest

that the industrial emphasis is at least as important as distance. The increased share to the East North Central region has already been accounted for by the wider participation of metal and metal products and machinery industries. The low level of home procurement for the West North Central region is the result of the electronic nature of the subsystem activities in Iowa and Minnesota. The electric component, electric equipment and testing capability of the home region is smaller than that located on either Coast. Consequently, the Pacific and Northeast regions respectively received 48% and 26% of subcontract dollars let by firms in the West North Central region.

The large share of electronics procurement in the Pacific region is interesting since its share of prime and 1st tier procurement was primarily confined to the aircraft industry. The implication is that while California's electronic capability is sizeable, it is limited to the less complex activities. The larger more technical prime and subsystem projects are confined primarily to the East Coast complexes.

The New England, Middle Atlantic, and Pacific regions are the major centers of NASA contractor activity. Their combined share of total procurement at each level is as follows:

Procurement Activity	Share (%)
NASA Prime Universe	64.3
NASA Prime Sample	72.1
All 1st Tier	73.0
A. Subsystems	79.5
B. Non-subsystems	66.2
All 2nd Tier	75.8

These figures indicate that within the three regions there is a concentration

of subsystem and non-subsystem capability in the aircraft, electronics and communications industries. On this basis, there is reason to conclude that the military "R & D complex" areas discussed in studies by the Stanford Research Institute apply equally as well to NASA procurement. This is certainly the case for the Los Angeles and San Francisco complexes in California and the Boston and Northern New Jersey - New York City complexes in the Northeast. In addition, there is evidence of an additional complex in the Cape Kennedy area of Florida. It is less extensive and more dependent on the branch plants of a few "key" firms (Radiation, Honeywell and Electro Mechanical Research), but is able to attract a significant share of procurement at the three levels examined in this study (Prime = 4.5%, 1st tier = 4.5% and 2nd tier = 2.7%). The presence of a complex in the Cape Kennedy area is consistent with the emphasis of all major space efforts on final checkout and launch activities.

Because the complexes are the primary centers of space procurement, there is some degree of competitiveness among them. Over the four year time period of this study the share of 1st tier procurement received by the five complexes remained stable (64% to 68%). However, the amount received by a particular complex varies as the larger prime contracts move into different phases of their project. Variation in the share of total procurement to the East and West Coast complexes is primarily a function of the industrial emphasis. With a greater emphasis on subsystem and overflow work in the aircraft industry, the share of total awards to the Pacific complexes increases at the expense of those on the East Coast. The opposite is true when the emphasis is on the electronics or communications industries. There is further evidence of competition between the East Coast complexes for electronic and communications subsystems. When the share of awards received by one region increases, that of the other decreases proportionately (assuming the total amount remains constant).

The statistical technique of multiple regression analysis was employed to develop a means of predicting 1st and 2nd tier subcontract distributions given the size of the prime contract awards. From the results, it was concluded that the 1st tier distribution by state cannot be accurately predicted on the basis of each state's share of industry employment and occupational variables. The primary reason for this is the major role of subsystem procurement. As stated earlier, these awards are tied to the location of "key" R & D firms. Consequently, the distribution of subsystems is not necessarily correlated with a state's relative capability in a given industry. The best regression was a combination of the state share of electronic technicians plus employment in industry 382 (Measuring and Indicating Instruments). The R^2 was .79 and the beta coefficients were significantly greater than 0 at a .025 level of significance.

By virtue of the emphasis on non-subsystem procurement, 2nd tier regression equations generally provided more accurate predictions. It will be recalled that non-subsystem procurement is more responsive to the general industrial capability of an area. Of particular importance in this respect is the larger share of 2nd tier awards to the East North Central states. The best regression equation contained the state share of employment in industry 3694 (Electrical Equipment for Internal Combustion Engines), Metallurgical Engineers, and the distribution of total 1st tier awards. The 1st tier distribution was a proxy variable for distance and the electronics and instruments industries. The R^2 was .86 and the partial correlation coefficients were significantly greater than 0 at a .025 level of significance.

An alternative approach on a regional basis was offered as a more accurate method of forecasting. The primary objection to the multiple regression approach was that it did not reflect the difference in 1st tier subcontract

distributions which results from the different prime contracts. The predicted distributions were only valid for the entire subcontract program and even then they held only so long as the mix of prime contract activities did not change. To correct this deficiency, the alternative approach provided regional distribution forecasts based on three different prime contract categories. In each category the prime contracts consistently placed a different emphasis on subsystem and non-subsystem procurement and "in-house" capability and the extent of subsystem procurement under separate prime contracts. Because the manned spacecraft projects are the major sources of 1st tier subcontracts (the three in the present study accounted for 44% of the total dollar awards), an attempt was made to formulate a forecasting model for the prime contracts in this category. The forecasts were limited to the most important centers of 1st tier activity, namely the Pacific and Northeastern regions. The resulting equations are as follows:

(1) Total 1st tier procurement to the Pacific region = $.141\ (P) + .125\ (P_H) + .031\ (P_O)$

(2) Total 1st tier procurement to the combined New England and Middle Atlantic regions = $.080$ to $.173\ (P) + .125\ (P_H) + .019\ (P_O)$.

Where P = the cumulative prime awards for all manned spacecraft projects; P_H = the cumulative manned spacecraft prime awards in the home region; and P_O = the cumulative manned spacecraft prime awards in all other areas outside the home region. A 50% subcontract ratio and a 75%, 25% split between subsystem and non-subsystem procurement is assumed.

The first variable in each equation represents the share of total subsystem procurement (let by manned spacecraft primes) received by a given region. The different variable coefficients for equation 2 depend on the share of total

electronic and communication subsystems to the Northeast. Together, the second and third variables represent the share of total non-subsystem procurement (let by manned spacecraft primes) received by a given region.

ADDITIONAL STUDY AND DATA NEEDS

A. The basic conclusions described above have their greatest application in the area of regional economic analysis. As was pointed out in the introduction, the available studies on the regional impact of Federal procurement consistently have dealt with the subcontracting program on the basis of the employment distribution of "key" industries and a general assumption as to the size of the subcontract ratio. In the present study, it was pointed out that the subcontract ratio is highly variable and that although there is a definite correlation between "key" industry employment and subcontract location, the resulting regressions have limited application on an individual contract basis.

Consequently, further study is needed in an effort to integrate the Manned Spacecraft forecasting models into a regional employment or income model similar to those developed by Peterson and Tiebout and Se-Hark Park.[70] The subcontract ratio and geographic distribution relationships would provide a first approximation of the net final demand to the Pacific and Northeastern regions. In addition, the industry breakdown of subsystem procurement would provide a starting point for calculating the direct and indirect employment and income effects resulting from the change in demand of the major subsystem suppliers. An input-output table could be used for this purpose.

B. Since Department of Defense procurement represents a much larger dollar outlay than NASA, it is important to know to what extent the subcontract distribution conclusions reached in the present study apply to DOD prime

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[70] R. S. Peterson and C. M. Tiebout, op. cit. and Se-Hark Park, op. cit.

contract activities (particularly those involving extensive R & D efforts). As pointed out in Chapter 3, the conclusions of the SRI study of DOD awards bear a striking similarity to those for NASA developed by the present study. This is especially so with regard to the major role played by the Northeast and Pacific Coast "complexes". However, more comparative work must be done in order to determine the extent of such a similarity. It would be interesting to see if the relationship between the nature of DOD prime activities and the resulting sub distribution is the same and as consistent as for NASA.

C. More work is also needed on NASA procurement patterns. Of special importance is a larger more representative sample of 1st tier awards from primes in the New England and East North Central regions. This is particularly important for the conclusions regarding:

(1) The role of nearness to "complex" areas as a determinant of 1st tier distributions. The subcontracting patterns of the California and New York primes generally support the contention that prime contract location in or near complexes leads to large scale subcontracting in those areas. However, a larger sample from the New England and South Atlantic regions is needed to provide more conclusive evidence.

(2) The importance of the nature of prime work (as opposed to the prime firm and its location) in determining the distribution of 1st tier subcontracts. Most of the evidence pertains to California primes. Additional prime samples in the rocket engine, unmanned craft and initial R & D categories are needed from other states. Of course, it must be recognized that the firms most able to perform the major system work in these areas are concentrated in those states which are represented in the present subcontract sample. To the extent that major prime "capability" may not exist in other areas, the results of

this study would be sufficient. Therefore, a preliminary further step would involve determining the extent and distribution of such additional "capability".

D. To aid in determining prime and major subsystem capability, certain improvements in data classification and coverage would be helpful:

(1) A more representative SIC classification is essential. As already discussed, the present categories make no allowance for differences in technical and research inputs. At present, NASA and "appropriate agencies of the Government" are working on an industry classification which will more "adequately reflect product lines of the various aerospace companies"[71] Once this is completed, it would be instructive to reexamine the regression analysis of Chapter 5. It is quite possible that the added emphasis on R & D capability under the new classifications will improve the significance and reliability of the regression equations.

(2) An R & D vs non - R & D breakdown of subcontract activities would also be of value in explaining the various subcontracting patterns. The present work descriptions are not adequate for this purpose.

E. The method of reporting 2nd tier subcontracts needs to be reexamined in light of the conclusions of this study. In order to more accurately estimate the size and distribution of 2nd tier subcontracting, it is necessary to examine the 2nd tier patterns resulting from individual 1st tier contracts. Under the present report system, there is no way to associate 2nd tier subcontracts with a given 1st tier project. The importance of such an association at the prime - 1st tier level emphasizes the need for the same data at the 1st - 2nd tier level.

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[71] Pryor letter to Murray L. Weidenbaum, see Footnote 40.