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ARPANET MANAGEMENT STUDY: NEW APPLICATION AREAS

Carson E. Agnew, et al

Cabledata Associates, Incorporated

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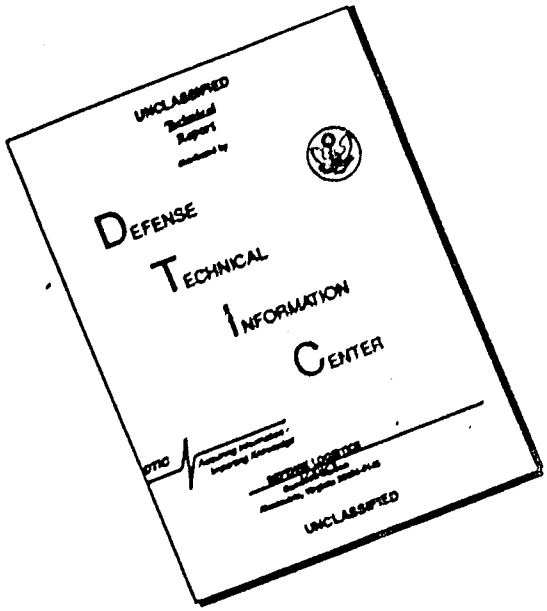

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Discusses new applications for computer-netting technology, developed by ARPA-IPTO, which has high payoff to DoD. Main thrust is on feasibility of automating certain routine data base/communications functions within defense procurement system. Target of work is potential dollar savings on the order of $100 million per year, and more rapid and effective procurement action under better defense management control. Also discusses procedures used in reaching the tentative conclusions; contains description of magnitude of the problem; and proposes preliminary hardware configuration design to allow more careful refining of parameters.

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ARPANET MANAGEMENT STUDY: NEW APPLICATION AREAS

FIRST QUARTERLY TECHNICAL REPORT

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ABSTRACT

This project seeks the discovery of new applications for computer-netting technology developed by ARPA-IPTO that have high payoff to the Department of Defense.

The thrust of the project is now upon the consideration of the feasibility of automating certain routine data base/communications functions with the defense procurement process. This domain was selected for the following reasons:

1. The potential dollar savings with even partial automation could be very high -- as a target we are aiming for savings of over $100 million per year.

2. Large secondary savings could also be expected by more rapid and effective procurement action under better defense management control.

3. The National Commission on Procurement has recently made recommendations for greater uniformity in the procurement process. Greater uniformity would simplify automated aids to procurement.

4. Some ancillary applications that would interconnect with the proposed system have already been automated and others are under consideration.

The report discusses the procedures used in reaching the tentative conclusions; contains a description of the magnitude of the problem; and proposes preliminary hardware configuration design to allow more careful refining of the parameters.

INTRODUCTION

This is the First Quarterly Technical Report submitted under this contract, and covers the first three months' effort. The present report is intended only as a snapshot of work in progress and as a statement of tentative conclusions subject to change and later refinement.

What we set out to do in this study is to proceed in a systematic manner to select the first of a few separate potential areas of application for new computer-netting technology developed by ARPA-IPTO that could have significant measurable benefits to the Department of Defense.

CONTENT

This report consists of a number of appendices that contain the meat, while the body of the report itself tries to keep itself mercifully brief for the busy reader. One Table of Contents serves both the report body and its appendices, and this is also true of the List of Figures and the List of Tables.

Purpose of Project and Methodology Used

The purpose of the project and the approach used is described in Appendix A.*

This first appendix discusses the basic methodology that we use to narrow the domains of interest and describes the process that we shall be following during the remainder of this study.

We set out to find that single area that we believed would produce the greatest payoff using computer automation via computer-netting. In our selection process we were concerned less with whether it was the greatest, or second greatest, or even the n'th greatest dollar saving application area, than we were in separating major domains involving very large potential savings from those that were relatively small.

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*This appendix is essentially taken from the initial proposal for this project and is included in the companion Quarterly Management Report. It is also reproduced here since the distribution list of this Technical Report is broader than that of the Management Report.

Where Does the Money Go?

Appendix B, prepared by Carson E. Agnew, examines the composition of labor expenditures within the Department of Defense seeking new domains for information automation to produce the size savings sought.

Agnew singles out functions performed by labor grades GS-11 through GS-13 as constituting the place where the largest total dollar volume resides. This middle level also tends to perform functions that have a sufficiently replicative component that might be accommodated within the near term state-of-the-art of information automation.

As an aside, we initially tried to follow the lead raised by Dr. Stephen Lukasik at the ARPA Principle Investigators' meeting in February 1974 in which he said in effect that the IPTO contractors were not producing computer automation efforts to help him and other people at his level in the Department of Defense in the performance of their jobs. We considered services for such applications, but as will be seen in Appendix B, Agnew shows that we can probably afford to invest about 60 times as much in automating the functions of middle rather than top management using the metric of tangible visible savings. Therefore, we decided to focus upon the GS-11 to -13 levels instead of the higher levels.

Why Procurement?

Appendix C, written by David Caulkins and Paul Baran, discusses why we selected procurement as the target domain to explore application of computer automation.

Basically, the reasoning is based upon the following five points:

1. the process is labor intensive;

2. the size of the activity is large;

3. the activity is highly information intensive;

4. the separate parts of the system are geographically distributed and would benefit by the new data communications capability;

5. it has received relatively little attention of past information automation efforts and the work of the National Commission

on Procurement now provides a good climate in which to consider innovation.

Relationship to Other Work

There are other governmental systems that exist today and some proposed for tomorrow that will interface and become important parts of the proposed overall system for procurement. It is helpful when considering such other systems to distinguish between basically logistic control systems as opposed to the procurement management system that we shall describe. The logistic support system art is a highly developed business and represents major successes of earlier DoD computer automation efforts. What we have in mind here is focusing upon that residual sector of the procurement process not yet successfully aided by the computer. What is different today than yesterday that makes this approach timely is:

1. the availability of new cost-effective computer communications system developments;
2. the availability of interactive software developments;
3. reduced costs of minicomputers; and
4. larger memory at lower cost.

All together these suggest that it is time to carefully consider extending computer automation to a new domain within the Department of Defense.

General Nature of the Proposed System

While some information automation systems have been built that can provide portions of the services envisioned, and still others proposed, our approach has been to stand aside from the distraction of present interfaces and review the entire process from afresh. This has meant finding out how the present procurement process works, by reading and by interviews, and seeking to incorporate as changes those new ideas for improvements raised by the National Commission on Government Procurement.

From this background we seek to suggest what might be possible using tomorrow's new technology, rather than restrict our thinking

to what we can do using yesterday's technology. Even at this early stage of investigation we can envision a potentially markedly different system than today's procedures. The differences are not merely in a one-for-one substitution of new technology to accomplish the individual steps of today's practices. Rather, the new technology permits a new opportunity to restructure the procurement system on a management-by-objectives basis, rather than merely mechanizing steps that must be done manually today solely because our present technology is not being considered as permitting supporting a clearly better alternative.

Magnitude of the Procurement Activity

Appendix D, written by Carson E. Agnew, presents a preliminary view of the magnitude of the procurement activity in the Department of Defense. It showed first that the distribution by size is very skewed: something under 2% of all procurements involve over 80% of the money spent in procurement. The average value of a procurement which falls within this 2% extreme is $169,000 while the average procurement has a value of $3517. Thus, we conclude that the procurement system should concentrate on the relatively few high-value procurements if it is to achieve really significant savings.

Agnew also shows that if each person in procurement used the system only 10 minutes a day it would represent a user community of 1000 simultaneous users. Since the system being contemplated will eventually grow beyond the domains of the present procurement organization and also couple to industry, even larger numbers of simultaneous users should be considered.

And, lastly, Agnew concludes that if an automated system can save 10% of the total man-hours spent in the procurement process, then its installation is justified provided it has an annual cost of less than $73.2 million per year. The system to be proposed should, of course, do more than save visible dollars. Time savings of others and elimination of overhead costs for transportation also are benefits and suggest that the manpower savings provide only a lower bound on the benefits to be derived from an automated system.

Information Processing Flows Within Today's Procurement System: Dimensions of the Information Flows

Appendix E, "Information Processing Flows Within Today's Procurement System: Feasibility of Automation," by David Caulkins and Carson E. Agnew, describes the procurement process as a data processing flow system and converts the implicit data flows into gross parameters to allow us to get on with the first nibbles of a design.

Basically the system would consist of a network of three to twelve special host computers served by a packet switched network. Each host would handle an on-line data base of about 1.6×10^9 characters and serve at least 100 simultaneous users each in a fast interactive response mode. Each file would be available from two different geographically separated file locations. Two of the hosts would have very large archival capacity.

The process of procurement is a paper-intensive operation. Consider the five-foot book shelf described by the National Procurement Commission as indicative of the books of regulations used at a local buying agency (see Figure 1). Even keeping up with day-to-day pen and ink changes is a monumental effort, particularly when you consider the number of copies of each document replicated by each office and each contractor's facility.

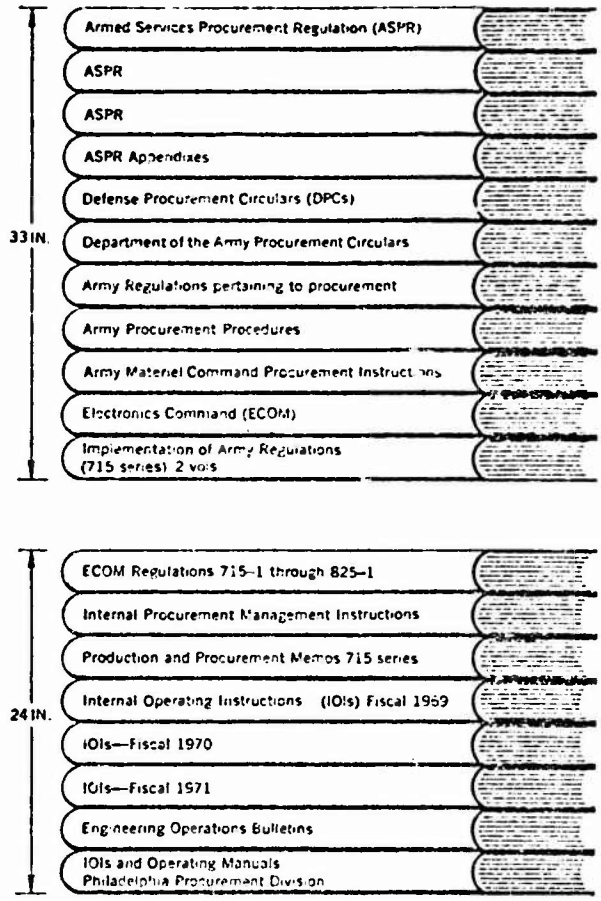
Figure 2, "Flow Down of Procurement-Related Regulations to DoD Contracting Officer," suggests the very dynamic nature of the process of continual changes. There is no single organization focal point. Almost everybody can and does get into the act, either as a source of regulations or as a recipient affected by such regulations.

Configuration

One way to think about what this system could do is to imagine that a full blown system exists. Let us consider some of the things that such a system might be able to do and some of the different ways that business could now be conducted.

Let us start off by imagining a very large terminal-based system -- perhaps on the order of several hundred to a few thousand

EXAMPLES OF BOOKS OF REGULATIONS USED AT A LOCAL BUYING ORGANIZATION

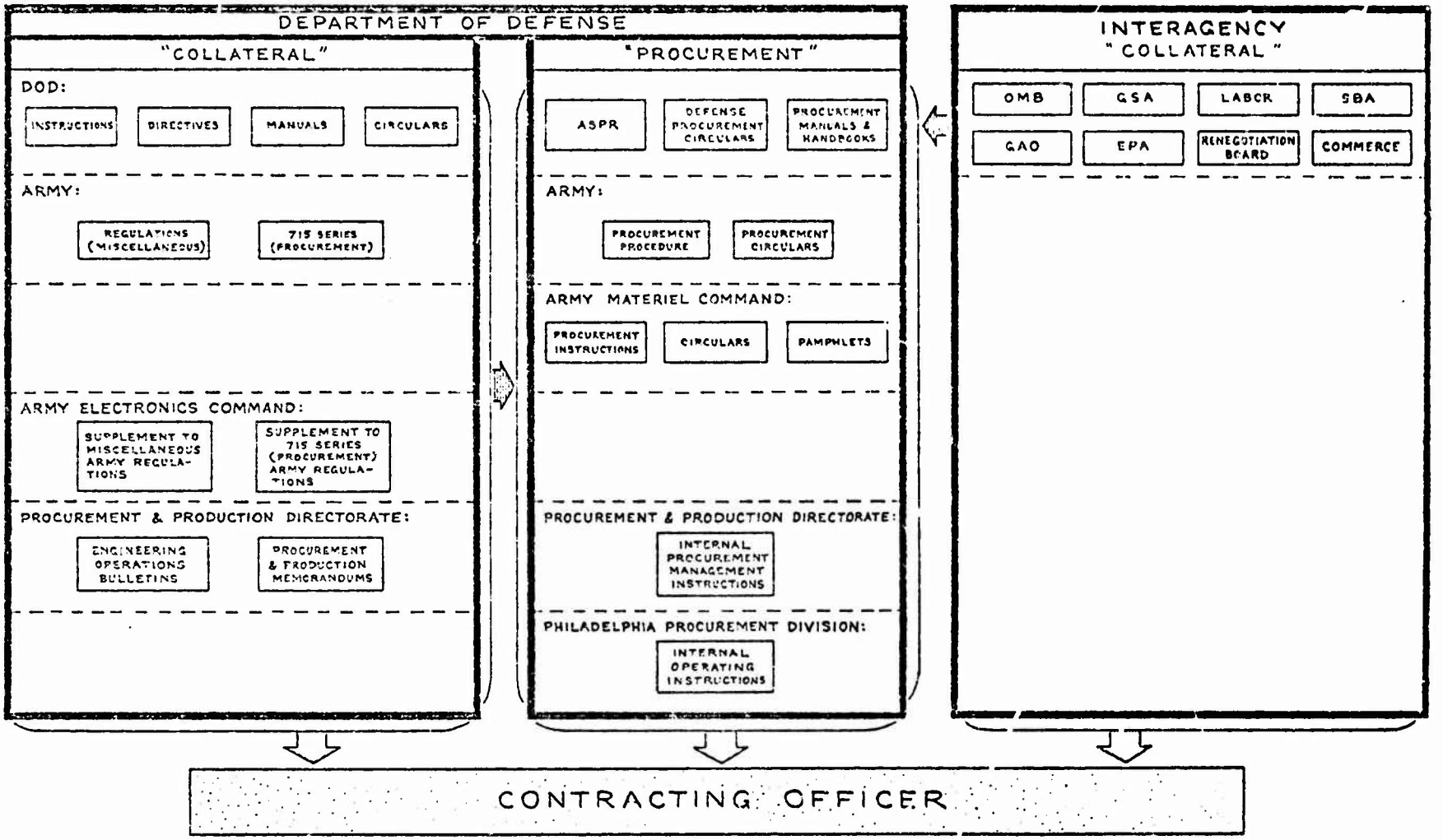


Source: Study Group 3, *Final Report*, Nov. 1971, p. 73.

Figure 1

Source: *Report of the Commission on Government Procurement*, Vol. I, 1972 p. 34

FLOW DOWN OF PROCUREMENT-RELATED REGULATIONS TO DOD CONTRACTING OFFICER



Source: Commission Studies Program.

Source: *Report of the Commission on Government Procurement*, Vol. I, 1972 p. 32

Figure 2

terminals serving all agencies of government; also, all contractors with enough business to warrant even an occasional connection. In other words we would want to connect together all those who are in any way involved in the procurement process. (As an end extreme we should even allow connection to the system by the taxpayer who has a pathological interest in how effectively and wisely his tax dollar is being spent.)

These terminals would be connected by telephone lines to a packet switched or equivalent communications network. Serving this network would be a set of several duplicate (backup) computer sites with equipment tailored specifically to this application and accessible to this system. Each user would have a password or passwords, corresponding to his rights to know; his rights to add information; and his rights to modify or delete information.

Each user would have the right (within defined bounds) to have his terminal act as a dump point for information that the system had acquired that had, either previously by requested arrangement (or by the generator of the information request) to be provided with material that was either relevant or was sought. The default option would also exist of not being informed except when specifically requested.

Data Bases

What sort of data bases would be handled? The earliest set of functions that would be handled would probably be the publicly available common data base files that are expensive to update locally. These would include, for example:

1. The ASPRs.
2. Federal Procurement Regulations
3. Other local procurement regulations
4. Cost accounting standards
5. Federal Register and possibly the Commerce Business Daily
6. DoD standard specifications and GSA specifications
7. U. S. Code
8. Detailed invitations to bid
9. Bidders lists
10. Solicited proposals
11. Unsolicited proposals

12. Stated requirements
13. Justifications
14. Detailed budgets
15. Contracts for procurement
16. Progress reports
17. Project status information
18. Evaluation reports
19. Deficiency reports
20. Etc.

Processes

The names of the files and data bases suggest only part of the picture. What is needed is a set of computer-based access capabilities for handling this data base. These would provide such services as:

1. Retrieval by:
   a. title;
   b. subject;
   c. author;
   d. date;
   e. organization;
   f. key word in context;
   g. relevance distance;
   h. accession number;
   i. by Boolean or weighted combinations of the above.

2. Machine aided input by:
   a. A good interactive text editing language;
   b. machine reading of text.

3. Procedure control programs for:
   a. Automatic dissemination of the existence of information in the system by:
      1) distribution list;
      2) expressed interest;
      3) procedural rules.
   b. Automatic status determination as to:
      1) who has seen what;
      2) who has changed what;
      3) whose approval is being awaited;
      4) fall back procedures to expedite slow approval arrivals;
      5) present status;
      6) forecast status.

4. Automated documentation preparation:
   a. Hard copy of COM/microfiche output of any report updated to the moment of request;
   b. Guided "fill-in-the-blanks" document preparation, i.e. contracts, by automatic insertion of standard form boilerplate.

Transitional Stages

What we are talking about here is a full blown, highly automated information system. Of course, unlike Phoenix, we don't build systems that way. The only ones that seem to work are those that are developed on a tested incremental basis, starting off with the things that we know how to do and then taking on the more difficult tasks.

The initial system will just be a simple on-line system (albeit with a large amount of semi-archival storage) to serve as a way to eliminate everyone maintaining his own copies of updated documents.

Later, simple automatic document preparation could be added. (The computer terminal would follow a program requesting the information sought and standard boilerplate would be inserted.)

Next, copies of documents would be electronically transmitted to all parties instantly. Changes and modifications would be automatically sent to all who have copies of the original information.

Later features might include mechanization from the initial point of original document creation.

Big systems are never really successfully built as big systems. Generally they start out small, prove their value and grow while adding additional services with time. We would also consider accretion in preference to a massive all-at-once construction.

However, we do feel it both prudent and almost technically mandatory to do the systems architecture first, rather than after-the-fact. It not only saves much embarrassment, it also avoids the awkward situations in system design that prevent one from going from here to there simply because no one thought of the need to go there in advance.

National Commission on Procurement

A very important development in the evolution of the procurement process is in the findings developed by the National Commission on Procurement.

Below we quote from its report and include an Appendix F, "Selected Background Information From the National Commission on Procurement." The purpose of including this material is to briefly describe what this commission is about and, also briefly, describe its view of the problems:

> The Commission on Government Procurement was created by Public Law 91-129 in November 1969 to study and recommend to Congress methods "to promote the economy, efficiency, and effectiveness" of procurement by the executive branch of the Federal Government....*
>
> The study was proposed in 1966, and preliminary hearings were held by the 89th and 90th Congresses....**
>
> The Commission and its participants reviewed thousands of pages of procurement reports, congressional testimony, documents, comments, and opinions; consulted approximately 12,000 persons engaged in procurement; held more than 2,000 meetings at 1,000 Government, industry, and academic facilities, including 36 public meetings attended by over 1,000 persons in 18 cities...; and received responses to questionnaires from nearly 60,000 individuals and many organizations. Government agencies, suppliers, and trade and professional associations all made significant contributions to the program....***
>
> The extensive study...resulted in 149 recommendations for improving Government procurement.****

DESIGN CRITERIA FOR ACCEPTANCE

Systems must live within the environment of other systems. In Appendix G, "Some Changes in the Future Environment for Procurement," by Paul Baran, we briefly consider the general context of a procurement system for the future. Perhaps the most significant aspects of the invisible design of the system are those of making it conform to the future national attitudes about openness of governmental decision making and acknowledging the taxpayer's

---

* National Commission on Procurement, Vol. I, p. vi.

** Ibid.

*** Ibid., p. viii.

**** Ibid.

increased concern with the justification of defense expenditures.

There are several constituencies that will be affected by transformation of the present procurement system. Full automation will, of course, probably always remain an unachievable goal. We are really only proposing an increasing number of information services to an increasing number of people involved in procurement.

Let us briefly consider how each of these constituencies might respond to such proposed computer automation efforts to provide ourselves with some design guidelines.

The affected constituencies include:

1. End Agencies. Those that have the need for the goods and services that are to be procured.

2. Procurement Staffs. Those within government responsible for the procurement itself.

3. Industry. The industrial sales sector who seeks to provide the sought goods.

4. The Taxpayer, as represented by elected Executive branch and Congressional branch.

There has to be something in it for each consitutency to allow a viable system to be built and effectively used. Let us consider how each of these constituencies would perceive the changes to an automated system to help provide us with some inkling of their response pattern. This exercise provides us with our preliminary basic design criteria.

End Agency Acceptance

We would expect that as a target the end agency would be reasonably happy with an automated system in preference to a fully manual one if it were to:

1. provide better information as to sources of supply alternatives;

2. reduce time of procurement;

3. allow a better fit between what is wanted and what is received in the end;

4. provide better information as to status of the procurement; and

5. require less red tape and paperwork.

These seem like reasonable goals and we should be prepared to show how a proposed system would meet these objectives. And, if it can, we would expect this first constituency to be satisfied.

Procurement Staff Acceptance

To be acceptable to the procurement staff who will be the prime users of this system, the system must:

1. not require acquisition of complex new skills not reasonable for the age-education-interest profiles of the users;

2. not require extensive job location movements;

3. not reduce the self-status of any individual;

4. not pose any threat to job security;

5. generally shift the duties from processing paper to that of doing things humans do best -- human communication and the exercise of independent judgment;

6. allow increased opportunities for individual job growth and acceptance of responsibility.

Appendix H, "Characteristics of the Procurement Work Force," provides a profile of the user population. There are two groups: civilian and military. Let us consider:

1. Experience. 70% of the military group have less than 10 years' experience and 34% of the military group is in grades GS-13 and above.

2. Age. 59% of the federal government procurement civilian work force is over 46 years of age while about 60% of the military group is under 35 years old.

3. Responsibility. 18% of the civilian group is at GS-18 levels and above, while 34% of the military group is at grades 0-4 (GS-13 equivalent and above).

4. Education. The civilian group average was high school plus about three months of college, while 64% of the military group were college graduates with about 25% with graduate or law school degrees.

5. Composition. 92% of the total staff is civilian; 8% military.

These numbers provide useful insights into the probable acceptance of the proposed systems.

The largest component is the civilian component. Here we must accommodate an age-education group that has in past automation efforts been the most reluctant and difficult to adapt. (The younger the staffs and the greater the education level, the more

comfortable they tend to be with computer terminals and automated processes.) Older workers tend to object less after they are shown that they will be "buffered" from the terminal and there is no loss of job security. But, some past automation efforts have failed simply because they were sabotaged* by the older workers that feared the system. For example, automation of newspaper typesetting has been held up many years because the older workers were reluctant to retrain -- even with offers of job security.

These numbers tell us that we must be very careful and design and implement the system in a manner that is least threatening to its users constitutency.

One ameliorating factor is that the civilian age group affected is near retirement age. Over 50% will be eligible to retire by the end of 1980. This suggests that it is reasonable to expect that it will not be necessary to eliminate any present positions. Rather, a policy of not filling some of the positions as they become open during the next five years should suffice.

In short, the automation population is not an ideal age group for acquiring the new skills needed, but the age group is such that there should not be any job security threat. Attrition should alone suffice to remove surplus positions created. And, lastly, the use of an electrically interconnected system allows lessened requirement that the procurement staff and the point of need be coterminous.

Industry Acceptance

We have conducted a few informal interviews with the sales representatives of defense contractors to see how they might respond to a system of this sort in preference to the way they presently do their business. In essence, when the conversations reached a meaningful level of frankness, the position seemed to go

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* This word sabotage is used precisely in its original meaning, deriving from the "sabots" (shoes) that the 19th Century French textile workers threw into mechanized looms to protest possible loss of their jobs. Automation is not new, neither is resistance to its adoption.

something like this:

> The governmental procurement game is a highly wasteful, ineffective and corrupting game. But, it is the game that we understand and know how to play and win. There are barely enough contracts to go around now. If all the procurement red tape, waste and nonsense were to be reduced we would find ourselves facing even greater competition with more efficient, lower cost outfits. No, we are better off playing the game just as it is. Of course we don't like it. But, why should we want to change the game with rules that someone else can play better?

Of course a few interviews doesn't really define acceptance or non-acceptance, but it does tell us that we must be prepared to consider this aspect of acceptability.

One assumption voiced in the above interviews is that the defense contractors tend to be less effective than non-defense contractors.

One confirming signal is that from 1962 onward the rate of return for defense business in the U.S. has slipped to about two-thirds that of civilian business. This is a clear signal that the first choice business of industry is non-governmental and government business is increasingly second-choice.*

Taxpayer Acceptance

Our last constituency to be considered is the most important of all -- that of the taxpayer and his directly elected representatives, the Congress.

The National Commission on Procurement report represents Executive and Congressional bi-partisan effort and its findings represent a measure of general consensus. It can and should be regarded as an action document describing the thrust and direction of evolution of the governmental procurement process. We have included Appendix F, "Selected Background Information from the National Commission on Procurement," to provide the reader with

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* See: Neil H. Jacoby, *Corporate Power and Social Responsibility*, Chap. 11, pp. 225-45.

the flavor of what the commission is and a statement of the sorts of problems it has addressed (and, conversely, what it has not addressed, which is of interest to us since it has not addressed the procurement information automation issue.) We believe that many of its objectives could much better be met provided such capabilities existed. The absence of inclusion of demands for information automation may be simply because they did not realize what could be done. Rather, they limited themselves to viewing the future without considering the impact of the new technology.

Let us consider several important dimensions of societal change for the future that contain implicit ground rules for system design. These are:

1. The amount of money available for defense in the long-term may be expected to be a decreasing percentage of GNP. This is described in Appendix G, "Some Changes in the Future Environment." Since procurement is a labor-intensive activity it will be difficult to maintain the same relative personnel strength without diverting funds from the purchase of weapons and fighting troop maintenance.

2. The procurement process by all government agencies may be expected to be centralized to a higher degree than the present structure based upon the National Commission on Procurement's funding.

3. And thirdly, the area that defense decisions will be made in will be a much more open one than in the past, and must be able to operate in an environment where there is no consensus as to the wisdom for defense expenditures -- even at present levels and where the public distrust of all institutions has increased. (This is also described in Appendix G.)

Hardware

The last appendix of this report, Appendix I, "Preliminary Design for Procurement Data Base System Hardware Configuration," by David Caulkins, contains the hardware system description that has been singled out as the preferred configuration for further exploration at this time.

This work represents a present view of the system structure. The software system design is yet to be specified, and the validity of some of the early conclusions will, of course, hinge on what is found during that stage. But, anyway, it is clear that an awfully

interesting computer system could be built for a sum that is small in proportion to the major significant savings that would be possible by successful automation of even parts of the procurement function.

GOALS

What we are looking for is a major saving to the Department of Defense. It has been shown in this report that the direct visible costs for procurement are about 2.5% of the procurement budget. If we could save only 10% of these costs by improving efficiency, then we are talking about an annual saving on the order of over $100 million. Of course there are other savings, perhaps even more important, and these are in the increased speed and timeliness that the procurement action would hold to national defense.

APPENDIX A

PLAN OF THE PROJECT

Purpose

The purpose of this study is to find applications and ways to aid the technology transfer of the computer-netted system development sponsored by the Information Processing Techniques Office of the Defense Advanced Research Projects Agency to unmet needs present in the Department of Defense.

During the first three months of this study we set out to answer five questions:

(1) Where is the money going in the DoD budget today that might be saved by automated information processing?

(2) What single domain of activities is ripe for automation that would make a good candidate application?

(3) How would the proposed system operate?

(4) How should such a system be designed?

(5) What is its configuration?

The proposal calls for exploring the application of network information processing techniques, specifically resource and data base sharing to produce savings for and improve the effectiveness of the Department of Defense. As cost reductions are felt to most likely be in proportion to present expenditure patterns, we seek to identify a few information processing functions whose automation via networking should produce significant savings.

The specific tasks called out by the proposal include:

(1) Creation of a quantitative estimate of the size of DoD activities that could be affected by new information processing technology.

(2) Isolation of a few information processing functions which are most amenable to implementation by networking techniques and for which significant cost savings can be anticipated (e.g., message switching, inventory and manpower data base sharing, office automation, building management and control, etc.)

(3) Initial identification of some of the missing elements that would facilitate more extensive use of the technology (e.g., lower cost communications, single-function hosts, support of very large user populations, improved network and/or host reliability).

Methodology

The flow of work in this project is organized in the general manner shown in the flow chart of Figure 1. Below we consider each of the eleven separate boxes of Figure 1 in terms of questions that we wish to answer along the path of the study.

(1) Department of Defense Potential Impact

To pick the points where the maximum payoff of computer-netting will impact on the Department of Defense budget, we first start with the printed DoD budget and track where the dollars flow towards high information processing tasks. This is done to permit elimination of areas of study which simply do not lend themselves to information automation -- such as driving a tank. This initial brief analysis provides a gross overview and focuses on the most potentially fruitful domains for detailed consideration.

(2) Examination of Information Processing Functions Performed

We are next to examine the particular places on a general functional basis where the impacts of information processing can be felt by the Department of Defense and its contractors. Of course we are not considering the full gamut of data processing needs of the Department of Defense. Rather, we are only ascertaining those areas that seem most amenable to savings with the application of computer-netting technology where it is not currently being used.

(3) Functions Subject to Automation

There are limits to the applicability of computer-netted systems. In this part of the study we will explore some of the functional requirements that would appear to be better served by computer-netted systems than stand-alone systems or those not automated at all.

(4) New Computer Communications Technology

The applicability of information processing to Department of

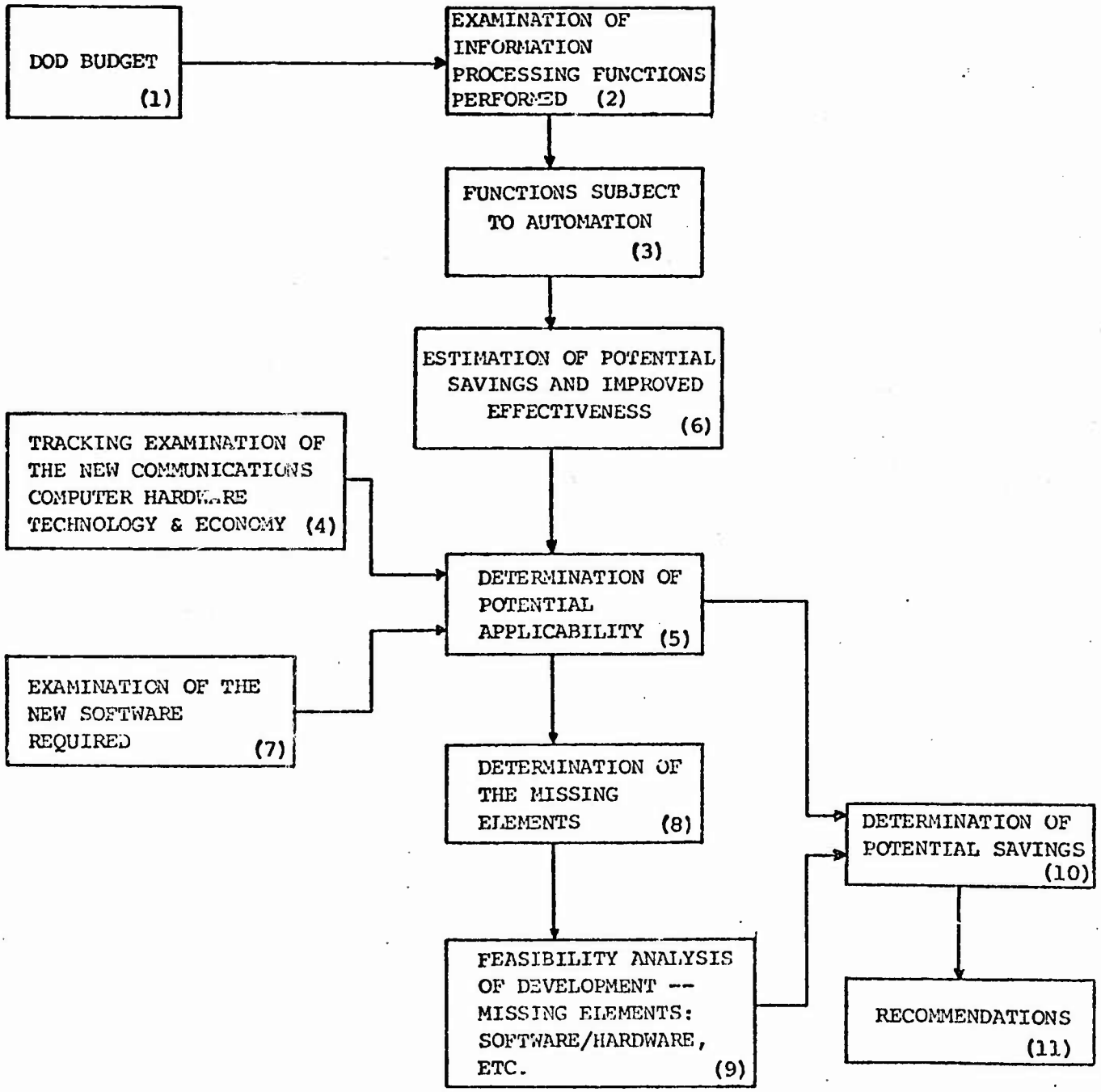

Figure 1. Simplified Flow Chart for Project.

Defense functions is very much a function of the state-of-the-art of communications and computer technology. What might make poor economic sense today may be a prudent use of automated information processing tomorrow. The anticipated time-frame availability of hardware is a function of future needs as well as theoretic possibilities. Therefore, we are also considering the interaction of changing needs for information processing based upon forecasts of availability of cost-effective computer communications based systems.

(5) Determination of Potential Applicability

One of the more challenging aspects of this study is that of considering an extremely broad subject, the applicability of computer-netting techniques to the Department of Defense, in breadth and in a depth to be meaningful. We seek to produce a significant contribution which will satisfy apparently conflicting requirements by examining the subject broadly before focusing in detail on functions that are not only of high payoff in themselves, but also have broad-based applicability to the Department of Defense.

(6) Estimation of the Potential Savings and Improved Effectiveness

In this examination we are also going to try to estimate the potential savings possible by more complete utilization of the present state-of-the-art of information processing by extensions of computer-netting and suggest the areas where the greatest savings are to be expected.

(7) Tracking Examination of the Software Required for the Proposed Applications

Just as the validity of the conclusions of this study hinges on hardware availability, so it will also be necessary to track the potential availability of the software relevant for this analysis We would then seek the reasonable expected boundaries of software development and the time and costs for its development to help provide some bounds for the use of computer-netting techniques. This

will give us some insight to the cost savings that might be possible by sharing software among the users of a netted system as compared to the development of locally-used-only software.

(8) Determination of Bottleneck or Missing Elements

In this step we seek to delineate the key critical missing elements that limit or prevent the widespread use of the new resource sharing computer-netted technology.

(9) Technical Feasibility Analysis: Development of the Missing Elements

Next, we focus on overcoming the existing maximum impact bottlenecks within the limited scope of the contract.

(10) Determination of Potential Savings

Following this we consider payoffs for each of a number of potential new developments that appear desirable and technically feasible as a result of the preceding work.

(11) Recommendations

Lastly, examining the overall potential impacts upon the Department of Defense, we consider specific developments that will best aid the infusion of the new computer-netted capabilities in the Department of Defense.

APPENDIX B

PATTERNS IN DOD CIVILIAN EMPLOYMENT

C A B L E D A T A A S S O C I A T E S, I N C.

701 Welch Road • Palo Alto, California 94304 • (415) 328-2411

W O R K I N G P A P E R

CAWP # 143-A

PATTERNS IN DOD CIVILIAN EMPLOYMENT

by

CARSON E. AGNEW

ALSO APPENDIX B TO
FIRST QUARTERLY TECHNICAL REPORT
ARPANET MANAGEMENT STUDY

1974 MARCH 25

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INTRODUCTION

This working paper examines the dimensions of the Defense Department's civilian employment in order to pinpoint areas within the Department which are good candidates for automation. Although the analysis is carried through at a gross level of aggregation, it suggests that the functions where automation has the highest potential payoff are in middle and upper management. At lower administrative levels the cost of an employee's time is not currently high enough to justify the use of automation, while at the very top of the hierarchy there are too few positions to justify the software and hardware development which would be required.

Because this paper concentrates on the automation potential of Defense Department functions, it restricts attention to civilian employment. Many military personnel are, of course, engaged in performing administrative jobs which are similar or identical to those done by civilians. But military personnel also perform specific military functions which cannot be separated easily from administrative ones. Restricting the analysis to civilian labor eliminates the problem of distinguishing these service-connected functions.

MAGNITUDE OF CIVILIAN LABOR COSTS IN DoD

The FY 1975 budget anticipates a Defense establishment of 3.19 million people, including 1.01 million civilian employees.[1] The civilians constitute 39% of all Federal employees and make up fully 1.3% of the total U.S. civilian labor force. For comparison, all of the private sector employment attributable to

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[1] *The Budget of the United States Government - Fiscal Year 1975 - Appendix*, U.S. Gov't Printing Office, 1974, p. 265 and pp. 977-980. Hereafter referred to as the *FY 1975 Budget (Appendix)*.

Defense spending constitutes only 3.9% of the labor force.[2] Thus, the civilian employees of the Defense Department make up the largest part of the civilian defense establishment.

Of these 1.01 million civilian employees, roughly half, about 591,000, are subject to Civil Service regulations and are referred to as "graded." The non-graded employees are principally Wage Board employees, a group which includes unskilled workers, manual workers and craftsmen, whose pay is determined by reference to private sector wage rates for specific skills. Graded employees include the professionals,[3] managerial and clerical workers at all levels. These personnel are typically engaged in administrative activities which involve considerable information handling but relatively little manual labor and, as such, are logical candidates for the application of information automation techniques. Throughout the rest of this analysis, these Defense Department employees will be taken as the target study population.

The graded employees are a significant budget item. The estimated payroll in Fiscal 1975 for graded employees is 8.977 billion dollars, as compared to the military payroll of 16.327 billion dollars.[4] The graded civilian payroll is thus 8.6% of the Fiscal 1975 budget. Even with the recent and proposed military pay increases, the average graded civilian is still paid more than the average soldier: $7900 per year as against $7500 per year. Furthermore, the administrative functions performed by graded employees mean that a relatively large fraction of them are relatively

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[2] U.S. Bureau of the Census, *Statistical Abstract of the United States: 1973*, U.S. Gov't Printing Office, 1973, pp. 262-3.

[3] Certain scientific and professional personnel not subject to Civil Service will also be included in the category of graded employees at the equivalent grade of GS-16. Personnel engaged in the so-called civilian portion of the budget (e.g., the Panama Canal Zone government) have been excluded from all tabulations.

[4] Civilian payroll estimated from the *FY 1975 Budget (Appendix)*, p. 964 and pp. 977-980. Military payroll from pp. 265-269. Reserve units are not included.

highly paid. The median graded employee is paid approximately $11,500 per year (not including fringe and secondary costs).

DISTRIBUTION OF GRADED MANPOWER AND MANPOWER COSTS

Table 1 shows the way in which graded employees and employee costs are distributed by grade. The second column gives the percentage of all graded employees with the grade specified in the first column. Column three gives the percentage of the total wage bill for graded employees allocated to that grade.

It is apparent that there are two peaks in the grade distribution of employees. One of these occurs in grades GS-11 through GS-13, and the other in grades GS-3 through GS-7. Employees in the higher of these two ranges, paid between $16,000 and $24,000, occupy the middle managerial positions. The lower group, paid between $7000 and $12,000 per year, are lower managerial, clerical and secretarial personnel. The upper managerial ranks begin at about GS-15 with salaries of $29,000 and up.

Table 1 suggests that middle management positions are good candidates for information automation. The "supergrades," GS-16 and above, comprise 0.28% of the graded civilian positions in the Defense Department and account for only 0.71% of the wage bill (about $613 million). On the other hand, grades GS-11 through GS-13 comprise 27.6% of the labor force and receive 40.2% of the wages ($3.2 billion). A one percent saving in labor costs due to information automation is thus worth about half a million dollars if applied to top management functions, but $32 million if applied to functions performed by middle management grades. Accordingly, we could invest almost sixty times as much on middle management automation as on top management automation, given that equally effective technologies are available in both cases for the same first order payoff.

Another way of displaying the data of Table 1 is by means of a Lorenz curve, Figure 1. This curve shows the relative shares of labor costs received by various fractions of the graded civilian labor force. Figure 1 plots the cumulative fraction of employees

Table 1

Distribution of Graded Manpower and Manpower Costs

Grade	Percent of all employees	Percent of total payroll
Exec. Level	.0086	.025
GS 18, 17	.037	.098
GS 16 + Scientific & Professional	.23	.59
GS 15	1.05	2.50
GS 14	2.51	5.18
GS 13	6.47	11.40
GS 12	9.86	14.71
GS 11	11.27	14.09
GS 10	1.07	1.22
GS 9	11.62	12.05
GS 8	2.01	1.89
GS 7	9.13	7.76
GS 6	5.87	4.49
GS 5	14.07	9.66
GS 4	14.00	8.59
GS 3	8.85	4.83
GS 2	1.70	.82
GS 1	.24	.10

Source: *FY 1975 Budget (Appendix)*, p. 964 and pp. 977-980.

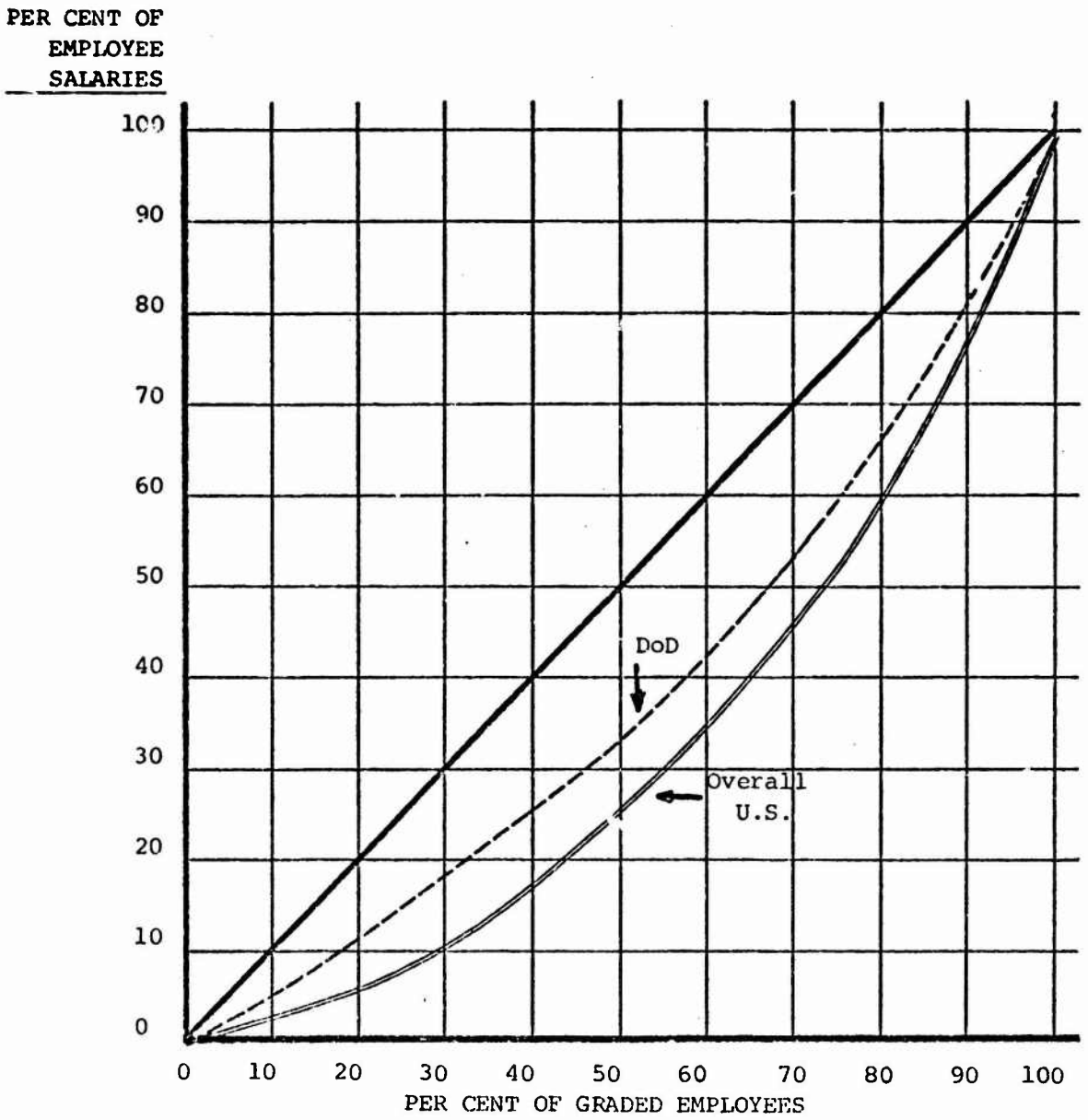

Figure 1. Distribution of Employee Salaries.

(Lorenz Curve)

(ranked from lowest grade to highest) along the abscissa and the corresponding share of the salary costs received by each grade along the ordinate. If salary costs were uniformly distributed, the Lorenz curve would lie along the diagonal line in Figure 1. Because employees at higher grades are paid more, the curve lies below the line, and the distance and curvature provide a qualitative indication of the degree to which salary costs diverge from uniformity.

Because it is desirable to generalize any conclusions reached about the Defense Department's automation potential to larger populations, it would be useful to compare the distribution of salaries within DoD to the distribution in the private sector. However, comparable data on salary distributions is unavailable, so the curve labeled "Overall U.S." in Figure 1 presents the distribution of incomes as a proxy.[5] It can be seen from the figure that there is considerably less asymmetry present in DoD salaries than there is in the whole country. However, the difference is probably less than indicated because: 1) reported income included unearned income as well as salaries and wages, and 2) the national statistics include families whose income is derived from manual or unskilled occupations. Both of these effects tend to pull the Lorenz curve away from the diagonal line and so overstate the difference between DoD's salary policies and the private sector's.

No significant differences were found when a comparison similar to Figure 1 was made for DoD salaries against the rest of the Federal government.[6] The two curves effectively overlapped each other. Therefore, the conclusions made about the relative merit of information automation at different levels of DoD can be extended to the entire Federal establishment. It is possible,

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[5] U.S. Bureau of Census, *Statistical Abstract of the United States: 1973*, p. 328.

[6] U.S. Civil Service Commission, *1972 Annual Report*, March 1973, p. 64.

based on Figure 1 and the comments made above, that these conclusions can be extended to the private sector as well.

It is possible to extract further information about the distribution of salary costs in the Defense Department from Figure 1. Table 2 summarizes some of the more interesting results.

Table 2

Comparison of DoD Salary Costs With National Income Distribution

Population group	Percent of DoD salary costs	Percent of U.S. family income
0 - 20%	11.4	5.5
21 - 40%	13.6	12.0
41 - 60%	17.2	17.4
61 - 80%	24.0	23.5
81 - 95%	23.2	27.2
95 - 100%	10.6	14.4

Table 2 reinforces the conclusions reached from examining Table 1. Namely, that top management is not the first place where new information automation techniques should be considered since most of graded civilian wage costs occur at the middle management level. The top five percent of DoD graded employees receive only 10% of the salary budget, as opposed to 14.4% nationwide.

However, there are certain agencies of the Defense Department where the distribution shown in Figure 2 displays the Lorenz curves for the Defense Department as a whole and for ARPA in particular. It can be seen that while the middle group of DoD employees (41 - 80%) accounts for 41.2% of the DoD wage bill, the same group in ARPA accounts for 60.5% of ARPA's salary costs. ARPA has correspondingly smaller fractions of its wage costs coming from the lowest and highest employee groups. The grade

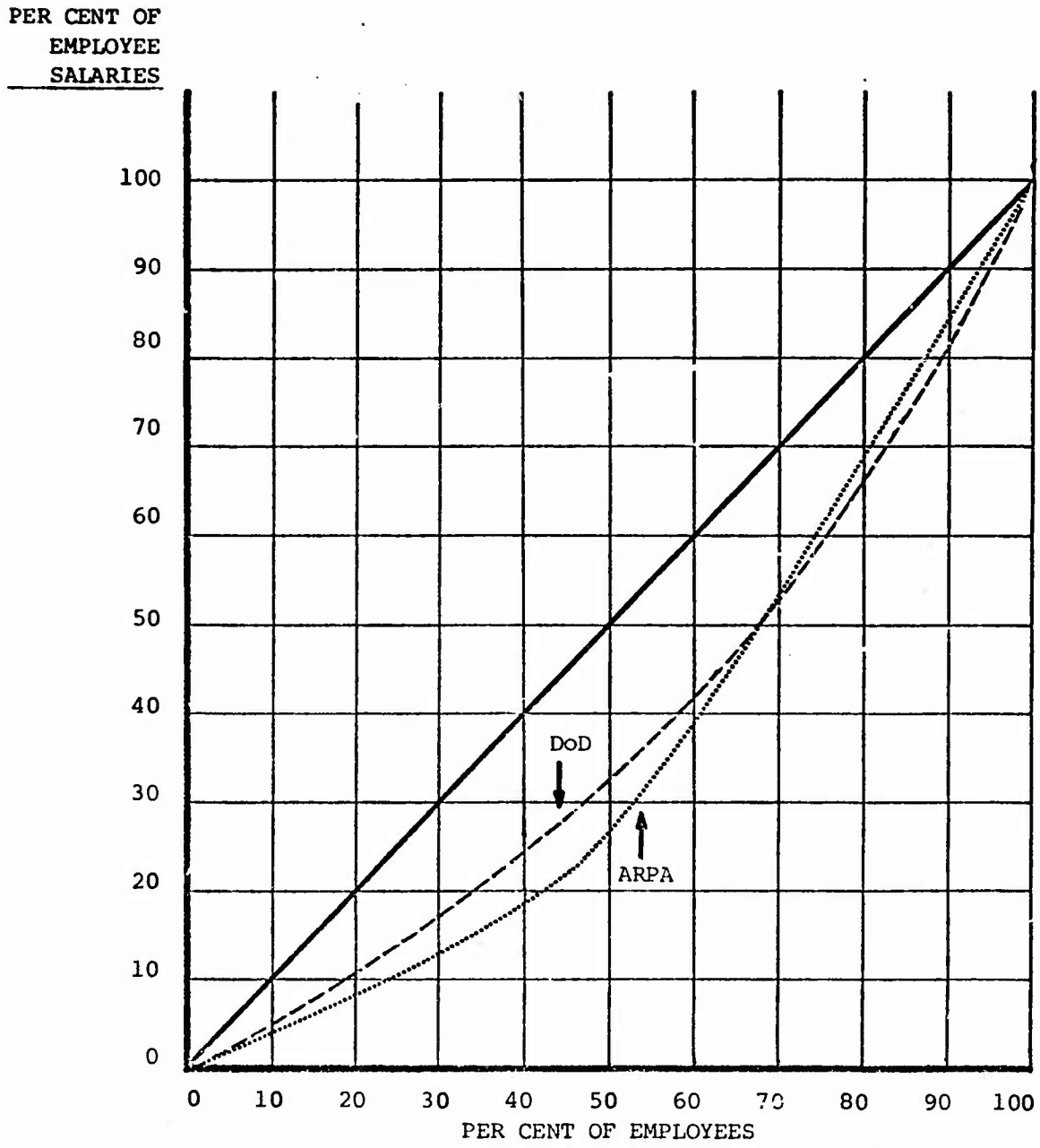

Figure 2. Distribution of Employee Salaries for DoD and ARPA.

(Lorenz Curve)

distribution associated with Figure 2 is also different from the overall DoD distribution. In ARPA, employees in grades GS-14 through GS-16 (including Scientific and Professional) comprise 46% of the staff and receive about 68% of the salaries (about 1.76 million). In the Defense Department as a whole, the corresponding percentages are 3.79% and 8.27%.

These differences undoubtedly arise because ARPA is not a typical Defense agency. As a small lead organization, it subcontracts some day-to-day administrative functions to others, so it would naturally contain a higher than normal proportion of upper level managers. Furthermore, ARPA's need for technical expertise in research evaluation means that high salaries must be paid in order to compete with the private sector for qualified personnel.

Each organization tends to perceive those functions most in need of automation to be those that they themselves do. In the case of top ARPA management, which contains so many high level managers, this agency can be expected to see their own group, rather than the ones below it, as the one which can benefit most from information automation. If automated tools particularly well-adapted to the needs of upper level managers are available, this conclusion may be correct. But it will not be correct if moderate benefits can be obtained by automating lower level functions because there are so many more of these employees to be automated.

GEOGRAPHIC ASPECTS OF DoD EMPLOYMENT

Another aspect of the question of where information automation can increase DoD effectiveness is seen when the geographic distribution of graded civilian employment is considered. The Department of Defense is, in fact, an unusually dispersed organization and this dispe[illegible]urs not only in military personnel, but also in civilian pe[illegible]nel.

This can be seen in Table 3, which displays the regional distribution of DoD civilian employment relative to total DoD graded civilian employment, and to the regional non-agricultural labor force. DoD civilian employees are distributed widely around the

Table 3

Geographic Distribution of Graded Civilian Employment

Region	Percent of total DoD employment in this region[1]	DoD employment as a percent of non-agricultural labor force
New England	4.29	.94
Middle Atlantic	11.31	.80
East North Central	9.16	.62
West North Central	3.99	.72
Southern Atlantic[2]	17.88	1.70
East South Central	5.55	1.35
West South Central	11.39	1.79
Mountain States	6.94	2.39
Pacific Coast	20.63	2.17
District of Columbia	8.78	12.86

[1] Does not add to 100.00 because of overseas employees.

[2] Except District of Columbia.

Sources: U.S. Civil Service Commission, *1972 Annual Report*, (March 1973) p. 63

U.S. Bureau of Census, *Statistical Abstract of the United States: 1973*, p. 229

country. Recalling that nationwide they comprise 1.3% of the civilian labor force, the third column of Table 3 indicates that the distribution is densest in the less urban regions of the South and West, and sparse in the Northeast. From this we can infer that the Defense Department must make relatively heavy use of communications and transportation facilities in order to function effectively.

This is confirmed by comparing the distribution of Defense contracts to the distribution of Defense civilian personnel, as is done in Table 4. Although the two distributions follow each other to some extent, it is clear that there are fewer civilian employees per contract dollar in the Northeast than there are in the South. Matching administrators in one place to contracts in another must entail extraordinary communications and transportation costs.

CONCLUSIONS

The rationale for studying the distribution of Defense Department labor costs is the general observation that the cost of an administrative function can be decomposed into the product of two factors. Thus we may write:

Total cost to perform a function	=	Quantity of labor required for performance	X	Cost per unit of labor required

Automation can be used to reduce the labor input required to perform a given function, but only at some cost for hardware, software and operations. Since current automation technology is characterized by large, fixed costs, regardless of the function to be automated, it is best to choose functions involving large numbers of expensive man-hours as the first to be augmented by automation.

The distribution of wage costs over civil service grades in the Defense Department as a whole suggests that the appropriate level at which to consider automation is in grades GS-11 through GS-13. Employees in these grades are typically middle managers

Table 4

Geographic Distribution
of Defense Contracts and Employment

Region	Percent of total DoD employment in this region[1]	Percent of Prime Contract dollars
New England	4.29	9.49
Middle Atlantic	11.31	17.95
East North Central	9.16	10.03
West North Central	3.99	9.00
Southern Atlantic[2]	17.88	13.40
East South Central	5.55	4.17
West South Central	11.39	9.15
Mountain States	6.94	3.43
Pacific Coast	20.63	22.57
District of Columbia	8.78	.82

[1] Does not add to 100.00 because of overseas employees.

[2] Except District and Columbia.

Sources: U.S. Civil Service Commission, *1972 Annual Report*, (March 1973) p. 63

U.S. Bureau of Census, *Statistical Abstract of the United States: 1973*, p. 262

of DoD engaged in line as opposed to staff functions. This conclusion can be extended to the Federal government as a whole because the distribution of graded labor costs is the same in the rest of the government. In research-oriented agencies, such as ARPA, the functions performed by grades GS-14 through GS-16 may be more appropriate for automation, because these agencies tend to have more professional and staff personnel and few line managers. However, this will depend on the cost of providing automated services to that group.

The geographic dispersion of Defense Department graded civilian employees and the relationship of this distribution to the distribution of Defense contracts suggests that DoD makes extraordinary use of communication and travel facilities in performing its administrative functions. It follows that automation techniques should be considered which substitute less expensive communications media and procedures for existing ones, thereby reducing the cost per labor unit instead of the labor requirement in our equation.

These two conclusions are based on the general analysis conducted above. But there is every reason to expect them to hold as more detailed functions are considered. On this more detailed level it may on occasion be necessary to trade one of the two factors off against the other, but in general the data suggests that in information automation it is probably more beneficial to opt for small reductions in large costs rather than the converse, all other factors being equal.

APPENDIX C

WHY PROCUREMENT AS A DOMAIN FOR POSSIBLE AUTOMATION?

CHOICE OF PROCUREMENT

In this working paper we examine the DoD budget seeking areas where computer networking technology might yield significant cost savings. We selected procurement as an activity within which computer networks could find useful application for a number of reasons including:

1. The size of the activity. Procurement is a large-scale activity. Table 1 lists major DoD budget items representing expenditures of $500,000,000 or more in order of size. It can be seen that procurement expenditures are twice as large as the next largest item and comprise 21% of the DoD budget. Because of its sheer size, considerable absolute savings could be realized if even a little effort is saved in each procurement as a result of applying computer network automation to the procurement process.

2. The labor-intensive nature of the activity. The volume of procurements and the demands of the regulations governing the procurement process by their very nature require large amounts of labor. As can be seen in Appendix D, "The Magnitude of the Procurement Activity: Preliminary Assessment," the number of people involved in procurement is high and the labor is relatively highly paid.

3. The information-intensive nature of the activity. The procurement process requires the processing of large amounts of information by many different groups of individuals -- commands, Defense agencies, contractors, etc. This processing currently requires the creation, reproduction, distribution, perusal and filing of large numbers of documents. By its very nature this is almost pure information processing and forms a domain clearly suitable for information automation. For example, an automated text editor coupled with large amounts of on-line mass storage are helpful in expediting document preparation, storage, retrieval and transmission.

4. The geographic distribution of the activity. Defense contractors and interacting governmental agencies are dispersed throughout the country. The procurement activity is thus similarly distributed which necessitates travel and communications expenses which could, for example, be decreased if conferences could be conducted remotely by electrical means; if approvals and comments could be gathered automatically; if correspondance related to each procurement could be more rapidly generated, handled and centrally filed. The new computer-netting art makes an automated procurement system that can perform these functions closer to reality than possible in the past.

Table 1

DoD BUDGET - MAJOR CATEGORIES

Item	Amount ($x10^9$)			%				Item
	'73	'74	'75	'73	'74	'75	Page*	#
Procurement	18.57	18.65	19.87	21.6	21.1	21.0	289	-
Industrial Funds	8.83	9.25	9.54	10.3	10.5	10.1	342	-
Research, Development, Test & Ev.	8.11	8.30	9.30	9.4	9.4	9.8	312	-
Army Personnel	7.79	7.78	7.98	9.1	8.8	8.4	266	99.0
Air Force Personnel	7.40	7.49	7.50	8.6	8.5	7.9	269	99.0
Air Force Operation & Maint.	7.15	7.21	8.14	8.3	8.2	8.6	280	99.0
Army Operation & Maint.	7.90	7.60	8.08	9.2	8.6	8.5	277	99.0
Navy Operation & Maint.	6.00	6.89	7.93	7.0	7.8	8.4	278	99.0
Navy Personnel	5.50	5.74	5.81	6.4	6.5	6.1	267	99.0
Military Construction	1.46	1.82	2.15	1.7	2.1	2.3	320	-
Marine Personnel	1.59	1.68	1.74	1.8	1.9	1.8	268	99.0
Defense Agencies, Oper. & Maint.	1.51	1.69	2.10	1.8	1.9	2.2	282	99.0
Corps of Engineers	1.95	1.66	1.62	2.3	1.9	1.7	357	-
Family Housing	0.86	1.12	1.29	1.0	1.3	1.4	330	99.0
Army Nat. Guard, Oper. & Maint.	0.45	0.55	0.61	0.5	0.6	0.6	286	99.0
Air Nat. Guard, Oper. & Maint.	0.47	0.54	0.61	0.6	0.6	0.6	287	99.0
Marines Operation & Maintenance	0.44	0.48	0.51	0.5	0.5	0.5	279	99.0
Totals	85.98	88.45	94.78	100	100	100		

* Source: *Appendix to the Budget of the United States Government, Fiscal Year 1975.*

5. The time is ripe. The procurement process has been singled out for institutional updating and overhaul by Congress. The key recommendations of the National Commission on Procurement form a basis upon which to open the process for consideration of new structure and procedures to help rationalize the process. The structure that may be expected to emerge will form a better one upon which new information processing techniques can be applied than the previous structure. And, it is to be noted, the business of procurement has remained relatively untouched by earlier information automation efforts.

APPENDIX D

THE MAGNITUDE OF THE PROCUREMENT ACTIVITY: PRELIMINARY ASSESSMENT

C A B L E D A T A A S S O C I A T E S, I N C.

701 Welch Road • Palo Alto, California 94304 • (415) 328-2411

W O R K I N G P A P E R

CAWP # 147

THE MAGNITUDE OF THE PROCUREMENT ACTIVITY: PRELIMINARY ASSESSMENT

by

CARSON E. AGNEW

ALSO APPENDIX D TO
FIRST QUARTERLY TECHNICAL REPORT
ARPANET MANAGEMENT STUDY

1974 MAY 10

DISTRIBUTION RESTRICTION

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ADVANCED RESEARCH PROJECTS AGENCY
OFFICE OF INFORMATION PROCESSING TECHNIQUES

INTRODUCTION

This working paper presents preliminary estimates of the labor and dollar magnitude of the procurement activity in the Defense Department. The cost of the procurement activity, as distinct from procurement costs themselves, includes the cost of effort expended by the Defense Department in obtaining plant, equipment and services but not the cost of those items. As such, the costs of the procurement activity are much less well documented than are the costs of procurement itself. In this paper the data which was available before April 30, 1974 is used to form some preliminary estimates of the number and size of procurements which will be handled by the proposed automated system and estimates of the current cost of procurement.

PROCUREMENT VERSUS PROCUREMENT ACTIVITY

The FY1975 Department of Defense Budget material provides only the magnitude of the items being procured during any particular fiscal year. Of more interest to this study is the magnitude of the procurement activity as carried on by DoD. This section presents estimates for the costs and size of the procurement activity in the Defense Department. These estimates show that a substantial fraction of the total DoD effort is expended on a relatively small fraction of high value procurements. These procurements are the most promising candidates for automation by the system which is discussed in CAWP #143-A, "Patterns in DoD Civilian Employment," (Appendix B of this Report).

WHAT IS A TYPICAL PROCUREMENT?

Table 1 lists the FY1973 experience with procurement by the type of award. Of a total of $37 billion, $30 billion involved procurements whose value was more than $10,000. However, these procurements comprised only 177,000 of the 10,499,000 procurement actions which took place during the year. That is, about 1.7% of all procurement actions involved 81% of the money. These above-$10,000 actions had an average value of $169,000, although the overall average procurement in 1973 had a value of only $3517.

A "typical" procurement is usually thought of as the result of a random drawing from the population of all procurements. It is in this sense that the average procurement is often thought of as typical, even though its value is only $3517. Table 1 implies that the size distribution of procurements is notably skewed, and that average is a deceptive way of summarizing it. Indeed, it is probably more reasonable to think of a typical procurement as having a value of several hundred thousand rather than several thousand dollars.

Table 1

FISCAL YEAR 1973 PROCUREMENT
BY TYPE OF AWARD

Category	Amount (million $)	Number (thousand $)	Average value ($)
Intragovernmental	3,038	744	4,083
Under $10,000	3,652	9,578	381
Over $10,000 (subtotal)	29,913	177	169,000
Fixed price	20,752	154	134,750
Cost reimbursable	8,923	20	448,400
Other	238	3	79,300
Total	36,920	10,499	3,517

Source: Office of the Assistant Secretary of Defense (Comptroller), *"Military Prime Contract Awards and Subcontract Payments or Commitments - July 1972 to June 1973,"* Table 16.

This skewness in the procurement distribution is a result of combining two types of purchasing under the heading "procurement." The first type is the purchasing of routine items in small quantities. These items undoubtedly constitute most of the load for the procurements which are shown as "under $10,000" in the table. But the ordering, receiving and payment operations which are done for these procurements are really a sort of inventory management problem, and the only reason these items are lumped under the heading "procurement" is that they must be purchased in accordance with the ASPRs and the related documents. Indeed, the routine nature of small procurements is recognized by the allowable shortcuts in the ASPR procedure. For instance, many items whose value is less than $10,000 can be ordered through standing basic ordering agreements not involving solicitation of either technical or price proposals at the time the contract is issued.

The other type of procurement is the one with which we are concerned--procurements which involve the acquisition of products in which one or more of the following attributes is high: cost, risk, or technological content. These procurements of non-routine items comprise the high-value components listed in Table 1 and typically dominate the procurement activity of many DoD agencies. It is on these procurements that an automated system for procurement could profitably concentrate, because these relatively few events involve most of the money and, as will be shown, most of the labor used in procurement is already expended on them.

Later in this paper it will be important to assume something about the shape of the distribution of these large procurements. Although, as has been remarked, the overall shape of the distribution of procurements is not easy to observe, it seems a safe assumption to take the tail of the distribution to be an exponential. That is, we will represent the distribution of the value of procurements V over $10,000 by the density function:

(1) $f(V) = me^{(-m(V-V_o))}$

where V_o = $10,000 and the average value of V is $1/m + V_o$. The standard deviation is $(1/m)$.

HOW MUCH EFFORT DOES PROCUREMENT REQUIRE?

If we are to make any estimates of the savings to be had from automating the procurement process we must first know how much effort is expended on procurement in its present form. That is, how many man-hours of what type are used up buying plant, equipment or services for the military, and what does this manpower cost?

A complete answer to this question requires more data than we have yet assembled. In particular, it requires time budgets for DoD personnel which would tell us, for example, how much time is spent on different procurement-related activities such as reading proposals, writing RFPs or attending the meetings of source evaluation and source selection boards.

However, enough data is in hand at this time to enable us to address a somewhat broader question: how many undifferentiated man-hours are spent on procurement, and what fraction of the whole DoD effort does this labor represent?

This question clearly requires less detailed data for its answer. Nevertheless, its answer is important if we are to assess the potential benefits to be had from an automated procurement system. Should even a rough calculation indicate little potential for benefit, there would be no point in proceeding to a deeper analysis.

Two kinds of data are available to answer this question: published data on the volume of DoD procurements and data gathered by Cabledata in interviews with present and former procurement officers. While the sources for the first kind of data will be cited as we proceed, it is appropriate to discuss the interview data more fully here.

ANALYSIS OF INTERVIEW DATA

Several present and former procurement officers have been interviewed about procurement procedures and policies. Their responses have been used to aid us in understanding the procurement cycle as discussed in Appendix E of this Report, "Information

Processing Flows Within Today's Procurement System: Feasibility of Automation." During these interviews the men were asked to assess the effort required to conduct procurements of various sizes.

The interviewees' responses are summarized in Table 2. It is apparent that the level of effort on any particular procurement is extremely variable. Part of this variability is undoubtedly due to the difficulty which the interviewees had in relating their personal experiences to the general pattern. Each one gave a range of values which was probably wider than he had experienced to allow for possibilities of which he was unaware. This source of variability should disappear as more data is obtained. However, some of the variability is due to the fact that some procurements receive more attention than others.

Despite the variability, the average levels indicated in Table 2 are probably about right. For instance, data on the Defense Supply Agency, whose primary mission is procurement, show that that agency spends an average of 15.7 man-days on procurements whose average value is $4750. In the light of this figure the 60 to 160 day figure drawn from the table for $100,000 procurements is not unreasonable.

Indeed, it is reasonable and the data confirm that procurement effort is not proportional to the value of the procurement. For small items there is always some minimum effort required. As the value of the procurement rises the number of man-hours of effort expended also rises, but less than in proportion to the value, since for the relatively few very large procurements there is only so much that can be done. A function of the form

(2) $L = aV^b + c$

where L is the effort measured in man-days, V is the value of the procurement in dollars and a, b and c are constants, is likely to give an acceptable representation of the process. For instance, given the data available the function

(3) $L = 1.9\ V^{.3} + 5$

provides an acceptable approximation for the number of procurement (i.e., non-technical) man-days expended on a procurement of value V.

Table 2

INTERVIEWEES' ASSESSMENTS OF
EFFORT LEVELS ON LARGE PROCUREMENTS

Effort by....	$ 10^5	$ 10^6 - 10^7
Technical personnel	30-80	60-200
Procurement personnel prior to the release of RFP or IFB	30-80	60-150
Procurement personnel after the release of RFP or IFB	10-30	40-90

Entries are in man-days.

CALCULATION OF PROCUREMENT MAN-LOADING

We are now in a position to make some trial calculations of the amount of effort expended on the high-value procurements. These calculations will be made using the data already assembled for DoD as a whole and for the Defense Supply Agency. The estimates for DSA will be most nearly comparable to the available data.

The Defense Supply Agency and its relation to all of DoD is shown in Table 3. It can be seen that DSA's procurements, although they comprise 23.2% of all DoD procurements, have only about half the average value. This is due to the greater use of competitive contracting in DSA.* In other respects, however, DSA resembles the rest of the Defense Department in its procurement activity. In particular, it procures roughly 11% of all items (by value) and also roughly 11% of all the items whose value exceeds $10,000.

The first step in the calculation is to find the average number of man-days expended on a high-value proposal. Assuming that the distribution of high-value procurements is represented by an exponential density function and that the number of man-days required depends on the function given above, we want to find:

$$(4) \quad \bar{L} = \int_{V_o}^{\infty} (aV^b + c)\, me^{(-m(V-V_o))}\, dV$$

which can be evaluated using tables of the incomplete Gamma function.** In Table 4 the value of $\bar{L}$ is given for both DSA and DoD and for three different sets of values for a, b and c. These three values include the one given above (a = 1.9, b = .3, c = 5) and two others which bracket this equation (a = 3.4, b = .25, c = 0 and a = 1.1, b = .35 and c = 10). The entries represent

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* Office of the Assistant Secretary of Defense, *Military Prime Contract Awards and Subcontract Payments or Commitments - July 1972 to June 1973.* p. 40

** E.g., M. Abramovitz and I. Stegun (eds.), *Handbook of Mathematical Functions with Formulas, Graphs and Tables.* National Bureau of Standards Pub. 55, Nov. 1970 (Ninth printing)

Table 3

PROCUREMENT ACTIVITY IN THE DEFENSE SUPPLY AGENCY
COMPARED TO ACTIVITY IN ALL OF DoD

	DSA	DoD	DSA as a Percent of DoD
Value of procurements (million $)	3913	36,920	10.6
Value of procurements over $10,000 (million $)	3180	29,914	10.6
Number of procurements (thousands)	825	10,499	7.86
Number of procurements over $10,000 (thousands)	41	177	23.2
Average value of procurements over $10,000 ($)	77,500	168,900	45.9

Source: Office of the Assistant Secretary of Defense, *Military Prime Contract Awards and Subcontract Payments or Commitments - July 1972 to June 1973.* Table 16.

Table 4

AVERAGE MAN-DAYS EXPENDED ON PROCUREMENTS
EXCEEDING $10,000

Coefficients	DSA 1/m=67,000	DoD 1/m=159,000
a = 3.4 b = .25 c = 0	53.2	63.0
a = 1.9 b = .3 c = 5	57.0	68.9
a = 1.1 b = .35 c = 10	62.4	77.1

the amount of effort spent on an "average" high-value procurement by procurement personnel (excluding technical time because DSA has no technical component). The table shows that the average DSA procurement requires roughly 2.5 man-months of effort by procurement personnel, which is roughly 20% less than DoD as a whole because of the lower average value of the DSA procurements.

Notice how insensitive the estimates in Table 4 are to the values of the coefficients used. The extreme values of the estimates differ by only about 10% from the middle value. This indicates that further refinement of the functional relationship between V and $\bar{L}$ will not change the conclusions of this paper. Attempts will be made during the next phase of the project to secure new data such as time budgets which may clarify our picture of these functions.

It is also possible, using the data from CAWP #143-A (Appendix B of this Report) and Table 4 to estimate the direct and indirect costs of procurement. Recalling that the median DoD civilian employee is paid $11,500 per year, and assuming 240 days per year and 25% for fringe benefits, gives a direct cost for labor of $60 per man-day. Thus, the average high-value procurement requires $3420 in DSA and $4130 in DoD as a whole. This represents 4.5% of the value of a DSA procurement and 2.5% of an average DoD procurement, and these are only direct costs. It is entirely possible that the total cost (direct plus indirect) is two or three times this amount--$7000 to $10,000 for DSA and $8000 to $12,000 for DoD as a whole.

Finally, it is possible to estimate the total cost of procurement in labor and money. Combining data from Tables 3 and 4 gives the total number of man-days per year devoted to procurement. These are tabulated in Table 5.

Table 5 shows that the direct expenditure by DoD on procurement amounts to 50,860 man-years per year costing $732 million. These man-years comprise 4.5% of the total civilian man-years available to DoD, while the direct cost of procurements is 2.5%

Table 5

TOTAL LABOR AND DOLLAR
PROCUREMENT COSTS

	DSA	DoD
Number of procurements over $10,000 (thousands)	41.0	177
Total direct man-years expended on these procurements	9750	50,860
Direct cost of these man-years (million $)	140	732

of the total value of procurements. As noted the total cost of these high-value procurements may be two or three times the three-quarters of a billion dollars cited here for direct costs.

SUMMARY AND CONCLUSIONS

This paper has presented a very preliminary look at the magnitude of the procurement activity in the Defense Department. It showed first that the distribution of procurements by size was very skewed: something under 2% of all procurements involve over 80% of the money spent on procurement, and the average value of a procurement which falls within this 2% extreme is $169,000 even though the "average" procurement has a value of $3517. It is not difficult to conclude that any procurement system should concentrate on the relatively few high-value procurements if it is to achieve any savings for the Defense Department.

Next, the paper turned to estimating the labor requirements of the procurement activity. Although the data available from published reports and interviews was limited, we have been able to establish the relationship between the value of a procurement and the labor expended on it and so to estimate the labor requirement of the average high-value procurement. Specifically it was seen that the labor requirement gave $\bar{L}$, the number of man-days expended on the procurement, as a function of the 0.3 power of V, the dollar value of the procurement. This power law was used to estimate that the average high-value procurement in DoD requires about 70 man-days of direct labor--a cost of $4130 per procurement. Total labor costs per procurement are probably between $8000 and $12,000, which represents about 6% of the average value of these procurements. This percentage itself does not seem out of line, but the idea that roughly three man-months are required for each of the 177,000 high-value procurements suggests that some savings ought to be possible not only through decreased labor requirements, but also from speedier procurement procedures.

It was also estimated that almost 51,000 man-years were spent in DoD on procurement-related activities. Regarded as employed positions rather than man-years, this indicates that over 50,000 individuals might need access to an automated procurement system. These individuals will undoubtedly not all need access at once, but if each one used the system for only ten minutes a day they would represent a user community of about 1000.

Finally, the total cost of procurement was estimated to be about $732 million in direct cost and perhaps two or three times that ($1.5 billion to $2.2 billion) when indirect costs are included. This number is large in comparison to the cost of the automated procurement system discussed in Appendix I of this Report, "Preliminary Design for Procurement Data Base System Hardware Configuration," indicating that even small increases in effectiveness might justify automation. If an automated system can save 10% of the total man-hours required for procurement, then its installation is justified as long as it costs less than $73.2 million per year. The system which is being proposed should, of course, do more than save effort. The value of the time savings and elimination of overhead costs for transportation ensure that the manpower savings provide only a lower bound on the benefits to be derived from an automated system.

APPENDIX E

INFORMATION PROCESSING FLOWS WITHIN TODAY'S PROCUREMENT SYSTEM: FEASIBILITY OF AUTOMATION

THE PROCUREMENT PROCESS

DoD policies and procedures relating to the procurement of supplies and services are formally defined in the Armed Services Procurement Regulation (ASPR).

Figure 1, following this page, shows the procurement cycle as defined by the ASPRs. Blocks 1 and 2 of the diagram show activities which take place outside of the procurment agencies and so are not broken down to the same level of detail as the rest of the diagram. The first decision to be made in the procurement cycle is whether it will be advertised, two-step, or negotiated. In 1973 the dollar value of formally advertised procurements was 10.8%, while the dollar value of two-step procurements was 23.2%.* The remaining 69% of all procurements were negotiated.

The principle difference between negotiated and formally advertised procurements is that in a formally advertised procurement all bidders must produce to a pre-defined specification. Hence, price is the only figure of merit upon which competitors can be judged. In a negotiated procurement, the item to be procured is not specified in advance. Hence, in a negotiated procurement vendors may propose both different specifications and different costs.

When a formally advertised procurement is to be conducted the work statement and the procurement request are used to prepare an invitation for bid (IFB). A synopsis of the IFB is published in the Commerce Business Daily and the IFB itself is sent to all potential bidders on the qualified source list. Optionally, the procurement office can conduct a pre-bid conference to answer questions from bidders and receive their comments. This may result in the cancellation of the procurement. If it is not cancelled,

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* Office of the Assistant Secretary of Defense (Comptroller), *Military Prime Contract Awards and Subcontract Payments or Commitments*, Table 9, p. 41.

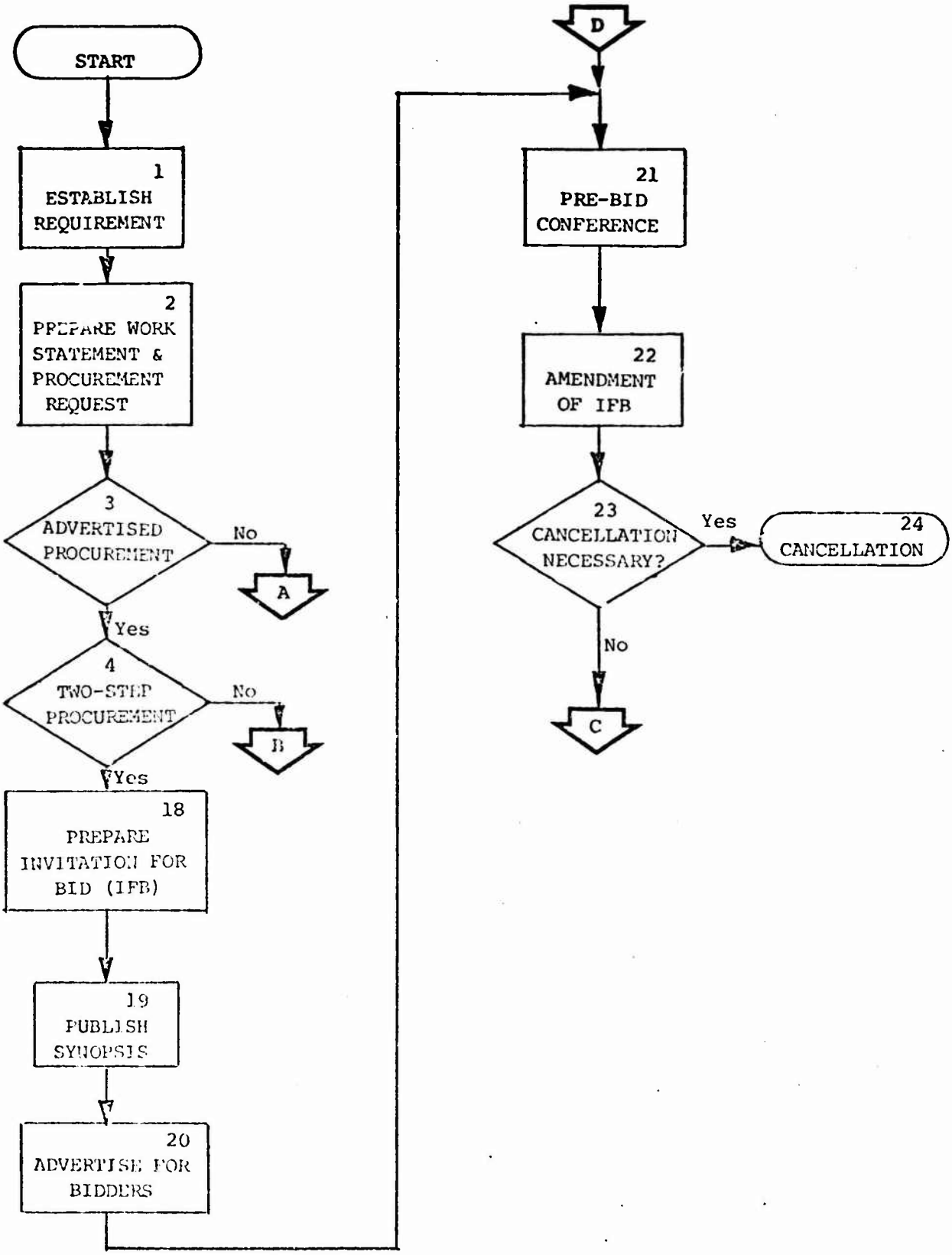

Figure 1. The Procurement Cycle, as defined by ASPRs.

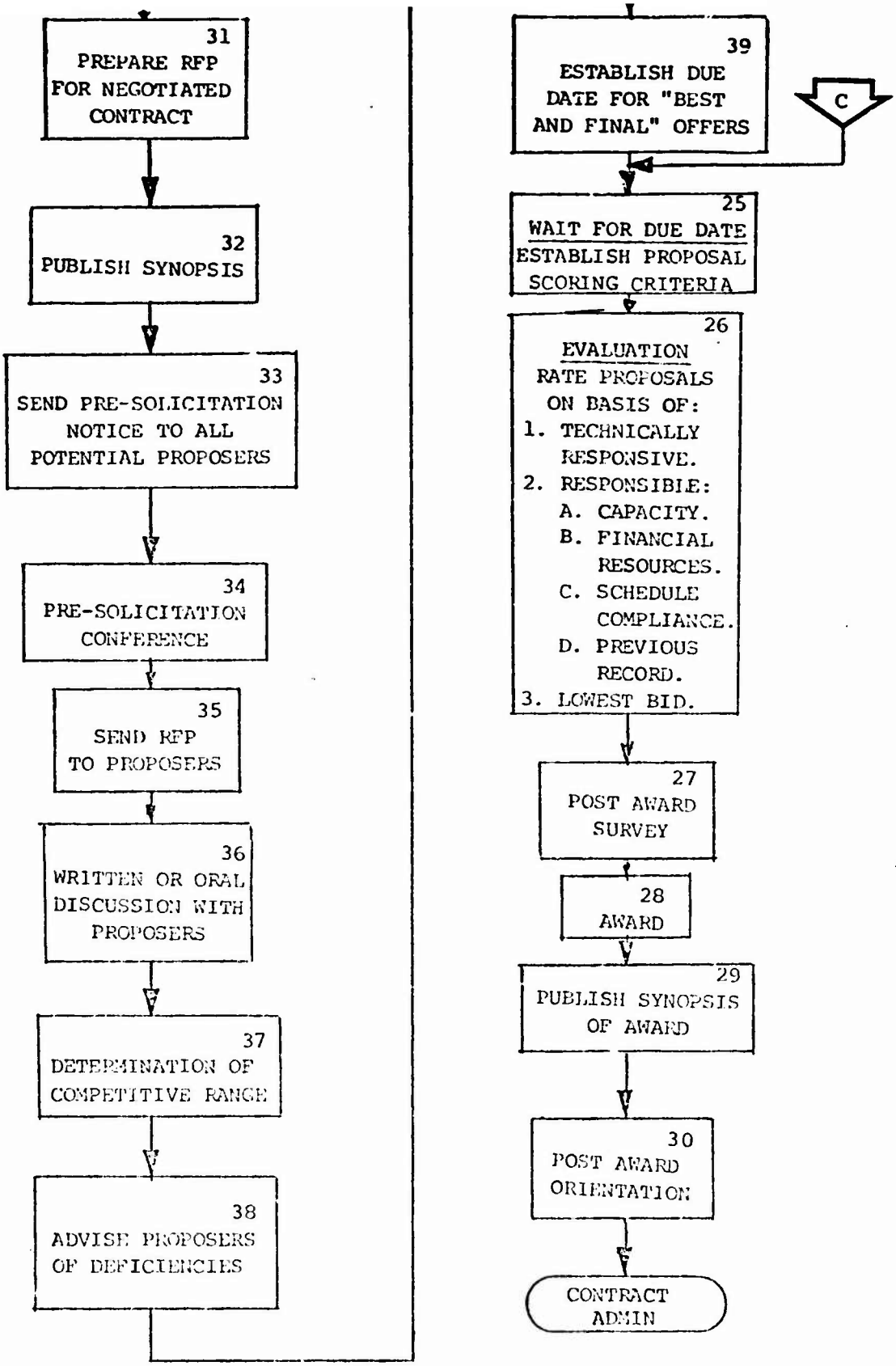

Figure 1a. Procurement Cycle, as defined by ASPRs.

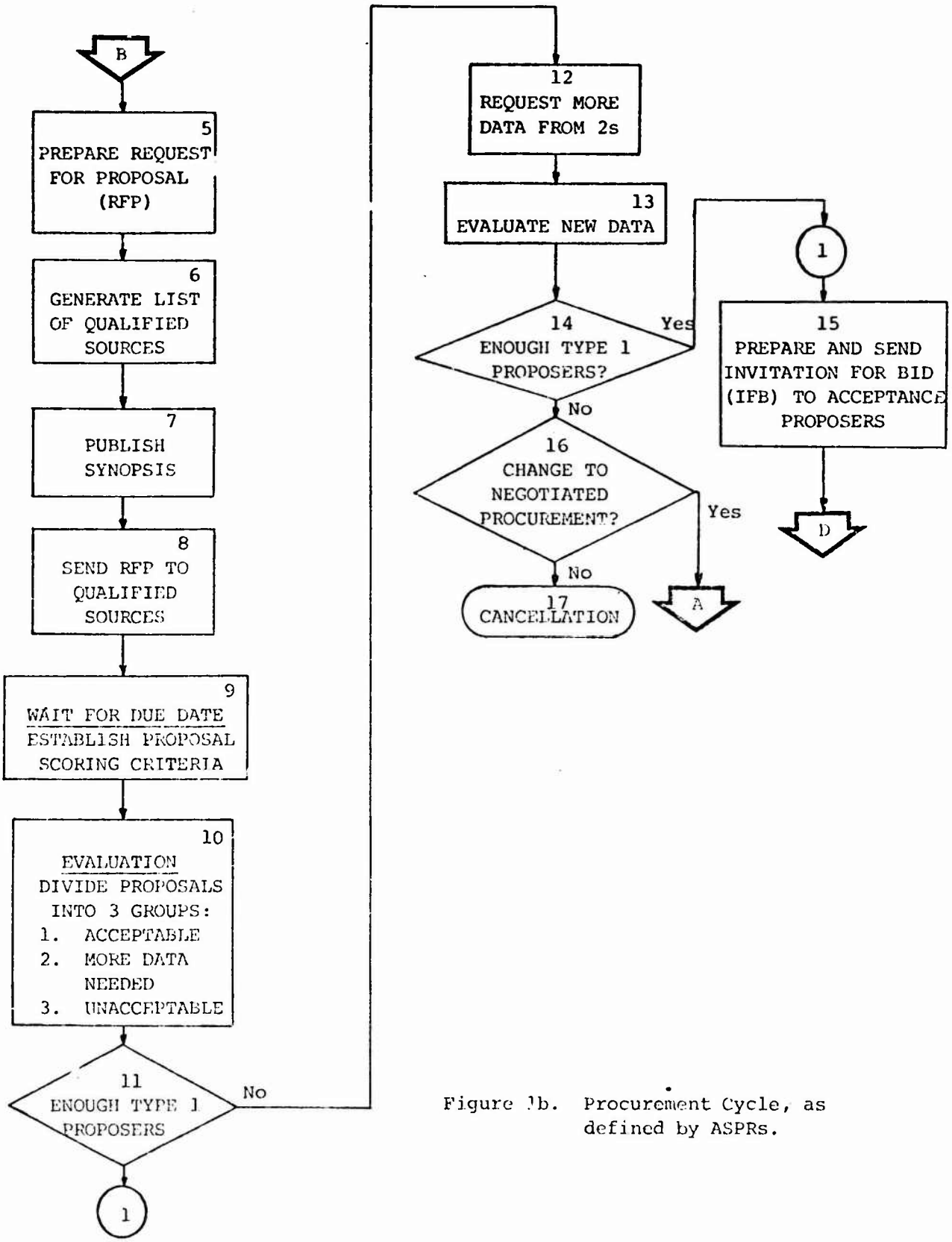

Figure 1b. Procurement Cycle, as defined by ASPRs.

path C is taken, which leads to the evaluation of bids and the award of contract.

When a negotiated procurement is to be used, the work statement and the procurement request are used to prepare an RFP for the negotiated contract. A synopsis RFP is published in the Commerce Business Daily and a pre-solicitation notice is sent to all potential proposers. ASPR permits proposers who do not receive the pre-solicitation notice to have themselves placed on a list to receive the proposal, if they are judged responsive by the procurement agency. Following an optional pre-solicitation meeting the RFP itself is sent to all proposers. After the RFP has been sent out, the procuring agency may have written or oral discussions with proposers to clarify the nature of the proposal or to discuss the type of contract which will ultimately be awarded. The procurement agency will also make a determination of the competitive range within which final proposals must fall in order to be accepted. They will advise proposers of the competitive range and of deficiencies which they may rectify prior to submitting their final proposal. Finally, at this time, the procurement agency will establish a due date for the "best and final" offers.

Source evaluation and source selection boards are now established with procurement and technical members. The source evaluation board establishes rating criteria based on technical, management, financial and other factors such as past performance. They review responses to the IFB or RFP. The source selection board sets up weighting criteria and reviews the work of the source evaluation board and the responses. A list of responders is developed, rank-ordered in two dimensions: by technical content and by price. This together with supporting material is sent on to the person in charge of the procurement (source selection authority). A source selection board is required for procurements above $1 million in value. If the procurement is above $2.5 million, it is handled in a central procurement office; if less, it can be handled in a field office.

Although not shown in the figure, this period is the one in which the proposers prepare their proposals. Their activity includes not only responding to the specific requirements of the proposal, but also providing certification that they have the requisite management, accounting, quality assurance and reliability facilities to meet the requirements of the contract. Although these certifications do not change materially from proposal to proposal, they must be provided with each proposal which is submitted.

Negotiations with potential bidders are conducted prior to evaluation. A contracting officer establishes negotiating objectives and negotiates with each bidder. Any substantive changes which result from negotiations must result in all bidders being informed. The results of the negotiations are presented to the source selection authority. The bidders' scores, determined by the source evaluation board, are reviewed and a winner is selected by a source selection authority.

When a selection has been made the award is announced to winning and losing bidders. ASPR prohibits the Defense Department from revealing what scores are used on any proposal. However, as indicated in the figure, proposers are rated on the basis of technical responsiveness, responsibility and capacity to perform the work to be contracted for, and their bid price. A post-award survey may be made of all proposers. Following the award a synopsis must be published and post-award orientation may be conducted.

The third page of the figure illustrates the steps in a two-step advertised procurement. Although two-step advertised procurements represent almost 25% of the dollar volume of DoD procurement, they comprise .3% of the volume in terms of the number of procurements per year.* In a two-step procurement an RFP is first generated in order to establish the nature of the specification and

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* Office of the Assistant Secretary of Defense, *Military Prime Contract Awards and Subcontract Payments or Commitments*, p. 43.

technical proposals are solicited from bidders without price information. Following this phase, an IFB is produced which asks for cost information from those competitors who wish to respond to a particular specified contract.

The first step in the two-step process is to prepare an IFB from the work statement and procurement request. The IFB is reviewed by a procurement committee. The work statement and other parts of the IFB are used to develop qualified contract research criteria; these are used on a potential contractor data bank to obtain a list of qualified sources. The data banks contain performance records on previous contracts and there is a procedure by which a new contractor can submit data and be included on future lists of qualified sources. The RFP is then sent out to the qualified sources. While awaiting a response, the procurement office establishes proposal scoring criteria, as was done in the case of a negotiated procurement. In the evaluation phase proposers are divided into three groups. Proposals may be acceptable, more data may be needed, or proposals may be unacceptable. If there are enough acceptable proposers an IFB is prepared and sent to the acceptable proposers. If there are not enough acceptable proposers, more data can be obtained from the middle group and evaluated. If this procedure does not result in enough acceptable proposers, the procurement may be changed to a negotiated type or it may be cancelled. If the procurement is to be negotiated, a new RFP is prepared for a negotiated contract and the procurement proceeds as before.

During the phases up to the time when the IFB or RFP is issued, the procurement activity involves a procurement team consisting of perhaps three professional level procurement officers, and technical people. The amount of time which these people devote to an individual procurement is highly variable. CAWP #147, "The Magnitude of the Procurement Activity: A Preliminary Assessment," (also Appendix D of this report) discusses the estimates which were given of the time spent on a procurement. Typical times allowed for response by potential bidders or proposers also varies

widely. When an advertised procurement is being conducted, a response is often required in 30-45 days. When a negotiated procurement is involved, proposals may be due in that time or a considerably longer period may be allowed.

Financial decisions also proceed in parallel with the procurement. A budget line item is selected prior to the preparation of the work statement and procurement request. When negotiations with a successful bidder are complete, a commitment document is prepared and forwarded. This commits funds from the budget line item, although they are not obligated until the final contract has been approved and signed by both parties.

Activities which take place prior to the decision to begin a procurement include: drafting of a statement of work by the technical personnel, assembly of the specifications and drawings which comprise the requirement package, development of a source list, consultation with reliability, quality assurance, and financial people about the procurement, and the preparation of schedules and cost estimates for the procurement itself. PERT cost is used to control the procurement process itself, although manpower shortages often mean that it is not followed in practice.

Three basic activities are going on; text preparation, text review and conferences. At present these activities are carried out almost completely by manual methods. Considerable time, energy and expense is devoted to the creation, duplication, review and transportation of documents. Smaller, but still significant expenditures are made to transport people to conferences.

We contemplate a system (its technical details are covered in Appendix 1, "Preliminary Design for Procurement Data Base System Hardware Configuration," by David Caulkins) consisting of a network of several (3 to 12) special host computers. Each host would be equipped to handle an on-line data base of approximately 1.6×10^9 characters and would be designed to support roughly 100 simultaneous users with reasonable response times: this implies a total user community of approximately 1000 per host. Two of the hosts would have archival mass storage, each with on-line capacity ranging from 6 to 40×10^9 characters. The system would be designed

so that any file (with the possible exception of some off-line archived material) would be available from at least two geographically separated hosts. In addition, no single hardware subsystem failure within a given host will be able to make the files on any particular unit of removable medium storage unavailable to network access.

This network of procurement data base hosts must be substantially more reliable and robust than existing network services; we believe this to be an absolute requirement for a system on which the bulk of DoD procurement activity may become dependent. We believe several current technological lines of development (some of them ARPA sponsored) make such a system within the mature state-of-the-art today. Some of these lines of development are:

1) Distributed computer networks with arbitrarily low error rates capable of using diverse communication facilities.

2) Modular high bandwidth central memories permitting construction of powerful and 'fail soft' multiprocessors.

3) Reliable, inexpensive and high capacity moving head disk storage.

4) 'Midi' computers of considerable power (approaching that of a 370/145) and low cost that lend themselves to multiprocessor configurations. Examples of such machines available today are the Interdata 7/32 and the Modcomp IV.

5) Inexpensive and reliable peripheral controllers built around microprocessors.

Procurement-related material can be divided into two classes -- contract specific material (descriptions of the item or service to be procured, delivery schedules, etc.) and general material applicable broad classes of procurements (labor law requirements, contractor financial data, etc.). Contract specific material must be almost wholly created for each contract while general material need only be assembled (with at most minor modification) for inclusion in the body of text.

Major advantages accruing to an automated system are as follows:

1) Only the master copy of reference documents (such as the ASPR, MIL specs, etc.) need be maintained; all references by

users will be to the most recent revision. The elimination of the current update and distribution mechanism should significantly lower costs. For instance DoD has estimated that revisions 8 and 9 of ASPR cost $482,000 (72 man-years).* Contractor costs must have been several times this amount. Virtually all of these costs could have been eliminated using an automated system.

2) Many people can have simultaneous access to the current working draft of a particular piece of text. These people can be geographically distributed.

3) The issues of privacy and security requirements are raised in Appendix I of this report, but will be considered in detail later. The system goal is to maintain access records and audit trails (who accessed what body of text; when; for how long; for what purpose; etc.) for all current text in the system with the exception of general reference documents.

4) Review and approval cycles can be made into parallel instead of serial processes; cycle times can be reduced.

5) Review and scoring of much of contractor submitted non-contract specific material (financial data, performance on previous contracts, etc.) can be automated; the time required for these operations can be substantially reduced.

6) On-line automated conference procedures can be added to or substituted for procurement conference activity in most cases, with reduction in personal and organizational bias effects (by suitable use of anonymity controlled inputs), improvement in quality and speed of the decision making process, and reduction in the amount of travel by conference attendees.

7) The effects of schedule and/or financial changes in one procurement on other procurements or existing contracts can be made explicit.

8) The bulk of the text material handled by the system will be English; advantage can be taken of the known redundancy characteristics of this language and powerful encoding techniques (Huffman coding) can be applied to reduce the bandwidth requirements of the system's network communication channels.

9) Data bases can be built in the system by clerical personnel with little training in system use. 'Fill in the form' techniques on CRT terminals can be used; consistency and completeness checks will be applied to the data as it is input to minimize errors and omissions.

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* Report of the Commission on Government Procurement Vol. 1, p. 55.

10) Powerful machine-based search techniques can be invoked to quickly locate vaguely defined items. Interested users can be automatically notified of changes in documents affecting their work.

Once in existence the system can be expanded to include additional interesting capabilities:

1) Changes in existing or contemplated procurement activities can be modeled to determine financial, schedule or other effects.

2) Personnel can be trained or evaluated by running simulated procurement activities with known parameters under system control, in a 'management game' situation.

3) Sophisticated economic and mathematical techniques can be used to evaluate contractor proposals.

4) The system can be applied to the contract management phase of operation after contract award. As more and more people from lower levels in both government and contractor organizations get used to the system, it is hoped that the negotiation, award and administration of DoD contracts can become more of a cooperative and less of an adversary situation.

Some present anticipated limitations of the automated system include:

1) Graphics are difficult to handle. Line drawings, charts and other materials with no color or gray scale can probably be dealt with. Photographs, renderings and similar materials of high optical complexity are hard to put into a form completely amenable to computer input and output at this time. However, microfiche retrieval plus mail backup can be used--but this isn't very elegant.

2) A considerable and probably painful period of transition between the old and new procurement systems would have to be endured. The new system will be easier, faster and better in most respects, but it represents a major change in modus operandi for the people involved. Great care must be taken to bring potential users in at an early stage as collaborators in the creation of the system, instead of presenting them with a threatening fait accompli. This is discussed elsewhere in the Quarterly Technical Report.

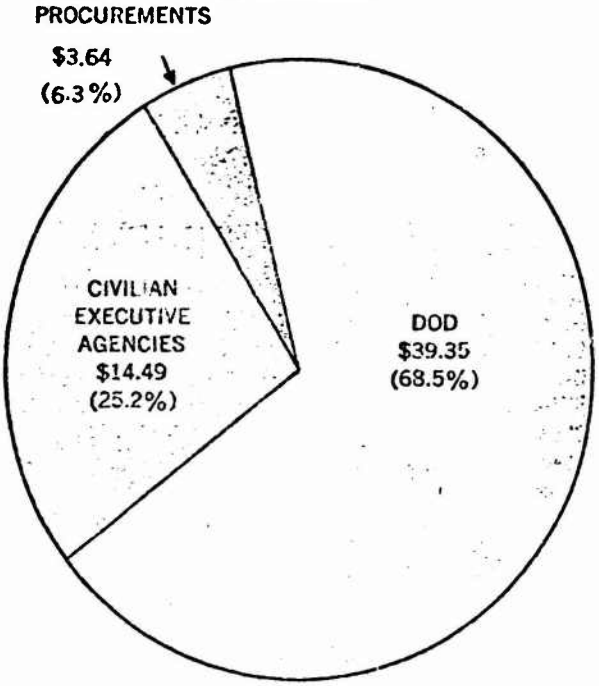
APPENDIX F

SELECTED BACKGROUND INFORMATION FROM THE NATIONAL COMMISSION ON PROCUREMENT REPORT

The following selected excerpts are taken from the National Commission on Procurement Report and provides the reader with an appreciation of the magnitude of the implications of the process of federal procurement--of which most is DoD procurement.

ESTIMATED TOTAL GOVERNMENT PROCUREMENT

FISCAL YEAR 1972
($ BILLIONS)



Does not include salaries of personnel engaged in procurement activities.

Figure 1

Source: *Report of the Commission on Government Procurement*, Vol. I., 1972 Appendix D

CHAPTER 1

Introduction

From the time the Second Continental Congress established a Commissary General in 1775, Government procurement has commanded the attention of public officials and private citizens. All too often, the attention has focused on individual abuses rather than the overall system.

In many respects, Government procurement is guided by the same considerations the Commissary General faced in 1775: maximize competition, obtain reasonable prices, and assure accountability of public officials for public transactions. Despite the similarity of principles, present-day purchasing agencies have additional problems. Huge and exotic systems to meet military and civilian needs; spiralling costs; and far-reaching economic and political effects of Government purchases complicate the Government procurement process and continually keep it before public and congressional attention.[1]

THE NEED FOR THIS STUDY

The extensive hearings[2] conducted by Congress on Public Law 91-129 indicated that: (1) the procurement process is overly complex, (2) patchwork solutions to procurement problems will no longer suffice, (3) Government procurement is important economically and politically in both its methods and goals, and (4) Congress and the public are deeply con-

[1] See Appendix G for an account of the "Historical Development of the Procurement Process."

[2] U.S. Congress, House, hearings before a subcommittee of the Committee on Government Operations on H.R. 157, 90th Cong., 1st sess., 1967, on H.R. 474, 91st Cong., 1st sess., 1969; Senate, hearings before the Committee on Government Operations, 91st Cong., 1st sess., 1969.

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 1.

cerned about the effectiveness of procurement and the manner in which it is conducted.

In establishing the Commission, Congress recognized that the annual expenditures for procurement and the attendant administrative costs are so great that even small improvements promise large rewards; that not only the Government but industry and ultimately the American people could benefit greatly from a full-scale study of the entire procurement process.

Procurement Expenditures

The Commission estimates that in fiscal 1972 the Government contracted to spend $57.5 billion for goods and services.[3] Savings of two percent on these contracts would have saved the American taxpayer more than $1 billion.

Modernize and Simplify the System

No systematic review of Government procurement has been undertaken since the First Hoover Commission in 1949 and the Second Hoover Commission Task Force in 1955, which was limited to military procurement. Neither of these bodies was devoted exclusively to studying the procurement process.

In the meantime, numerous newly created departments and agencies have undertaken significant procurement activities in support of their programs, such as improving the Nation's transportation system, purifying the environ-

[3] See Appendix D.

Source: *Report of the Commission on Government Procurement*, Vol. 1 1972 page 1.

ment, and providing adequate housing. The military arsenal continues to require multi-billion dollar weapon systems, and undertakings of similar size and complexity are needed for space, nuclear power, and other technologically advanced programs.

Over the past 20 years, Government procurement has increased sixfold.[4] Some 80,000[5] Federal employees are engaged in this process, and many more are employed in private industry.

Despite new programs, spiralling growth, and complicated products, military and civilian procurements still are governed primarily under laws enacted more than 20 years ago—the Armed Services Procurement Act of 1947 and the Federal Property and Administrative Services Act of 1949.

The procurement process as it has developed over the years has, in general, served the Nation well and should not be subject to blanket criticism. At the same time, it has developed in a piecemeal fashion. The magnitude of the outlays involved, the important program needs dependent on procurement, and the impact of procurement policies on the private sector underscore the importance of making certain that procurement operations are carried out as effectively and economically as possible.

Better Coordination and Management

The congressional hearings disclosed that procurement regulations, practices, and procedures are relatively uncoordinated and often inconsistent.[6] The volume of expensive paperwork swells yearly, and procurement procedures grow more complicated with each passing day. New agencies grope for direction as they begin to establish procurement ground rules. As a result each one's rules may differ from those already used by older agencies or from those being developed by other new agencies.

As the agencies generate new rules to control procurement and new devices to motivate contractors, Congress continues to receive an

[4] Legislative History of Commission on Government Procurement, Public Law 91-129, Nov. 26, 1969, prepared by Office of General Counsel, U.S. General Accounting Office, p. 19.

[5] See Appendix E for summary of data developed through a questionnaire used by Study Group 5.

[6] See note [1], *supra*.

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 2.

increasing volume of complaints, inquiries, and suggestions concerning Government procurement. Efforts to correct deficiencies or inequities have been fragmented and, at best, have produced only stopgap remedies.

The varying requirements of the agencies and the millions of individual procurement actions cannot be reduced to a single neat formula. However, the situation suggests that there is urgent need for a more unified approach to procurement.

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 2.

IMPORTANCE OF PROCUREMENT

Economic Significance

The $57.5 billion spent on procurement by the Government in fiscal 1972 represented about one-fourth of the budget (fig. 2), a truly formidable amount, particularly when combined with the estimated $39.1 billion expended through Federal grants.[8] Procurement expenditures are thought to generate some three times their amount through the "multiplier" effect (secondary and related consumer spending). Thousands of Government activities are involved in acquiring products and services or supporting programs that affect millions of persons.

The impact of Government procurement on the Nation's economic and social well-being is more far-reaching than even these figures suggest. The award of a major contract can stimulate the growth of States and localities; the withdrawal of a contract may cause the decline of long-established communities and enterprises; and the failure of a large Government contractor may plunge sizeable areas into economic hardship.

Catalytic Role in Economy

Federal procurement plays a catalytic and pacing role in bringing Government-developed standards and products into practical commercial use. These range from automobile safety standards and Apollo fire-resistant materials to solid-state computer components. Entire segments of industry have been spawned by technological breakthroughs and spinoffs from Government procurements for electronics, metallurgy, fuels, and lubricants.

Social and Economic Implications

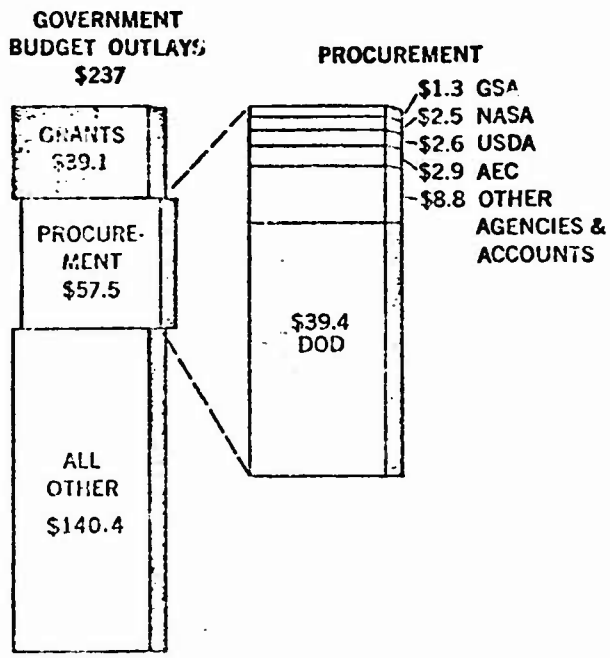
The magnitude of Government procurement provides leverage which is used as an instrument for achieving national, social, and economic objectives that do not pertain directly

[8] Part F outlines a plan for improving the use of grants and contracts in Federal assistance programs.

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 3.

RELATIONSHIP OF BUDGET OUTLAYS TO GOVERNMENT PROCUREMENT AND GRANTS

FISCAL 1972 ESTIMATE (Billions of dollars)



Sources: Appendix I.
The U.S. Budget in Brief, Fiscal Year 1973, Office of Management and Budget, table 8, Budget Receipts and Outlays, 1789–1972, p. 85.

Figure 2

to deliverable goods and services. For example, procurement is used to assure equal employment opportunities, improve wages and conditions of employment, and channel employment and business opportunities into labor-surplus areas.

CONCERNS OVER THE PROCUREMENT PROCESS

There is genuine and specific concern over the manner in which the procurement process works and over its deficiencies.

Major Systems

Understandably, the public is concerned over the cost growth of major systems, a characteristic of almost every major procurement hav-

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 3.

ing a long leadtime. This includes not only major weapon systems but also large commercial or Government buildings and other large but conventional undertakings. Because of their magnitude and because they do not contribute directly to the fulfillment of growing domestic needs, investments in major weapon systems inevitably are singled out for special scrutiny.

Cost increases have been ascribed to early planning deficiencies, organizational rivalries, abnormal inflation, changes in design to meet new threat assessments or to counter obsolescence, weak contractor management, Government interference, contractors underestimating in order to "buy-in" to the ultimate production stages, overoptimism by program advocates, and premature progression toward more costly stages of development without adequate technical validation. The degree to which these factors contribute to cost growth is considered in the discussion of major system acquisition, Part C.

Source Selection and Competition

The procedures for selecting a contractor for a major system frequently are challenged on grounds of integrity, priority, or competence. Most major systems and many lesser procurements are subjected to such challenges. Sometimes the Government is charged with disregarding its own selection criteria to assure preservation of a needed industrial source; at other times, it is charged with conveying or transfusing information on the superior technical characteristics of one bidder to his competitor; and still other charges allege that the Government uses techniques that inhibit true competition.

Accounting Practices and Profits

During periods of crisis, the profits of major contractors often come under public scrutiny. Such scrutiny has been particularly close in the past few years. Concern over total procurement costs has led to various attempts to com-

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 4.

pare profits of defense contractors with those of other commercial enterprises. It also has led to enactment of a new law intended to promote more uniform cost accounting standards in order that costs and profit comparisons can be made with greater ease and validity.

The Industrial and Technological Base

The United States recognizes that industrial preparedness for defense is a major deterrent to war. In the post-World War II era, planning for industrial preparedness has become extremely complicated since rapidly evolving technology has accelerated the rate of obsolescence of existing equipment.

The weapons build-up caused by international tensions of the past two decades and the space and nuclear competitions have maintained and nurtured the technological and industrial base. However, recent fluctuations, adjustments, and cutbacks in almost every field of technological and industrial activity raised serious questions regarding the future viability of the base.

Characteristics of the Private Enterprise System

Coupled with concerns over the industrial base are questions related to the traditional reliance of the Government on the private sector of the economy. The diversity of Government needs has compelled it to develop new purchasing methods in order to optimize the blending of public and private skills and resources. For example, the Government furnishes industry with facilities such as machine tools or heavy equipment, and provides advance funding, thus relieving industry of many of the normal risks of commercial enterprise.

The degree of risk industry assumes is debated continually; particularly with respect to firms that are Government-fostered, partially Government-protected, and which, in some respects, operate outside of the traditional free enterprise concept. One important issue is the

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 4.

amount of profit that should be permitted on capital invested in this environment as contrasted with return on risk capital in the regular commercial world.

Contract Disputes and Remedies

Disputes and protests result from the award, performance, and administration of Government contracts. Such disputes must be resolved fairly, efficiently, and economically. The system for resolving contract disputes is said to be too time-consuming and costly for resolution of smaller claims and is often said to lack procedural safeguards. Protesting a contract award is allegedly confused by a multiplicity of forums and lack of an effective remedy for those with valid protests.

GOVERNMENT NEEDS AND RESOURCES

Types of Procurement

The Government as a consumer participates in thousands of activities that involve millions of people and each year spends billions of dollars for the purchase or development of products and services. Many of these products and services are consumed by Government employees and military personnel, but billions of dollars go to buy "program support" in fields such as atomic energy development, scientific research, space technology, environmental improvement, housing, transportation, health protection, and many others.

An increasing number of acquisitions consist of major military or civilian systems of vital importance to the Nation's defense, technological advancement, and future well-being. Because the Government usually is the only customer for such major systems and the number of suppliers is limited, the normal rules of the commercial market do not apply fully.

Thousands of products, off-the-shelf or specially fabricated, and services are acquired from the commercial marketplace. Even here, the rules are partially tailored to the unique character of the Government as a customer,

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 5.

bound by legal, procedural, and social program requirements not generally applicable to other customers.

Alternative Sources

To satisfy its needs, the Government may rely on private industry, the academic community, or other nonprofit organizations. It may also resort to in-house facilities run by Government employees, or it may turn to not-for-profit organizations established and funded by the Government but operating in a manner that is neither wholly Government nor wholly private enterprise.

Traditionally, the criticality of the need and the "relative cost" to the Government of relying on private enterprise rather than Government sources have been the primary factors in deciding on the resources to be used.

Businessmen worry over what they believe is a trend, particularly in a period of cutback or belt-tightening, to retain work "in-house" that was previously performed commercially. It is alleged that this trend is encouraged by Government policy that favors performance in-house. However, Government employee groups are concerned that there is a trend toward increased use of contracts for services, especially when Government personnel ceilings limit hiring.

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 5.

Policy Goals

The law establishing this Commission declares it "to be the policy of Congress to promote economy, efficiency, and effectiveness" in the procurement of goods and services by the executive branch.[9] The methods for achieving this policy are spelled out in the law. Essentially, the law calls for (1) the reevaluation and improvement of policies for the Government to acquire goods and services in a timely, economical, and competitive manner; (2) an improvement in procurement organization and personnel; (3) the correction of duplication or gaps in laws, regulations, and directives; (4) uniformity and simplicity when appropriate; (5) fair dealing; and (6) overall coordination of Federal procurement programs.

Recommendations are contained throughout the four volumes of our report. Clearly, not all are of equal importance or of similar impact. Some call for a fundamental recasting of the procurement process; others for alleviating ills that have plagued Government and industry. Taken together, the major recommendations will achieve the policy goals set forth in the congressional mandate establishing the Commission.

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 6.

A Concluding Thought

The Commission has not attempted to make an estimate of the savings which could be achieved through the adoption of its recommendations. Indeed, it would have been impossible since many of them are in the nature of policy changes for which estimates could not be made with any degree of precision. At the same time, the Commission is certain that substantial savings can be made and has so indicated at many points in its report. For example, one recommendation alone—increasing from $2,500 to $10,000 the limit on exemptions from using advertised procurement procedures for small purchases—would save approximately $100 million.

Source: *Report of the Commission on Government Procurement*, Vol. I 1972 page 7.

APPENDIX G

SOME CHANGES IN THE FUTURE ENVIRONMENT FOR PROCUREMENT

Introduction

This Appendix discusses two topics. First it considers the changing defense budget, viewing it as a long term statement of national priorities. Secondly, it considers the resulting sorts of attitudes that defense procurement might expect to encounter in the future. Lastly, it suggests that designing the procurement system for "openness" may be more than prudent, it might be mandatory in the future.

Can We Afford to Defend Ourselves?

Why does the U.S. defense posture appear to be so relatively underfunded when expenditures for defense appear not to have declined?

Not so many years ago, the national concern about defense from a foreign aggressor was so overwhelming that the Department of Defense was able to request, and Congress concur in providing a significant portion of the National GNP annually. Defense was always the overwhelming portion of governmental expenditure.

Figure 1 shows the trend of national defense expenditures in current dollars. And, it is a clearly rising curve.

But, if we look at DoD expenditures in terms of deflated (constant FY1969) dollars the picture is different, the curve for defense expenditures is a straight line of essential level spending since 1952. (See Figure 2.)

And, lastly and most importantly if we consider the defense budget as a percentage of GNP, it can be seen to be a rapidly declining curve. (Approaching zero in the year 2010, if we extrapolate the rate.) (See Figure 3.)

Implication

These curves dramatize the trend that funds for defense are continuously declining. A nation's priorities are expressed in

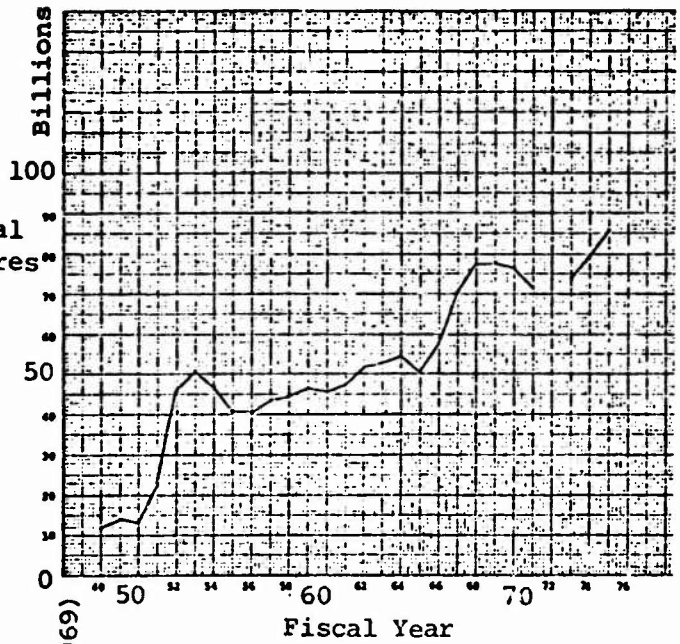


Figure 1. National Defense Expenditures in Billions of Dollars

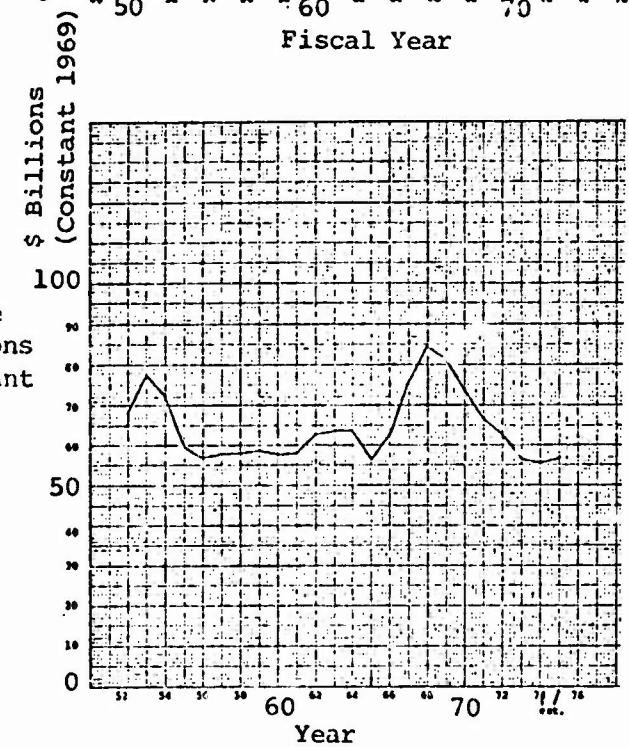


Figure 2. Defense Spending in Billions of Dollars (Constant FY 1969)

(From OMB)

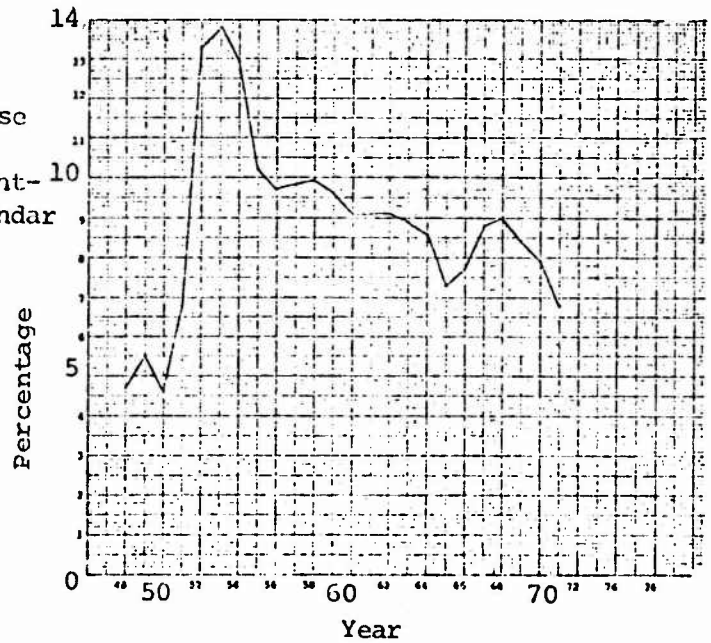


Figure 3. Defense Spending (Fiscal Year) as a Percentage of GNP (Calendar Year)

Source:
Neil H. Jacoby, Corporate Power and Social Responsibility, MacMillan, 1973, pp. 225-245.

See also:
The Economics of Defense Spending: A Look At The Realities, Department of Defense (Comptroller), SupDoc #0800-00176, 1972.

the nation's budget. And, the signals to the future defense planner are clear. Less money as percentage of GNP; probably even less money in terms of constant dollars.

At this point it is clear that there probably won't be enough Defense dollars around to buy the weapons systems and military defense capability that the leaders entrusted with maintenance of defense capability believe required. The only place where free dollars can be developed is from increased effectiveness of dollars being presently expended.

While Defense technology has and is becoming increasingly more effective with time on an absolute basis (but not necessarily on an international comparison basis), the increasing labor component in this budget is wiping out most of the effective increase savings. For example, we have heard figures which appear reasonable (but which are not yet personally verified) that the percentage of the defense budget now devoted to paying for manpower has increased from 25% of the defense budget in 1960 to 50% of the budget in 1973. Unless there can be a major increase in the efficiency of people there is clearly going to be a further steady erosion in what a defense dollar spent on what salary buys.

Evolving Public Attitude Toward Defense

The concensus for the wisdom of expenditures for defense has disappeared, and may not appear again until the nation faces a unifying catastrophic challenge. But, in the meantime, the responsibility for providing for defense expenditures will have to be exercised on a stage where many in the audience are suffering from taints of paranoia, and have no compunction for even a respectable silence.

Defense procurement has moved from the arena of sole concern by a small group of trusted leaders whose decisions were rarely to be questioned (and then only with an acknowledgement that they probably have more information about the problem than the doubters and that the reasons for the decisions could not be revealed because the information would give aid and comfort to

the enemy). This has now given way to an environment where a significant sector of society views each dollar spent on defense as a dollar devoted to waste at best and genocide at worst.

On "Openness"

These are not pleasant thoughts but are raised to help dramatize the importance of a new system design parameter: a level of openness of decision reaching never before realized may become a necessity in the future.

A procurement support system that is to be designed for the future should be designed for use by a society with an evolving set of social values. For example, we now have a society that is placing increasing trust in the Freedom of Information Act and less in the Secrecy Act and in its effectiveness. This clearly is a markedly different constituency than our past society, and this change should be considered in the design of a procurement system that must effectively serve such a constituency and allow good decisions to be reached quickly and where each dollar must be justified by whoever desires to question and for whatever reason.

If the system does not lend itself to complete openness for review by interested parties, it will be subject to greater suspicion than a system that operates completely in the open. Of course conventional military secrecy protection will still be required. But for an increasing percentage of procurement-related activities, more openness will be demanded by the public in the future.

The standards of conflict-of-interest are increasing and possibly in the future will be of such a nature that even the shadow of possible suspicion of the potential for misdeeds will be regarded by a significant political constituency as constituting a misuse of public funds or even fraud.

The post-Watergate standards for conflict-of-interest, for example, should be expected to be different than allowable in the past, and the system design should reflect this change.

If we are correct in our assessment of the evolving attitude of the new public, the old fashioned string-pulling by a congressman to get a defense contract into his district would have gone out of existence, the same way that the spoils system that was a part of the operation of government well beyond the last century has diminished in intensity.

APPENDIX H

CHARACTERISTICS OF THE PROCUREMENT WORK FORCE

This Appendix provides the reference source of the data used in the section describing the present procurement work force.

APPENDIX E

Data on the Procurement Work Force

THE PROCUREMENT WORK FORCE HIGHLIGHTS, 1971

SIZE

ESTIMATED TOTAL —80,000
POSITIONS REPORTED—61,000
POSITIONS ANALYZED—57,000 (THOSE ANSWERING QUESTIONNAIRES)

DEPARTMENTAL DISTRIBUTION

76%—DEPARTMENT OF DEFENSE
24%—ALL OTHER DEPARTMENTS

GOVERNMENT PROCUREMENT REFERENCE (CIVILIAN STAFF)

NONE, OR LESS THAN 1 YEAR — 8%
1–5 YEARS —26%
OVER 5 YEARS—66%

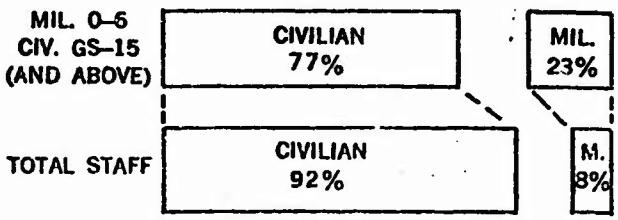
OVER 50% WILL BE ELIGIBLE TO RETIRE BY END OF 1980—OBVIOUSLY FROM THE MOST EXPERIENCED GROUP

AVERAGE EDUCATION (CIVILIAN STAFF)

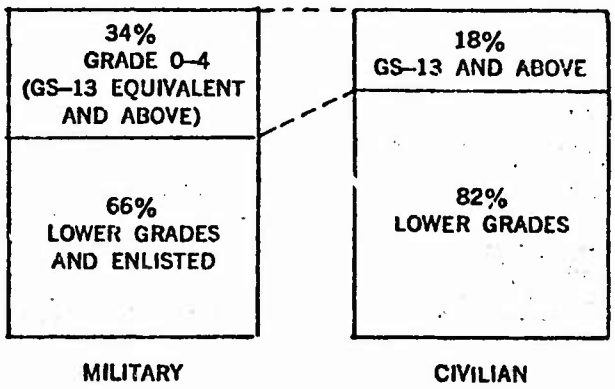
HIGH SCHOOL, PLUS 3 MONTHS COLLEGE

Source: Commission Studies Program (based on responses to Commission questionnaires).

MANAGEMENT LEVEL MIX



DISTRIBUTION OF HIGHER LEVEL CIVILIAN AND MILITARY PROCUREMENT POSITIONS



COMPOSITION OF THE FEDERAL GOVERNMENT PROCUREMENT WORK FORCE, BY AGE

Age	*Civilian*	*Percent*	*Military*	*Percent*	*Total*	*Percent*
20 and under	12	—	61	1.4	73	0.1
21—25	1,206	2.3	749	17.3	1,955	3.4
26—30	3,093	5.8	1,060	24.5	4,153	7.2
31—35	4,324	8.1	721	16.7	5,045	8.7
36—40	5,934	11.1	838	19.4	6,772	11.8
41—45	7,215	13.5	449	10.4	7,664	13.3
46—50	11,235	21.1	279	6.4	11,514	20.0
51—55	10,845	20.4	143	3.3	10,988	19.1
56—60	6,176	11.6	24	0.5	6,200	10.8
61—65	2,674	5.0	4	0.1	2,678	4.6
66—70	579	1.1	—	—	579	1.0
Total	53,293	100.0	4,328	100.0	57,621	100.0

Source: Commission Studies Program (based on responses to Commission questionnaires).

Source: *Report of the Commission on Government Procurement*, Vol. I, 1972 Appendix E.

COMPOSITION OF THE FEDERAL GOVERNMENT PROCUREMENT WORK FORCE, BY HIGHEST LEVEL OF EDUCATION

Level of education	*Civilian*	*Percent*	*Military*	*Percent*	*Total*	*Percent*
Less than high school	2,073	3.9	38	0.9	2,111	3.7
High school	20,864	38.9	891	22.0	21,755	37.8
Post high school	1,513	2.8	16	0.4	1,529	2.6
At least 30 semester hours of college credit	4,228	7.9	211	5.2	4,439	7.7
At least 60 semester hours of college credit and/or a junior college certificate (AA) (AS)	3,812	7.1	154	3.8	3,966	6.8
At least 90 to 120 semester hours of college credit	2,787	5.2	108	2.7	2,895	5.0
Bachelor's degree	14,529	27.1	1,572	38.8	16,101	27.9
Law degree (LLB, JD, etc.)	1,104	2.1	82	2.0	1,186	2.1
Master's degree	2,183	4.1	923	22.8	3,106	5.4
Doctor's degree	475	0.9	58	1.4	533	0.9
Total	53,568	100.0	4,053	100.0	57,621	100.0

Source: Commission Studies Program (based on responses to Commission questionnaires).

COMPOSITION OF THE FEDERAL GOVERNMENT PROCUREMENT WORK FORCE, BY YEARS OF GOVERNMENT PROCUREMENT EXPERIENCE

	Number of persons					
Government procurement experience	*Civilian*[1]	*Percent*	*Military*[2]	*Percent*	*Total*	*Percent*
None or less than one year	4,303	8.0	391	9.6	4,694	8.2
1— 5 years	13,809	25.8	2,428	60.0	16,237	28.2
6—10 years	13,078	24.5	659	16.3	13,737	23.8
11—15 years	8,593	16.0	339	8.4	8,932	15.5
16—20 years	7,609	14.2	190	4.7	7,799	13.5
21—25 years	3,739	7.0	34	0.8	3,773	6.5
26—30 years	2,041	3.8	9	0.2	2,050	3.6
31 years and over	396	0.7	3	—	399	0.7
Total	53,568	100.0	4,053	100.0	57,621	100.0

[1] Government procurement experience in a civilian capacity.

[2] Government procurement experience in a military capacity.

Source: Commission Studies Program (based on responses to Commission questionnaires).

Source: *Report of the Commission on Government Procurement*, Vol. I, 1972 Appendix E

APPENDIX I

PRELIMINARY DESIGN FOR
PROCUREMENT DATA BASE SYSTEM
HARDWARE CONFIGURATION

INTRODUCTION

This working paper presents a conceptual design for computer network system hardware to support automated DoD procurement activity as discussed in Appendix E. The design proposed is not intended to be a definitive statement; its intent is solely to suggest that system design goals can be achieved in the 1975-1980 time frame at modest cost and use only mature hardware technologies.

The system would consist of two major parts:

1) A number (probably 3 to 12) of host computer centers specialized for efficient handling of procurement data processing requirements. Growth would be evolutionary after the first two or three.

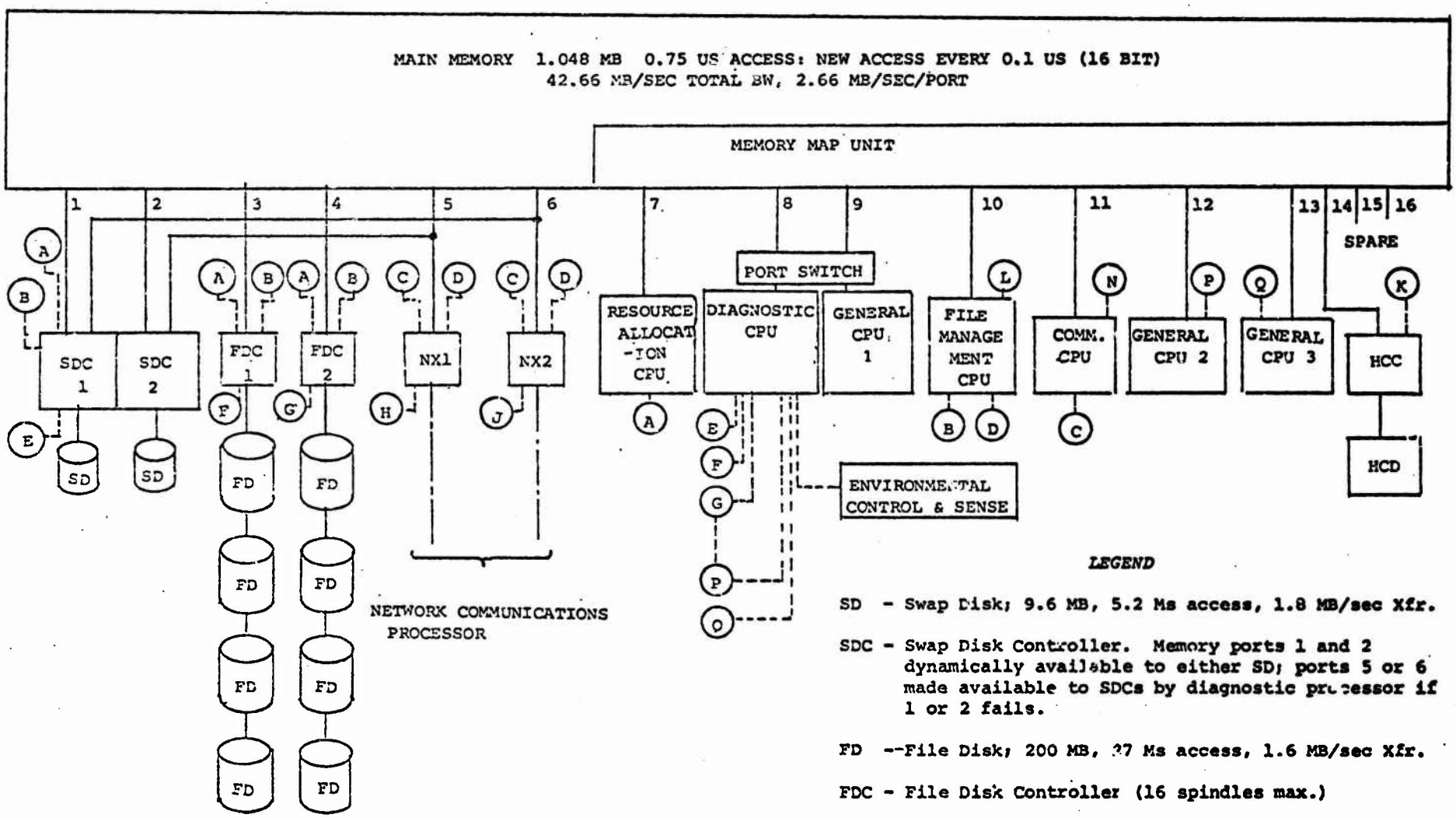
2) A packet switching network connecting these hosts. This network could be a self contained broadcast satellite system or an overlay user network on a commercial packet switching network using telephone lines. While the use of a satellite is discussed, its use is secondary to the main thrust of the discussion.

HOST COMPUTER

A block diagram of the host computer system is shown in Figure 1. The system's central processor is a multiprocessor format using seven independent minicomputers as central processing units. Serving the processors are memories organized into a four level hierarchy:

1) The first level of the hierarchy is 1.048 megabyte (MB) of high speed random access main memory. This memory will have 16 ports, each of which can handle data at a 2.67 MB/sec rate (one 16 bit word every 0.75 us). Each port would be able to accept a new store or fetch request every 0.1 us; each such request to a memory port will be accepted or rejected (in the event of contention from a higher priority port) after a fixed time delay of several tenths of a microsecond.

2) The second level of storage is 19.2 MB of fixed head rotating storage with 5.2 Ms average access time; two drives with 9.6 MB each.



LEGEND

SD - Swap Disk; 9.6 MB, 5.2 Ms access, 1.8 MB/sec Xfr.

SDC - Swap Disk Controller. Memory ports 1 and 2 dynamically available to either SD; ports 5 or 6 made available to SDCs by diagnostic processor if 1 or 2 fails.

FD --File Disk; 200 MB, 37 Ms access, 1.6 MB/sec Xfr.

FDC - File Disk Controller (16 spindles max.)

NX - Network Interface. Serial data put directly into main memory buffers.

HCD - Hard Copy Device, COM unit, printer, OCR and/or Etc.

HCC - Hard Copy Controller

Figure 1. Host Computer System

3) The third level of the hierarchy is approximately 1600 MB (minimum of 400, maximum of 6400 MB) of moving head rotating storage with 27 Ms average access time; 8 drives with 200 MB each.

4) The fourth level is archival large bulk memory located at perhaps two of the host computer systems on the network. These will be designated as archive hosts and be equipped with enlarged tertiary storage capability; the full complement of 32 moving head disk drives (6400 MB) and/or an Ampex TBM type mass store.

The architecture proposed is somewhat unusual--the use of a group of minicomputers in a multiprocessing configuration to control a very large complement of peripheral storage. We chose this configuration primarily because:

1) We couldn't obtain the desired performance at the desired high reliability level with the more usual system configurations;

2) The system configuration lends itself to what we believe will be powerful privacy and security maintenance techniques; and lastly,

3) The low cost and very powerful processing capabilities of some of the newer larger minicomputers provide a system of total overall lower cost, than other alternatives briefly considered.

The host computer system is structured so that no single hardware subsystem failure can seriously degrade system operation--with the inevitable single exception. That single subsystem that remains critical to host operation is the main memory. We propose that the main memory be partitioned so that no single failure would make more than 25% of the memory unavailable, while most failures will not affect more than 6.25% of the first level memory's capacity. At this time we believe that the main memory can be built with an MTBF (mean time between failures--unanticipated errors) in excess of 1500 hours, and MTTR, (mean time to repair) of 30 minutes for 90% of the failures encountered. Peripheral subsystems would be divided into two sections, where loss of one section will not affect operation of the other. Peripheral controllers would be distributed across the memory ports so that failure of any one port can not affect more than half of one of

the rotating storage media peripherals. Each peripheral controller would access two control ports and be serviced by one of two CPUs as dynamically determined by the CPU assigned the diagnostic function role. In most cases a malfunctioning CPU's functions could be taken over by another CPU upon direction by the diagnostic CPU without necessity for human intervention. The CPUs would all be plug compatible allowing a spare CPU be recabled to replace a malfunctioning one in a matter of minutes.

The diagnostic CPU plays a central role in the operation of the host computer system. Because of its unique role requirement, the diagnostic CPU would be connected to one of two memory ports, insuring itself memory access in the event of failure of a single memory port. The diagnostic CPU has three main functions:

1) Control the main memory map unit physical memory address register loading.

2) Continuously monitor the remainder of the system for correct operation. This is done by checking status tables in main memory and by direct status interrogation via special status cables connected to all peripheral controllers, other CPUs and main memory. Upon need, the diagnostic CPU would reconfigure the system to maintain operation circumventing single unit malfunctions.

3) Lastly, it would control the privacy and security systems* and in consequence must be physically secure. Critical sections of its program would be executed a read only memory (ROM). The diagnostic CPU together with its ROM and control panel would be locked into a safe during operation. Any unauthorized disconnection of one of its cables or other unusual events will cause a security alarm.

Since the diagnostic CPU is unique in that its correct operation is necessary for the rest of the system to function, it will probably be desirable to provide a standby CPU in the safe with the diagnostic CPU. The primary diagnostic CPU would reset a watch dog timer flag at several points during its program. If this timer ever counts beyond the anticipated reset period the standby diagnostic CPU will be interrupted from an idle loop, disable the primary diagnostic CPU, take over its functions and notify the operator.

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* These systems will be treated in detail in a separate working paper.

The diagnostic CPU (or pair of diagnostic CPUs) would be the only CPU(s) in the system dedicated to a unique function. The CPUs assigned to resource allocation, file management and communication have specific tasks by virtue of their I/O bus connections to particular controllers, but can share in the general computational load as directed by the operating system software. If more computational capacity is needed, additional CPUs may be connected to spare memory ports 15 and 16 shown in Figure 1.

The cost-effectiveness advantage of using CPUs of modern design over conventional mainframes is significant. A comparison between three CPUs (the IBM 370/145, the DEC PDP-10 and the Interdata 7/32) is given below. Gibson mix* calculations were made for each of the three configurations described (see Table 1.) A somewhat arbitrarily defined figure of merit was calculated for each of the machines, and the results are shown in Table 2. There is a factor of 50 between the price-performance ratios of the best and worst CPUs.

Of course merely extrapolating the figure of merit estimations to obtain a feeling about the number of simultaneous users places us on very shaky ground. But, in the temporary absence of more careful estimates it is helpful to consider that the six non-dedicated CPUs shown in Figure 1 are roughly equivalent to 3.7 KA-10s or 2.1 KI-10s. If we assume that a KA-10 based TENEX system could support 30 users comfortably, on the same basis we would assume that the CPUs of Figure 1 would support about 111 users (that is 30 x 3.7).

Table 4 presents a cost comparison of systems similar to that of Figure 1, mechanized with two different choices of CPU and main memories. Each system is made up of 6 subsystems:

Main Memory
CPUs
Swap Store
File Store
Network Equipment
Miscellaneous

} Peripheral Subsystems

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* C.G. Bell and A. Newell, *Computer Structures: Readings and Examples* (New York: McGraw-Hill Book Company, 1971) pp. 49-50.

TABLE 1

Comparison of CPUs

Instruction Type	PDP-10 (KA10)				370/145				7/32			
	Instr.	Time (us)	Gibson Wt.*	Time x Wt	Instr.	Time (us)	Gibson Wt.*	Time x Wt	Instr.	Time (us)	Gibson Wt.*	Time x Wt
Arith, Fixed	ADD	2.53	3	7.59	A	2.38	1.5	3.58	A	3.25	1.5	4.88
" "	-	-	-	-	AR	1.37	1.5	2.06	AR	1.0	1.5	1.5
" "	SUB	2.53	3	7.59	S	2.34	1.5	3.51	S	3.25	1.5	4.88
" "	-	-	-	-	SR	1.58	1.5	2.37	SR	1.0	1.5	1.5
" "	MUL	10.6	3	31.8	M	20.08	3	60.24	M	16.0	3	48.0
" "	DIV	16.2	1	16.2	D	34.77	1	34.77	D	100.0	1	100.0
Load/Store	MOVEM	2.47	25	61.75	L	1.69	12.5	21.12	L	3.25	12.5	40.62
" "	-	-	-	-	ST	1.5	12.5	18.75	ST	3.0	12.5	37.5
Cond. Brnch.	JFCL	1.36	20	27.2	BC	1.79	20	35.8	BTCW	2.5	20	50.0
Compare	CAM	2.53	24	60.72	CH	2.95	24	70.8	CH	5.25	24	126.0
I/O	CONO	3.9	7	27.3	CLRIO	11.15	7	78.05	OC	4.5	7	31.5
	TOTALS	42.12	86	240.15		81.6	86	331.05		143.0	86	446.38

* Average Gibson instruction times:
PDP-10 KA10: 240.15/86 = 2.79 us; PDP-10 KI10: 1.40 us**
370/145: 331.05/86 = 3.85 us
7/32: 446.38/86 = 5.19 us

Instructions per second:
PDP-10 KA10: $1/2.79 \times 10^{-6}$ = 358,000 inst/sec; PDP-10 KI10: $1/1.40 \times 10^{-6}$ = 716,000 inst/sec
370/145: $1/3.85 \times 10^{-6}$ = 260,000 inst/sec
7/32: $1/5.19 \times 10^{-6}$ = 193,000 inst/sec

** We were unable to get exact KI10 instruction timings; local DEC people said the KI was twice as fast as the KA.

Table 2

CPU Characteristics

Type	(1) Gibson Avg(us)	(2) Instr/Sec.	(3) No. of Instrs.	(4) Purchase Price,$*	(5) Figure of Merit**	(6) Cost-effectiveness [(5)/(4)] x 10^6	(7) Price-performance ratio (6)/1.6
370/145	3.85	260,000	179	595,000	0.93	1.6	1.0
PDP-10							
KA10	2.79	358,000	366	170,000	1.27	7.5	4.7
KI10	1.40	716,000	378	240,000	2.20	9.2	5.8
7/32	5.19	193,000	239	9,950	0.78	78.4	49.0

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* These prices are not exactly comparable. Both IBM and Interdata sell processors only with a minimum quantity of memory (131 KB for the 370/145, 32 KB for the 7/32); an ingenious marketing device to guarantee purchase of at least some of the manufacturer's high priced memory.

** Figure of merit (FM) calculation:

FM = (I)(W1)(N1) + (IC)(W2)(N2) + (WS)(W3)(N3)

I, IC and WS are machine parameters. They are:

- I - number of instructions per second the machine can execute
- IC - number of instructions in the machine's instruction set
- WS - the machine's word size in bits

W1, W2 and W3 are weighting factors. Their values are:

W1 = 0.7
W2 = 0.1
W3 = 0.2

N1, N2 and N3 are normalizing factors to bring each term into the range from 0 to 2.0. Their values are:

N1 = 0.0000037
N2 = 0.0035
N3 = 0.03

Table 3

Peripheral Subsystem Costs

Subsystem	Purchase Cost($)*	Manufacturer
Swap Store** (two disks)	216,000	Digital Development Corp.
File Store** (eight spindles)	200,000	ISS (Sperry Univac)
Network Equipment	70,000	?
Miscellaneous	200,000	-
Total	686,000	

* No allowance has been made for quantity purchase discounts

** Includes two controllers

Table 4

System Cost Comparison **

	Conventional System (System A)					Minicomputer Based System (System B)				
	Type	word size (bits)	No.	Purchase Cost ($)	Mfg.	Type	word size (bits)	No.	Purchase Cost ($)	Mfg.
Main Memory	64K Wd. modules 4 ports	36	4	320,000	DEC	524K words 16 ports	16	1	400,000	Systems Concepts
CPUs	KI10	36	2	480,000	DEC	7/16	32	7	70,000	Interdata
Peripheral Subsystems	*	-	*	686,000	*	*	*	-	686,000	*
	Totals			1,486,000					1,156,000	

* See Table 3

** Hardware costs only.

In each mechanization considered in Table 4 only the first two subsystems are changed, while peripheral subsystem costs are held constant to simplify the comparison. (Table 3 provides costs for the peripherals.) Any comparisons of this type are, by their nature, inherently gross; this one is especially so because of the differing memory word sizes and port structures. But it does provide useful insights.

Table 5 shows dollar and percentage costs for the system of Figure 1, estimated for 1974 technology.

Table 5

Cost Estimate for the System of
Figure 1 (1974 technology)

Subsystem	Purchase Cost* ($)	% of Total	Manufacturer
Main Memory	400,000	34.6	Systems Concepts
7 CPUs	70,000	6.1	Interdata
Swap Store (two disks)	216,000	18.7	Digital Development Corp.
File Store (eight spindles)	200,000	17.3	ISS (Sperry Univac)
Network Equipment	70,000	6.1	?
Miscellaneous	200,000	17.3	-
Total	1,156,000	100	

* No allowance has been made for quantity purchase discounts.