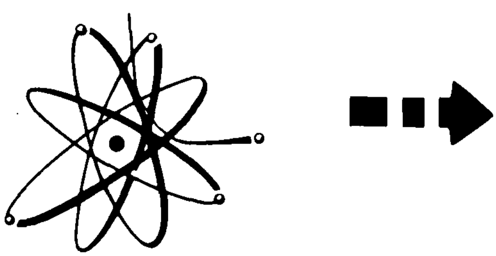
ELECTRONICS IN MANAGEMENT

LOWELL H. HATTERY
and
GEORGE P. BUSH

EDITORS



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ELECTRONICS IN MANAGEMENT

Electronics in Management summarizes advanced thinking about management implications of electronic computers. It captures the experience of pioneers in the field. Contributors bring direct experience in applying the new electronic computer systems to management uses.

The book is adapted from the proceedings of the First Institute on Electronics in Management presented at The American University in November 1955. The purpose of the Institute was to review and analyze the management potential and the problems arising from the development and installation of automatic systems, especially data processing systems. Among problem areas treated were planning, procedures, organization, personnel, fiscal and executive.

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ELECTRONICS IN MANAGEMENT

ELECTRONICS IN MANAGEMENT

Edited by

LOWELL H. HATTERY

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THE UNIVERSITY PRESS OF WASHINGTON, D. C.

WASHINGTON 9, D. C.

1956

Library of Congress Card Number: 56-8504

PRINTED IN THE UNITED STATES OF AMERICA BY
THE LORD BALTIMORE PRESS, INC., BALTIMORE, MD.

FOREWORD

This volume summarizes advanced thinking about management implications of electronic computers. It captures the experience of such pioneers in the field as the National Bureau of Standards, the U. S. Bureau of the Census, the Metropolitan Life Insurance Company and the United States Steel Corporation.

I believe the book is required reading for teachers and students of management, and for management personnel of government, business or industry whether or not in the immediate market for electronic computers. No one can afford to neglect an understanding of the management implications resulting from the development and potential impact of these machines if he is to be abreast of his field.

At The American University we have tried to maintain sensitivity to the impact of technological change on management and to provide such training programs and facilities as needs have warranted. For example, the growth of organized scientific research placed a critical stress on management and science personnel. We have helped to meet the need for management improvement in scientific activities through a series of institutes followed by regular course offerings and graduate curricula and supplemented by research and publications. The development of electronic data processing equipment and its adaptation to management functions has placed another critical stress on management personnel. This challenge we shall help management meet in a similar manner.

Especially the editors of this volume deserve major credit for making possible the distribution of information in this field at this time when it is needed most critically. I commend their vision and their attitude of service to management. Other contributors and advisors deserve high praise for their active participation in this challenging endeavor.

CATHERYN SECKLER-HUDSON

PREFACE

This volume is adapted from the proceedings of the First Institute on Electronics in Management presented at The American University in November 1955. The purpose of the Institute was to review and analyze the management potential and the problems arising from the development and installation of automatic systems, especially data processing systems. Among problem areas treated were planning, procedures, organization, personnel, fiscal and executive.

Contributors to the volume are, for the most part, persons who have had direct experience with electronic data processing equipment, and who have in addition a sensitivity to management problems and their solution. Although hardware is discussed, emphasis in the book is on management. There are instances of overlap in the various chapters and some differences in point of view will be found. The editors believe that in such instances the comments of the contributors are significant and should be documented. We do not have final answers in this field. Those who have computers say that the only experts are those who don't have them.

Several features are included to make the volume more useful to management. It has been divided into parts, each with its major theme. A selective annotated bibliography presents only those items which are of specific pertinence to the busy executive or management specialist who must inform himself about important and fast-moving developments.

The editors are grateful to the contributors and to the members of the Institute Advisory Committee all of whom have given generously of their time. Thanks also go to Mrs. Helen E. Peck, the secretary of the Institute, who assisted with the preparation of the manuscript; and to Miss Mary H. Million by whose patience and skill recording tapes were transcribed.

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PART I

MANAGEMENT IMPACT

Editors' Note

To provide a setting for the volume, one of the editors reviews the outlook for the impact of electronic data processing equipment. The new equipment brings to management both major problems and major opportunities.

MANAGEMENT IMPACT OF ELECTRONIC SYSTEMS

LOWELL H. HATTERY

The wonderful existence of electronic computers is now commonplace knowledge. What is *new* and immediately before us, is the contribution of electronic computing systems to management, and the challenge of management to integrate these systems into its operations. Over and over, as one talks with specialists in the field about management of electronic systems, the answers are, "We don't know yet," and "We are feeling our way." This situation is reflected in the literature—much about the characteristics of computers, little about the management aspects of installation and operation.

The potential contribution of electronics is generally acknowledged. Experience already reported, along with concurrent developments in management such as the use of mathematical techniques in management decision-making, indicates the trend is sharply upward in appreciating the possible aids to management which high-speed computing or data-processing equipment can provide. The growing number of successful applications in payroll, cost analysis, logistics problems and other areas point the way unmistakably.

Automatic Revolution

Is the automatic world just before us?

Experience which shows that electronic computers *can* be adapted and applied to management problems has enhanced the already existing optimism about the advent of the automatic world, variously known as the automatic revolution, the second industrial revolution, or the electronic revolution. Naturally, producers of control devices and automatic business machines have contributed to the rosy picture of the immediate future. So have consultants and economists and other seers who do not want to be caught "short-sighted." Still another group has written with optimism—the management specialists who develop survey reports to sell top management on the new systems, and commit their reports to public print. Many of these reports are hugely optimistic.

Not many have had the conviction or, given the conviction, the courage to take a public stand of conservatism about the future—and in some cases these statements are obviously hollow words of comfort to the worried workers. In other instances, they are based on unconvincing precedents of Industrial Revolution I.

The total impression is that the automatic world and the second industrial revolution are upon us. However, *and this is a significant condition,* they can come only by the fullest combination of American *management* genius with the American *technical* genius which has already brought electronic tools into existence.

Management Problems

Experience in talking informally with persons who have had direct experience with electronic systems applications follows a common pattern: after an initial, compulsive statement about the marvelous wonder of the machinery there comes an equally compulsive, yet often furtive almost as though disloyal, statement of the tremendously difficult problems which have arisen and of the mistakes which have been made. These problems run a long gamut, including machine maintenance, employee training, employee morale, job classification and upgrading, physical facilities, cost analysis, organizational problems, data quality control, top management understanding and support, passive resistance, and many others.

Discussion of these problems has barely appeared in the literature—because the experience time has been so brief, and because it has not been the mood or fashion to talk about "problems."

Encouraging developments are under way. Among them are the conferences and publications of the American Management Association, the Systems and Procedures Association and the Association for Computing Machinery, and the conferences and training courses of American, Wayne, Harvard, Michigan and a few other universities. These institutions are concerned with the prosaic, but *critical intermediary role of management* between hardware marvels and achievement marvels.

Challenge to Management

But is there really anything essentially new in the nature of the demands on management because we have a faster office machine? Is the conversion to an electronic data processing system really any different from conversions which have been made successfully to punched card systems?

Yes, the new systems bring demands on management of a dimension which management has never before had to face. Don Mitchell says, "One thing is sure: Electronic data processing will tend to separate the men from the boys in commercial and industrial management."[1] Fred V. Gardner has said the new systems require "utter objectivity."[2] Peter Drucker says that "Management under Automation will need new intellectual skills in managing a business . . . new social skills, especially in training, placing and motivating people . . . management's moral performance and the moral practices through which it exercises its real leadership, will also have to be improved."[3]

Basic Premises

What are the elements in this new challenge? There are several important premises which need to be recognized by management. The first is that change-over to a system of electronic data processing represents a *firm commitment* because of the investment costs, organization and other adjustments. The extent of this commitment becomes evident as the *depth* of organizational and procedural change is recognized.

Another significant premise is that the introduction of an electronic data processing system can *easily be slowed or rendered ineffective* by organizational units or personnel who may resist the necessary change-over. Quality of input data, fidelity to the reporting schedule and other factors require a highly coordinated and responsive organization which every level of management must be alert to maintain.

A third premise related to the new systems is that *all management is affected.* In major applications some measure of participation is required from several areas of management. For example, placing an inventory system on an electronic data processor will require procedural, organizational or program changes by supply, production, accounting, personnel and other units.

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[1]Don G. Mitchell, "Introduction," in *Electronic Data Processing in Industry.* New York: American Management Association, 1955, p. 11.

[2]Fred V. Gardner, "Where Will Tomorrow's Cost Savings Come From?", *Advanced Management,* June 1955, p. 23.

[3]Paper presented before the 20th Midyear Meeting of the American Petroleum Institute's Division of Refining, May 10, 1955.

A fourth premise is that a primary responsibility for planning and decision-making in this area rests directly with *management at the very top.* Further dscussion of the importance of direct participation in office automation by the top executive level will be found below.

In addition to these rather fundamental premises there are several elements which must be given direct consideration by management.

Management Considerations

Investment Cost. The sheer purchase or rental price for data processing equipment makes rental or purchase an important management decision. The large systems cost about $1\frac{1}{2}$ million dollars or rent for about 30,000 dollars per month. Direct equipment cost, however, is only part of the total cost to the user. In addition, there is a substantial facilities cost for building or remodeling housing space for the system, which includes special wiring and air-conditioning. There are also heavy indirect costs for the systems analysis that will be required. There may also be a substantial cost for dual operations during the change-over period.

We don't yet have enough experience to give us a firm basis for judging the investment cost but it is obvious that the cost is substantial and runs far beyond the "hardware" price.

Procedural Changes. Experience to date, both with surveys and installations indicates that extensive procedural changes are necessary to place any operation which requires internal reporting on the electronic data processing machine. These procedures usually involve more than a single division or department of the organization. The changes usually involve many personnel at various levels and affect the nature of work demands on individual employees. Executives and supervisors must accept the changes, jobs must be re-tooled, personnel must be retrained and reassigned. The extensiveness of procedural change is *slowly but surely* impressing itself on management.

Organizational Changes. Re-designing a reporting system for electronic data processing may require more than change in procedures. It may result in new areas of intra-organizational relationships and in some instances the actual redesign of the organizational structure. Decentralization is undergoing a strain although the final effects are not yet evident. The location of responsibility for data processing in itself may have a major effect on the staff structure of an organization.

Personnel Adjustment. Human relations implications of electronic data processing systems are not yet fully discernible. We do know, however, that the awesome publicity which "automation" has received, the generally jaundiced eye with which employee unions have observed the trend, and the actual displacements which have occurred—all these factors put a severe strain on employee morale in the organization which is even "rumored to be beginning to consider" the installation of a giant brain.

We also know that several new jobs must be established, and that personnel must be recruited or retrained to fill those jobs. We know that some jobs will be changed and some will be eliminated. The quality of performance in some jobs will need to be higher. These and other factors indicate various personnel adjustments to be made, all of which may affect employee morale. Human relations planning is one of the most important planning considerations.

Maximum usage. The *range of potential application* of electronic data processing equipment is beyond that of the applied thinking of most organizations. It is natural that the accountants should tend to be limited in their considerations of applications to such matters as payroll, cost accounting and billing. The production department thinks primarily of applications such as inventory control, production scheduling and quality control. The traffic department is concerned primarily with optimum routing and billing. The same observation may be made for personnel, sales, research and other departments. Yet the investment in dollars, personnel and organizational stress is so great, and the potential usefulness of the new equipment is so great that maximum usage of the equipment is highly significant.

Top Management Responsibility

Only at *top management levels* can we expect to find the facility and the approach which take into consideration the full range of applications, including the possible interrelationships and integration of applications, and the development of new applications including those which are now generally described as "operations research."

Each of the five considerations cited above illustrates how fundamental the problems of management are, and how essential it is that top management be concerned about them. Unfortunately, top management has not yet assumed the responsibility which it must. The habit of delegating technical problems to technical people, and the extreme competition for executives' time have resulted in an unjustifiable lag in attention by top executives and top executive levels. An example of this is the failure of the United States Bureau of the Budget to give leadership to Federal Government use of electronic systems. This is especially difficult to understand when one observes the leadership taken by individual Federal agencies.

The same pattern of high-level attention lag is found in several of the executive departments of the Federal Government, and in corporations, as well. One company official recently told of plans which would involve setting up central data reporting and processing for six relatively independent divisions. The company officer, an assistant controller and chairman of a survey committee, when asked about top management participation, said, "Top management is expecting us to steer them; naturally we are cautious about doing that. It may slow things up a little."

Enlisting the essential participation of top management in the planning and installation phases of electronic systems is one of the major problems in taking full advantage of the potential which is available. In fact, failure of top management to participate actively may result in installation frustrations and failures. The irony of such a situation is that the finger of blame too often is allowed to point to the computer system instead of the real failure point—top management.

Teamwork

Of equal importance to top management leadership is the role of teamwork throughout the organization.

On the advance rumor of a giant data processor to be brought into the headquarters of a very large railroad system, an employee with forty years' service came to a top official in terror of losing his job with the company. The giant brain as an enemy is portrayed vividly now on the Broadway stage with Shirley Booth and three or four co-workers doing desperate and eventually successful jousting with an Immerac which threatens their jobs. After the machine fires everyone on the payroll from the President down, even management becomes disenchanted.

These evidences indicate that management has an initial morale problem on its hands. What can be done to neutralize the alarm that is likely to be spread by the CIO pamphlet with its cover emblazoned: *AUTOMATION AUTOMATION AUTOMATION?* Something—a great deal—must be done to develop positive incentives for employees to participate as teamworkers in the new system.

A second fundamental problem in employee morale arises from changes in job content and job procedure. Collection, processing, and checking of raw data will be changed. Routing will be adjusted. Lines of supervision will be altered. And these changes bring with them all the problems of worker adjustment to change with which we are so familiar. Strains on employee morale threaten the teamwork which is needed to bring to the processing center on time and in good form the data which are treated and ultimately used by management.

The professional staff is another element in the teamwork pattern. Here teamwork is required in a degree new to management. It is a concept which has been knocking at management's door from the directions of inter-discipline research, operations research for management, and external competition requiring higher order of interdepartmental and interpersonal coordination.

Understandably, but with some unfortunate results, it is the prevailing practice to assign control of data processing planning and programs to financial personnel. In other instances, control is assigned to a special-purpose mathematical group. In either instance, this assignment to a specialist-background, special-objective group tends to restrict applications to those areas which the interests and insights of the specialists turn to, or for which the specialists can enlist the participation of other departments and other specialists.

If the operation of data processing is to be under the supervision of accountants, or mathematicians, or electronics engineers, it is most important to provide direct supervision from top management or an interdepartmental committee, or to provide strong staff from other departments and other disciplines. I fear particularly that the natural interest of the accountant or controller in the year end balance sheet will often prevent progress in areas of long-run return and indirect return. This danger exists in both business and government.

A parochial approach to management of electronic systems is a hazard to the essential teamwork for the most effective system. Every effort must be made to achieve professional and interdepartmental teamwork in the enterprise.

Management Competition

Management excellence is one of the principal competitive assets of an organization today, whether it is business in competition with business or government in competition with government.

What is the outlook for the impact of computers on management excellence? I believe the development and application of electronic computers for management purposes will prove to be the greatest impetus which "scientific management" has received since its initial surge thirty or forty years ago. I believe this is demonstrable, as one analyzes the uses of the new equipment and the resulting emphases on exact description and management decisions based on data.

At the same time unless we take into consideration a second major management development, the "human relations emphasis," we may find that our newfound management machines and informational tools are rendered inoperable or relatively ineffective and unprofitable. Administration and the new technology are a challenge to much more than engineering and mathematical technology.

They are also a challenge to much more than the human relations proponents. The challenge before us is to approach management with a wholeness that generally we have failed to achieve in the past. Rensis Likert recognizes the need and discusses it in his recent writings. He believes that a combination of high morale and high productivity represents "an integration of the scientific management and human relations approach which has not yet been fully achieved and about which we know relatively little."[4]

It is the attempt to integrate these two approaches, trends, or emphases which has especially characterized the approach to management training at The American University. Catheryn Seckler-Hudson has, along with Harlow Person and a very few others, succeeded in developing a unified management philosophy from the trends which are separately exemplified by the writings of Frederick W. Taylor and Mary Parker Follett.[5]

The successful application of electronic systems in manage-

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[4] Rensis Likert, "Developing Patterns in Management," in *Strengthening Management for the New Technology.* New York: American Management Association, 1955, p. 46.

[5] See Catheryn Seckler-Hudson, *Organization and Management: Theory and Practice.* Washington, D. C.: The American University Press, 1955.

ment depends on sound answers to many highly specialized and technical problems. Problems such as re-engineering of procedures, re-design of reporting forms, re-orientation of the methods of auditing, re-training of employees and many, many others must be answered well. Analysis and solution of these problems however must take place in a "whole" view of the management process which includes hard thinking in such areas as those which are now variously referred to as human relations, employee-centered supervision, communications, participation, creative thinking, morale, motivation.

It is comforting to note that technological "break-through" seems to be an incentive to intellectual and management "break-through." Management can meet the challenge of automation and incorporate it successfully into public and private enterprise. However, the means to this end is not easy.

PART II

EQUIPMENT

Editors' Note

The hardware of electronic data processing is already a large and complex field in itself. There is no attempt in this volume to present either the engineering of electronic computing machinery or the detailed technical characteristics of currently available equipment.

However, for management understanding a perspective of the development of computers can be helpful and this should include an estimate of the current state of the art. We believe one of the important issues which individual users may face is the choice of standard, commercial equipment or tailored equipment. These matters are discussed in the ensuing chapters by men who are highly expert technically and who have given thoughtful consideration to factors in the use of equipment.

DEVELOPMENT OF AUTOMATIC COMPUTERS[1]

FRANZ L. ALT

Introduction

It is ten years, almost to the day, since the first large electronic computing machine, ENIAC, was completed and put in operation at the University of Pennsylvania. Today there are over a hundred such machines in operation, and their number is rapidly growing. We begin to discern clearly three broad fields of application:

Computations arising in scientific and engineering fields, including mathematics itself;

Solution of management problems; and,

Direct control of industrial operations (the process sometimes called "automation").

The first of these three fields gave the original impetus to the development of electronic computers and was predominant among their applications until recently. Applications to management problems came into the picture somewhat later but developed so rapidly that they are now overtaking scientific and engineering applications in volume and importance. As to automation, despite the publicity it has received, this field is still in its infancy; to date we have hardly begun to use large electronic computers for automatic process control.

The present paper is intended as an introduction, for persons not already familiar with electronic computers,[2] to the series of papers presented at this Institute concerned with the applications of electronic computers to management problems. These applications range from the mere collection and recording of information to the analysis of most complicated situations arising in operations research or "linear programming." A large part of management applications, however, is concerned with the collection of data of a statistical nature and with a relatively simple proc-

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[1]The author is indebted to Mrs. Ida Rhodes for a number of suggestions incorporated into this paper.

[2]Strictly speaking, we ought to modify our title so as to limit it to digital computers. Customarily, the field of electronic computers is divided into the two broad classes of digital and analog computers. The latter have, to our knowledge, rarely been used in management problems, nor do we see any prospects of their being nearly as useful to this field as digital computers.

essing of these data, such as occurs in cost accounting, billing, inventory record keeping, payroll processing, and the presentation of business statistics in a form suitable for use by management. Computers destined primarily for these operations are sometimes called "data processors."[3] This name describes the use to which these machines are put, rather than any fundamental difference in their characteristics. The differences between "data processors" and other computers are negligible compared to their similarities.

The machines with which we are dealing, then, are electronic (digital) computers. They perform the usual arithmetic operations of addition, subtraction, multiplication and, usually, division. Computing machines have existed for a long time. The reason for building electronic ones was to gain speed. When speed of numerical operation was obtained it was found to be useless without the addition of several other features, notably automatic control, fast access storage (Memory), fast input and output. This was recognized even as ENIAC was nearing completion; and all machines built after ENIAC provide separate components for them, i.e. each computer consists of one or more Arithmetic units, Control units, Memory units, Input and Output units.

Arithmetic

It was the use of vacuum tubes which revolutionized the computer field by making today's computing speeds possible. In turning vacuum tubes on and off there is no mechanical inertia to overcome; speed is limited only by the time it takes for an electrical transient to settle down. Thus, electrical pulses can follow each other at the rate of several million per second. These pulses can be used to perform the successive steps involved in an arithmetic operation. It would be possible to perform an addition in one or two pulse times, but most existing machines sacrifice speed to economy in the number of components, and thereby increase the addition time to anywhere from twenty to one hundred pulse times. A multiplication normally takes several addition

[3]The term "data processing" should not be confused with "data reduction." The latter refers to transformations applied to the results of physical or engineering measurements. It is superficially similar to data processing in that it involves a relatively simple set of arithmetic operations performed a large number of times; but unlike data processing it involves the estimation and control of errors, which are characteristic of scientific and engineering calculations.

times. ENIAC, the first electronic computer, performs a multiplication in 2.8 milliseconds. Many other machines now in operation have similar speeds, including the UNIVAC and SEAC, the National Bureau of Standards' machine. Other machines, designed more recently, are from three to ten times faster. These include the large IBM machines, the computer at Princeton, and a number of others patterned after it. The fastest existing computers, WHIRLWIND at MIT and NORC at Dahlgren Proving Ground, perform a multiplication in between 0.1 and 0.05 milliseconds, but much faster machines are possible.

The multiplication time is the most frequently used single indicator of machine speed, but it is by no means an accurate measure of a machine's performance. The speed of other operations, the kinds of instructions available (and, therefore, the number of instructions required to accomplish a given purpose), facilities for carrying out several machine functions simultaneously, the speed of access to the Memory and the speed of the terminal devices all affect the actual solution time for machine computation problems.

The vacuum tube has been replaced by crystal diodes in most of its applications in computers. Its remaining functions may soon be taken over by the transistor, which will give us small compact high-speed computers with low power consumption.

Automatic Control

In relation to the rapidity with which electronic circuits can perform numerical operations, the time which would be consumed by a human operator in directing the sequence of such operations would be absurdly large. As a consequence, the machine must be able to perform such a sequence without human intervention; it must be, in fact, "automatically sequenced." It is thus true that all "high speed" computers must also be "automatic" computers.

The older punched-card machines accomplish a fairly high machine speed without automatic control, by a device of repetition. They perform one operation repeatedly, without human intervention, on different sets of numbers. Some of the more modern punched-card machines occupy an intermediate position in that they are able to perform automatically short sequences of different operations, repeating such a sequence many times on different numbers without human intervention. For machines in this class the upper limit on the length of a sequence of operations is usually between twenty and eighty. This is combined with arithmetic speeds well below those of today's high-speed machines; for instance, with a multiplication time of at least 40 milliseconds. Automatic sequence control in the sense of modern machines, on the other hand, means automatic performance of a sequence of different operations of almost unlimited length.

The Control unit of a computer has the function of causing the machine to perform the desired operations on the desired numbers in the desired sequence. The sequence of operations in a modern machine is determined by a set of instructions, which are coded as numbers and are kept in the Memory of the machine in the same form as other numbers. We use the term "word" to designate both true numbers and instructions. The digits in an instruction word determine the operation to be performed on some numbers, as well as the location in the Memory from which these numbers are to be taken and/or to which the results are to be delivered.

Among the operations which may be performed are the arithmetic operations of addition, subtraction, multiplication, and division, the transfer of numbers from one part of the machine to another, reading of words or groups of words from the input devices and writing them on the output devices, selection of individual digits or groups of digits out of a number and shifting them to other positions, and selection of the next instruction to be carried out.

One of the most important characteristics of the Control unit in all modern machines is the ability to make the selection of the next instruction dependent on the result of a previous computation which the machine itself has performed. This enables the machine to choose between alternative courses of action according to present criteria.

Memory

Just as the provision of automatic control makes it unnecessary for the machine operator to initiate each arithmetic operation separately, so the memory feature spares him the effort of writing down the result of each operation. A human computer, equipped with a desk-type machine, normally records the result of each operation or group of operations by writing it down on a work sheet. Most of the numbers so recorded are used as inputs for further arithmetic operations occurring later in the same problem, while some are among the final answers desired. This process of writing is the source of numerous errors and requires about as much time as the arithmetic operations themselves. Therefore, all modern high-speed machines are provided with Memory units in which intermediate results are recorded and fed back into the circuits of the machine when needed, automatically and quickly.

It is interesting to note that the seemingly simple function of storing numbers posed an engineering problem of greater difficulty than that of performing arithmetic and control functions. Magnetic drums, acoustic delay lines (mercury tanks) and electrostatic tubes similar to those used in television sets were developed, one after another, in order to solve this problem and are still being used on many machines. At present, magnetic cores appear to be the most promising development, but still better devices are on the horizon.

The Memory of a computing machine is divided into "cells," each storing one word. They are numbered serially, 0, 1, 2, etc. The serial number of a cell is customarily called the "address" of the word stored in it. Thus, each instruction word is composed of one or more addresses and an operation code. The memory capacity, i.e. the number of cells, is at least 1000 for most large modern machines, and ranges up to 30,000 for certain applications. The access time, i.e. the time required for transferring a word from the Memory to the Arithmetic and Control units or vice versa, is an important characteristic of memory devices; it ranges from several milliseconds for magnetic drums to about 10 microseconds for electrostatic tubes and magnetic cores, and access times as low as one microsecond may soon be achieved.

In many memory devices access time depends on the order in which information is referred to. Random-access memory devices of large capacity (in the millions) though with relatively long access times (of the order of .2 seconds) are a new development and are of particular interest in management applications.

Input and Output

The problem of providing input and output facilities has proved to be so difficult, engineering-wise, that for a long time no adequate solution was found. Most existing terminal media are too slow by comparison with existing machine speeds, let alone with possible future improvements in speed.

Practically all machines are equipped with keyboards for inserting information manually, and with typewriters for obtaining a written record of the machine's results. Both these devices are so slow that in regular machine operation they are used only for occasional small bits of information and as an aid in monitoring the operation of the machine. Both are non-automatic, in the sense that the keyboard must be manually operated and the output of a typewriter, while automatically produced, cannot be fed back into the machine without human intervention.[4]

Three types of automatic input and output media are in general use: punched paper tape, punched cards and magnetic tape. Paper tape is the cheapest and least satisfactory of these. Cards are of intermediate speed and have several advantages not shared by any other medium. Among these are the ease of rearranging or "sorting" and of inserting, deleting or changing small items of information in the middle of a deck, the ability to communicate with the thousands of small-scale punched-card installations in the country and to use the vast amount of information previously recorded on cards, and the availability of a series of specialized small machines for processing of cards. Magnetic tape is the fastest terminal medium; most applications require the input-output speed of magnetic tape to achieve balance with the speed of the other machine operations.

Several innovations have recently been perfected or are being developed which will be of benefit especially to management applications. One of these is an output device which reproduces the contents of the machine's memory on the screen of a set of tubes in the shape of decimal digits, for almost instantaneous photographic reproduction. Another is a wide magnetic tape which combines high reading speed with a large number of channels of information.

An important function of automatic input and output media is to supplement the Memory of the computing machine. In problems whose storage requirements exceed the capacity of the Memory, some of the intermediate results obtained may be recorded on the output medium and later, when needed, be re-introduced into the machine automatically. This function of the input and output devices is referred to as "external storage." By contrast the term "internal storage" is used for the storage function performed by the Memory unit proper.

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[4] Devices for automatic reading of printed information are in the development stage. When completed, they will be of great benefit, especially in management applications of computers.

Conclusions

In the limited time and space available for this paper it has only been possible to give the broadest and most superficial description of the functions and components of electronic computers and their characteristics in terms of speed and capacity, and to explain a few of the commonest items in the vocabulary of the computing machine field. This report would be incomplete without a word about the key role played by the personnel surrounding these machines. The job of coding, i.e. of putting down the instruction words which have to be introduced into the machine, is not as difficult as it might appear to the uninitiated. On the other hand, the task of formulating and analyzing a problem and deciding on the method to be adopted for its solution is difficult indeed, as well as time-consuming. In our opinion it is not a task for amateurs, nor for persons specializing in the field in which the problem arises—valuable though the assistance of such persons is to the problem analyst. Rather, it requires a thorough knowledge of machine functions and, even more importantly, a very high order of ability, cultivated by study and experience, in dealing in an abstract way with complicated structures and relationships.

EUROPEAN EXPERIENCE WITH ELECTRONIC COMPUTERS

S. N. ALEXANDER

General Remarks

This talk is in the form of a travelog describing computer developments and applications as I observed them on my recent visit to Europe.

Computer activities in Europe are at a level that is behind ours, at least in magnitude. Everywhere I went the recurring statement was: of course, we don't have as big a country; we don't have as big organizations. However, I think in some respects this was by way of rationalization, because I did find that where they had thought about their problems, they appeared big enough. I think the main difficulty is that the Europeans have not been able to divert resources into this field as we have. Also we have to recognize that in this country the state of the art is a direct outgrowth of the intensive military development that preceded it. Europeans have not had this background.

Nevertheless, they are doing work that I consider first quality. I was particularly impressed with the quality of the people that they are able to bring into this field. They have been quite successful in attracting and developing capable people.

In the scientific computation area, from which most of their developments flow, they are doing commendable work. In many respects they will be close on our heels in another year or two. Another general observation is that in Europe I saw much of the pattern that we had in the late 40's and early 50's before we had a very well organized commercial effort. That is, there is government sponsorship for most of the activity in these countries.

Let me list the countries in which I saw significant activity. In England I saw the largest amount of activity. In France there is the next largest amount, followed by Holland, Germany, Sweden, Italy, and Belgium. The Germans have increased their effort and much of it will result in operating installations in another few months. It was obvious from talking with people that the Russians are quite active in this field but it is not certain yet how much they have done; how much is intention, work in progress, or actual accomplishment is hard to make out at this time.

England

In England, the direct government-sponsored activity comes out of the very early effort at the National Physical Laboratory, which is part of one of their major governmental departments, the Department of Scientific and Industrial Research. This organization provided the impetus and the budget for the machine that was designed to be a model for the final machine to be called the ACE. The Pilot Model was gratifyingly effective and is still in service at the N.P.L. Also a modernized and augmented version of the Pilot Model of the ACE, called the DEUCE, is being manufactured by the English Electric Company.

The English policy for government-owned patents is different from our pattern. The one area of patents for which the National Research Development Corporation (NRDC) saw a good opportunity for obtaining foreign exchange was the computing machine field, so NRDC actually made available public grants to foster the commercial development of these machines. This approach is different from the pattern of grants from our Office of Naval Research or the National Science Foundation. There is an obvious intent to foster developments which will lead to patents, which will in turn lead to patent holdings with which they could bargain, as well as to products to be manufactured by their economy that would produce revenue and foreign exchange.

Many of you may recognize the name "Williams tubes," which were developed by Professor Williams at the University of Manchester and were incorporated into an experimental machine that was tested at the University. A complete prototype machine was built under a subsidy from the NRDC for the University by Ferranti Ltd. This program led to a commercial product by the Ferranti Company in the form of a revised model of the Manchester machine. The University was supported to develop a faster and more versatile machine with the nickname "MEG" because it is a megacycle machine. It is in the prototype stage. The original prototypes at the University and at Ferranti have functioned well enough so that Ferranti is being supported to create the first complete model of the machine, which will go to the University to be proved in. The commercial version of the MEG will be known as MERCURY.

Earlier, the Ferranti people attempted to sell into a partial vacuum in the United States before the advent of the presently available commercial machines. They had considerable difficulty because of the reluctance of American firms to buy equipment that requires foreign source of supply of parts from abroad.

The National Physical Laboratory under the direct internal government sponsorship is building another machine, the ACE, and it is intended primarily, I believe, for their own internal scientific purposes. I don't think they hold any illusions that the ACE, designed on the technology and the organization they have laid down, will have a very vigorous demand corresponding to the demand that presently exists for models of the DEUCE. The main reason that the DEUCE has found a market is because it was a surprisingly effective machine for the amount of equipment involved. Moreover, a number of scientific activities have learned to use it, and N.P.L. has helped these agencies prepare problems and code them. Thus, there was a background of previous work that could be capitalized on if they use the DEUCE machine.

This serves to emphasize strongly a point that certainly must have been touched upon by other speakers and that I would like to re-emphasize: These machines are completely inanimate objects until the codes are prepared and run into the machines. Therefore, the two must be considered as a package, and when you buy a machine but have not bought the code, you have made only half your investment.

Another activity in England, which is notable in that it was a completely private venture, was the construction of a machine by the Lyons Tea Company for its own use. All the others I have referred to are primarily for computational purposes, either entirely technical or certainly only at the fringe of the kind that is of interest to this audience. It would be useful for things like linear programming, but it is certainly not a data processor that you would consider for office uses.

The Lyons people were surprisingly alert to the computer situation. It was a case of one or two people seeing the light very early and having the courage to try to do something about it, even though it meant being the guinea pig and perhaps making some mistakes that might mark them very noticeably as foolhardy adventurers. The Assistant Comptroller for the Lyons Tea Company, Mr. T. R. Thompson, visited this country during the "talk" stage of our computer development. That was in the period 1946-50, in which everybody was talking about his machine and giving very learned papers on what his machine was going to be like, but there was no machine available to illustrate or even encourage that there would be useful equipment within a reasonable period of time. Thompson became quite confident that these developments were realistic, and he began thinking in terms of how they could be used in bettering the work of a company that operates pastry shops and restaurants, selling tea and coffee on the side. For a man at that time to see a relationship between electronic digital computers and the activities of a tea company is quite remarkable.

At the same time, while we were busy talking to one another, an energetic Britisher from the University of Cambridge, Prof. Maurice V. Wilkes, visited the United States. He sat in on the first course on digital computers at the University of Pennsylvania and visited the groups in the United States that were developing equipment. From this, he got a rough idea of where the first immediate successes might occur and then went home and obtained support to try to do the same thing in Britain. And I think we should be a little bit ashamed of ourselves. Wilkes went home and, almost a year before anybody in the United States had an electronic machine going, had his sputtering and soon working.

The same project which created this machine, called the EDSAC, attracted the interest of Thompson who arranged for some company support to the Cambridge group. In return there was a kind of collaborative technical effort between these groups. The engineering group associated with the Lyons Company very quickly took issue with the implementation of the EDSAC. They had perfectly good reason because the EDSAC was built of gear left over from military electronic war surplus, and the machine appeared to be such a haywire contraption that one wonders how in the world it could function. But it did, and this gave the engineers at Lyons the lead: If the EDSAC functions at all, then if it is built in a sturdy well-engineered fashion, it ought to be a useful tool. They called their machine LEO, and it is in the main offices of the Lyons Tea Company in London. However, the Lyons Company very quickly ran into an important fact of life—that when you want to use the machine as a data processor, the central computer is only a part of the total installation. An input-output system had to be devised to cope with the volume of data that a business operation calls for. As a consequence, Lyons got no direct use of the computer for its own purposes initially.

In order to get some return on their investment, they sold time on their machine to various activities of the British government, getting experience, keeping it alive, and struggling with the problem of how to connect suitable input-output so that they could eventually make it useful for their own purposes. They now do their own payroll on the machine and were in the process of taking over the London Ford Motor Assembly Plant payroll under arrangements that made it profitable for the Ford Motor Company to give them this work. This is a pretty good indication that the British have developed a situation in which the economics were favorable for doing payroll on the machine.

Lyons also use the machine to up-date orders from about 200 pastry shops in the London area. Each manager has a list of standing orders. The standing order represents the manager's estimate of the way his business normally goes, containing his prediction of seasonal characteristics and other items for which he makes allowances. This is the basis for their gross long-term purchasing of flour and sugar and such commodities. The standing orders are consolidated by the machine for this purpose, being available to the machine as decks of prepared punched cards.

The store manager makes last minute modifications to his standing order whenever he has a reason to do so. At a set time each day he is telephoned from the central office for all variations in the standing order for the next day. Such changes are immediately entered into the LEO system and provide the basis for up-to-date orders for baking schedules and store deliveries. Variations from the standing order are also processed for reports to management for analysis of exceptions and trends for management's attention. The system is apparently working very well and is looked upon favorably both by shop managers and by central management.

Several other activities in England are outgrowths of the support of NRDC. One such is a machine developed by Elliott Brothers (London) Ltd., with direct support from NRDC. They designed a machine called the NICHOLAS, which is derived from their use of nickel wire delay lines as the memory for their computer. This memory is based on use of the acoustical delay in the nickel wire. This is comparable to the use of acoustical delay in a mercury tank, which is probably more familiar to you. The NICHOLAS machine, however, did not prove to be an adequate prototype for a production design. The model is being used at the moment for statistical work at an agricultural research center in England. However, this experience led to further developments around which the Elliott Brothers are preparing a commercial machine for the market. The Ferranti Company is also using the nickel delay line memory as the working memory, with a magnetic drum as the back-up store, in a machine which they are to market soon, called the PEGASUS. Both these machines are roughly in the IBM 650 or DATATRON class. Both British firms are planning to use this as an entry into the commercial market, and are probably going to provide magnetic type additions to their products.

France

The French have been active over a long period of time. The Bull Company, a manufacturer of punched card machines, has recently come out with their version of an electronic machine, the GAMMA-3, which I think is properly classed as a modernized version of the card program calculator. It is a machine that has cards in, cards out, and electronic computation with program control. It is available for sale in several of the countries in Western Europe.

There is another commercial group in France, the Societe d'Electronique et d'Automatisme (S.E.A.), that is also doing some very interesting computer work, mostly for the French military services. It is the company for electronics and servos, and they have built analog computers, digital calculating devices, and some simulating equipment. They now offer two machines for use as scientific machines, one called the CUBA and another one called CAB. The circuit technology used is interestingly different in several respects.

Germany

The next in order of activity is Germany, mostly in the technical universities. There are machine projects in the technical schools at Darmstadt, Munich, Goettingen, and one other at Dresden in the Eastern Zone of Germany.

All are modest efforts directed toward scientific machines based on magnetic drum memories. Several are supplementing the drums by adding a small amount of magnetic core storage as the working memory and will use the drum as the back-up store. The one at Goettingen is in regular operation, and the one at Munich is now working. The one at Darmstadt is in the final stages of construction and it is a very handsome installation. I hope that its performance will match its appearance.

Holland

In addition to a Ferranti machine installed by the Shell Oil Company at Amsterdam, the Dutch have two other machines in operation. One is located in Amsterdam at a scientific center which they call the Mathematisch Centrum. This computing device has some characteristics similar to the machine at the Institute for Advanced Study at Princeton, except that the primary storage is drum. It has been in operation about one year.

Another less elaborate machine is located at the research laboratories of the Post Office. In the usual European pattern, the postal service is in one organization with telegraph and telephone communication service. This computer was created primarily to assist the communication engineers, but I imagine that it is also a proving ground for techniques of possible application to the development of automatic message accounting that is a problem in all modern telephone and telegraph systems. A second machine is being designed as a joint endeavor of the Post Office and several other Dutch government activities.

There is nothing that I saw in Holland which represented a studied effort for data processing activities, except for the Postal checking account services. The Dutch use their postal systems for providing people with the equivalent of a bank checking account. There is a team of Dutch representatives visiting the United States in anticipation of attempting to handle the data processing task associated with this problem.

They essentially have a three-part document which permits you to indicate that you want a part of your checking account transferred to someone else's checking account, which is a paper transaction entirely. So long as it is a paper transaction, there is no charge for this service. Apparently it was instituted before 1910 as an anti-inflationary device, so there need not be money issued to handle this type of transaction, keeping it a purely paper transaction. There is a charge, however, if you wish to transfer from your account to someone who does not have an account. If he comes to a Post Office with a little stub, he can cash it, much the same way we cash a money order, and a small fee is charged. The public has found this service to be so convenient that the Post Office is now embarrassed by the volume. They are now in the process of trying to work out means for mechanization. I think it is an experiment well worth our following, because the origin of the transaction is such that the Post

Office can control the format and the method by which the document is created and processed.

The Belgians are also working at this same problem and, because this check scheme is widely used in many countries in Western Europe, will probably move into this field just as fast as there is promise that encourages their doing so.

Other European Activities

The Italians are using machines but not producing them. The equivalent of our National Research Council recently bought a Ferranti machine for the Italian Computing Center. It is now installed and in initial operation. I think it will be taken over finally in another few months. The Ollivetti Company has at various times sent people for training in this field, and they may be considering the design of data processing machines.

In Belgium a government board was established to obtain a computing facility to meet their own internal needs. A machine was proposed by a technical panel and was built by the Bell Telephone Manufacturing Company in Antwerp. The machine is complete and operating, but is still in the hands of the manufacturers. It will probably be moved in another several months to the scientific center where it will be put into use. The machine is interesting in that it already has in it the original seeds of a machine that is capable of being used for data processing. It was the first of the machines I saw in which they deliberately provided supplementary storage in addition to the drum storage from the very outset. They are long loops of magnetic tape.

As a result of a special board set up by the government to make a computing capacity available within the country, the Swedes now have a machine which is comparable in computing power with that of the technical centers in this country. Their original machine, called the BARK, was a relay calculator. Then they sent people to the United States to study. These men returned and decided to build a fast powerful machine patterned after that at the Institute for Advanced Study. Their machine is called the BESK and is in operation with a very good operating record. It is very interesting they have so much power in the machine. It is dictated by one of the primary problems the Swedes had interest in—the numerical prediction of weather. One of the research groups at Stockholm University is quite good at weather prediction theory and wanted the tool to carry out their research. This takes a lot of machine capacity. Their machine is occupied almost full time by a steady stream of outside problems, and as a consequence they are augmenting the machine. Another activity is at the University of Uppsala where a machine based on a magnetic drum as the main store is being built. The drum is being constructed for them by the central group in Stockholm. However, there is no evident interest in data processing activities.

The recent conference on Electronic Digital Computers and Information Processing at Darmstadt was attended by representatives of the central European development. The Czechs are engaged in constructing an ingenious relay machine. It is a relay calculator with drum storage, but is not yet complete. I was rather impressed with the fact that at this late date they were only at this stage in technological development. Their representatives, however, indicated they were quite familiar with the state of the art but that they had started on this project and they were going to see it through in order to have equipment in hand.

Another point of interest was that there were Russian delegates intended for the Darmstadt conference but they didn't arrive until the evening of the last day. They had not obtained a visa from the United States to leave Berlin. They were to make a report which is to be included in the proceedings. This should give some idea of the state of development that they have achieved. Europeans who had talked with other Russian representatives reported that they spoke in terms of the same technology that was used in Western Europe. Evidently they were talking from experience they have had, rather than from a knowledge of the literature.

Summary

The emphasis in Europe is still on calculation, using the machine as a scientific tool. In only a few places is interest beginning to leak over into the data processing field, with the lead being taken by the British.

TAILORED ELECTRONIC DATA PROCESSING EQUIPMENT

F. D. RIGBY[1]

Office of Naval Research

The role of the Office of Naval Research in the development of modern large scale computing machines for scientific applications is widely known. Perhaps less well known, however, has been our interest in the development and application of computers in the broad field of logistics, included in which are studies of data processing systems, as well as computational methods, for the planning, scheduling, and control of industrial and military logistics operations. We began to be active along these lines in 1948. From our earliest efforts until the present, we have found in the Aviation Supply Office, of which Admiral Hetter, one of the principal speakers at this conference, is now Commanding Officer, a thoroughly receptive and cooperative reaction to research in this area. We were able to make use of well formulated data processing problems which were then taxing the punched card capabilities of the Aviation Supply Office in making our first estimates of the desirable properties of electronic data processing equipment for Naval logistics use.

These first considerations on the use of computers for these kinds of applications impressed upon us two notable facts. The first was the lack of efficiency with which the versatile general purpose machines perform in a number of important special types of problems in this field. The second was that many of the extremely large data handling problems of business and logistics were beyond the capacities, in reasonable modes of operation, of the general purpose computers of the time—say 1949 to 1951. These observations led us to investigate the desirability of computers specially adapted for this kind of use. One result was the design and construction by Engineering Research Associates Inc., now a subsidiary of Sperry-Rand Corporation, the Logistics Computer now located at the Logistics Research Project of the George Washington University. This machine, some of whose

[1]The author wishes to express his appreciation to Dr. M. E. Rose of the Office of Naval Research for his discussions during the preparation of this address.

features I shall describe presently, represented a first approximation toward a logistics data processor as contrasted with a scientific computer. Progressive alterations are being made in the machine as more is learned about the functions it should be able to perform. It is, by the way, a progenitor of Sperry-Rand's new File Computer.

Before pursuing this line further, however, I should like to make a few remarks about special-purpose computers, and some of the conditions which make their variously limited talents worth evaluation. In the course of these comments I shall indicate several of the ways in which tailoring may be effective to good advantage.

The primary motivation of thought in the use of special-purpose computers lies in the desirability of viewing the computer in terms of its relation to the system and the area in which it is required to operate. To the extent which this tailoring requires, in any particular case, the versatility characteristics of the so-called general-purpose computer, I would include these also in the discussion. It is the *concept* of the special adaptation of the computer to its job which determines, to my mind, the degree to which a computer is to be considered a special-purpose computer, rather than any particular economy or engineering features of any particular computer itself.

What are, then, some considerations which enter into evaluation of such special-purpose computing systems? The first, and perhaps most important, is the definition of the problem area as part of the more general problem field in which the machine is expected to operate effectively. It is the variety of structural differences of these problems in a particular area, which dictates the versatility requirements of the machine. Second are the volume and time requirements of particular problems in the area. Capabilities along both of these lines must enter, I believe, in the evaluation of a machine's *capacity*.

Let us try to identify some of these features. One consideration, of course, is that of arithmetic speed and flexibility. For some problem areas, certain of the arithmetic requirements may be small and it becomes questionable whether such capabilities need be built into a machine unless, of course, such potential capabilities are desired because the extent of the problem area itself is, at present, not sufficiently well defined. A considerable economy in computing hardware, for example, can be achieved if it has been determined that necessity to perform the operation of division will arise infrequently. Such an operation can be programmed when needed at the modest expense of some computing time.

In another direction, some studies which were made on the general purpose SWAC and elsewhere have indicated that a large proportion of the operations performed have been in the nature of internal bookkeeping procedures for the program of the computer itself, rather than direct steps toward problem solution. Recent developments, such as the introduction of B-box techniques offer a partial solution to this problem. A further possibility lies in the merging of the capabilities of the internally stored program computers with those of specially wired machines to allow a more flexible interplay between the separate advantages of each in order to minimize, for many common sequences, the inordinate amount of such internal bookkeeping.

More difficult, and perhaps more important, is the identification of those structural differences among problem types which are relevant to data handling requirements on a machine or system. Here it would be very desirable to develop improved qualitative and quantitative methods for discussing the concept of the data handling capacity of computers. All computing machines are data handling machines, whether they are used for scientific calculations or for business type operations. The primary difference in the data handling requirements between these kinds of application is very often attributed to difference in the amount of data to be processed. This point of view may be somewhat naïve. Scientific problems can, and indeed do on occasion, generate as much, if not more, data for processing than is generally met with in business type problems. The essential significance of data handling capacity as a critical machine characteristic is only partly related to the ability to handle large volumes of data.

A more important consideration, perhaps, lies in the manner in which the data handling occurs. For a large class of scientific calculations, it is possible to handle quite large volumes of data effectively because reference to the data storage can be planned to proceed in an extremely orderly and determined fashion. That is, by a proper matching of the inquiry source to the data storage system, large volumes of data may be handled effectively in a data system which has, in another mode of operation low data handling capacity. The relatively low data handling capacities of such systems may become uncomfortably apparent, for example, when Monte-Carlo type problems involving the necessity for random access to extensive storage areas are attempted.

Similar types of data handling distinction which exist in business and logistic operations may be recognized. It appears that, for a rather extensive range of problems in the business or industrial areas, a large proportion of potential computer work is related to the maintenance, searching, and arrangement of filed data. To the extent that this kind of thing can be kept in the category of "off-line" or auxiliary operations, considerable economy in the data storage capacity of a computer system can be obtained through proper matching to the input source by, for example, extracting from a master file those items which must be processed, and, furthermore, sequencing the incoming items before updating operations proceed to the computer. Such off-line operations of computing facilities tend to permit the same kind of effective matching of input source to data storage as was noted in the case of scientific computational work. Gain from this sort of matching can be expected to be offset by increase in the length of time within which any particular item can be assured of being processed but this may be acceptable in many instances. It is to be expected, however, that extensive problem domains will be found in which off-line prearrangement of input data for on-line processing is not feasible. This gives rise to a tailoring problem whose only effective solution seems to be very large rapid access data storage capacity for on-line operations. It seems to me very reasonable to expect that special-purpose computers should evolve around the differences of these two types of data handling capacity requirements, as problem areas expand and the problems themselves are distinguished in these respects.

Another method which can be and is being used to increase the data handling capacities of systems is the use of variable word length in one degree or another. The advantages of this are, perhaps, immediately obvious in the implication of greater density of storage in the system since waste of space which would be filled with irrelevant entries in a fixed word length system can be avoided. However, it is not precisely clear, in general, what balance should be maintained between complete variability in word length and consequent increased complexity in programming and in the design of the computer itself.

The appropriateness of large general-purpose computers in many of the successful applications to business and logistics systems, thus far, can be attributed quite largely, I suggest, to the state of the definition of the problem areas at this time, in the following sense. The initial applications of computers as aids to management have been primarily explorations into areas in which individual problems may be successfully formulated and handled on the machines. The family of such problems is very large. The requirements of computing systems suitable for the broad and diversified demands of such exploration have justified the utilization of general-purpose computers. It seems to be probable, however, that as these explorations proceed and larger classes of problems having similar structural characteristics can be distinguished, we will tend to arrive at situations where more specially adapted computers will find efficient use, and will, perhaps, even be necessary to handle certain types of problems.

Let me turn, now, to a discussion of the Logistics Computer which we have developed. This is primarily a research machine; it was built with the research use in mind. We do not, therefore, regard it as a candidate for copying as it is. We do think, however, that machines having many of its properties will prove valuable in operational uses. The design of the computer was based upon "systems studies" of a few representative problems which arise in logistics operations, and took account of our intent to use the machine for further explorations of logistic functions in the light of electronic data processing potentials. Provision was made for ease of modification after installation.

Input to the computer is provided by punched-paper tape readers, although provision is being made for direct punched-card input. There is a magnetic tape reader also, which can be used for auxiliary purposes. Input and computation normally proceed concurrently. Control is attained by means of a removable plugboard which may be wired to perform a variety of operations and which permits any sequence which can be specified to the machine in not more than 40 program steps. A program sequence may, of course, be much longer than 40 individual steps since the availability of conditional jump orders permits the use of programs containing iterative loops.

In its normal operation, the computer accepts an item of information—that is, an address plus a quantity—from the input tape, performs its arithmetic sequence on this item and related data stored internally prior to the input of the next tape entry. This tape-controlled operation is not the only mode available. The machine can operate somewhat faster on data contained entirely within itself and, by ingenious use of the plugboard in conjunction with the memory, general-purpose operation is attainable at the expense of accepting relatively low speed. The basic operations are: transfers, addition, multiplications, and counting. Division is programmed. The simplest additions are performed at rates of 30- to 40,000 per second; multiplication of pairs of 6 decimal digit numbers at about 100 per second. It is a decimal machine using excess 3 binary coding and 9's complements for negatives. Its word length is at the disposal of the programmer and may be anywhere from four to 12 decimal digits. The internal storage device is a magnetic drum 8½″ in diameter, 14 inches long, which rotates at 3,450 rpm; this stores approximately 180,000 decimal digits. The number of words, of course, depends upon the word length: 26,500 for 6 decimal digit numbers. Access time is about 20 milliseconds. The standard output is by means of an electro-mechanical tape punch which handles 60 decimal digits per second. The memory contents, however, can be run out onto magnetic tape at 300 digits per second so that the drum can be unloaded in about 15 minutes. We have, so far, used an electric typewriter driven by a punched paper tape or by magnetic tape for printed output; this has been feasible because of the research use of the machine. Some kind of higher speed printer would be needed for operational use.

The machine cost about $350,000 including development; it is maintained by one engineer and an assistant, who also make modifications of the machine as needed. Machine reliability is quite high, unscheduled maintenance accounting for less than 4% of its time. It will be clear from all this that the Logistics Computer is far from being a general purpose device and has, in fact, been tailored to fit its intended use. This tailoring has been moderately successful.

The Logistics Computer has been used to obtain research and demonstration solutions of a number of logistics problems, included in which have been:

A determination of personnel requirements by rank and rate for Naval advanced base establishment;

Initial and re-supply material requirements for a Marine division lifted out to a combat area;

A prototype problem in the scheduling of a shipbuilding program, covering time-phased delivery of critical materials;

Tabulation of life of type attrition for all types of Naval aircraft;

Inventory control problems;

Rail network calculations of shortest routes between pairs of junctions in large systems;

Tests of priority methods in job-lot production scheduling; and a variety of problems of a more technical research nature.

One way in which our experience with the Logistics Computer can be viewed is as a laboratory experiment to test the hypothesis that specially adapted computers and data processing systems have an important role in logistic applications of electronic data processing machines. We do not claim that our experiment has produced conclusive proof that this hypothesis is correct. However, it has yielded rather convincing evidence in favor of correctness and has convinced us that the proprietors of data processing problems in management areas will do well to consider carefully the possibility of substantial gains in economy and efficiency resulting from special adaptation of electronic devices to their problem types.

As I noted earlier, we do not try to sell anyone the notion of copying the Logistics Computer. We recognize, also, that the appropriateness of specially designed equipment to any given set of applications may become apparent, if at all, only after exploratory experience with a general purpose computer. We do feel strongly that studies of the prospective advantages to management of electronic data processing should not terminate with the decision to buy or rent a machine off some manufacturer's shelf, but should carry on, perhaps with the aid of a suitably versatile device (which may well be rented off the shelf) to the point where a determination as to the best machine design for the applications in hand can be made without the constraints imposed by immediate commercial availability.

EVALUATING AND SELECTING EQUIPMENT

WILLIAM HOWARD GAMMON

The final answers to selecting and evaluating equipment for automatic data processing have to be worked out in your own individual situation after a rather complete analysis as to what your problem of application is. People have said that buying a computer is in some ways like buying an automobile. It is, and in some ways it is *not*. You may choose a car based on color combinations, body style, maximum horsepower, or maximum speed, or you may read *Consumer Reports* and *Popular Mechanics,* drive it yourself, and talk with those who already own one. You could choose a computer based on the speed of the computation alone; but if you did, it would be an unwise choice. What is the use of buying a computer that multiplies in a millionth of a second if the input and output rate is limited by the speed of an electric typewriter to 600 characters per minute or by a key punch, or if it is to be incorporated in a system in which the data coming through the machine or the problems entering into the machine are limited by times which make the very rapid computation speed of little effect?

Problem of Make-Ready or Programming Time

In this connection I would like to quote from *Data Processing by Electronics:*

> "To determine the total time involved in any data-processing operation as a whole is not alone a matter of considering speeds of reading data and instructions in and out of the central processing unit and of manipulation within the unit. The time that counts is the interval between the beginning of work upon the raw data and the completion of the results of processing, in report or other required form. In the input preparation phase, the time required for transcription of current-transactions data is still tied generally to the speed of key-driven devices used in punched-card systems. In addition, there must be included the time necessary to prepare the instructions, or program, and this must be reckoned in the order of several man-years for complex routines. . ."[1]

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[1]Haskins & Sells, *Data Processing by Electronics,* privately published, May 1955, p. 21.

The question of how long it takes to prepare electronic computer instructions or programs is one that was recently in the newspapers. The *Wall Street Journal,* reporting on the Joint Computer Conference in Boston said, "Electronic computers can create problems as well as solve them. Users note installation and personnel training pains. A two-hour job takes 20." This is a signed story by a staff reporter of the *Journal,* who comments also about General Electric problems. "General Electric, which is probably the biggest industrial user of computers, ran into a lot of trouble when it put a big model to work in August of last year on payroll accounting for 8,500 employees at its Louisville Appliance Plant."[2] The machine was expected to do the weekly payroll work in two hours, but GE finds the operation is taking 20 hours. Why so? "Developing such a program involves far more meticulous work than we realized at the beginning," said GE's Ralph J. Cordiner, but he also noted that GE is not discouraged. "We have 23 computers of all sizes on order of which six are monsters valued in the neighborhood of $1,000,000 each."

Problem Must Be Defined Before Selecting Equipment

Until you have thoroughly defined and analyzed the problem in your organization for which you are thinking about a computer, you could not make a rational decision about which equipment, if any, is for you. Maybe you ought not to buy or rent a computer at all. Instead, perhaps you should, in effect, hire a taxi service, using our analogy of buying a car. Taxi service in the computer field would consist of having data processing work done by the Census Bureau on their UNIVACs, or by some other organization which has a well-run computer installation operating on a service bureau basis.

Who Can Use A Computer System?

In this connection I quote from Ralph Lewis, who addressed a seminar for Washington people a few months ago. He said:

> "Who can use a computer system? It would be extremely convenient to say that any company with over a million dollars of sales, or 200 employees, or 10,000 accounts re-

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[2]Richard B. Cole, feature article, "Brain Trouble, Electronic Computers Can Create Problems as Well as Solve Them," *Wall Street Journal,* November 11, 1955, p. 1, col. 6.

ceivable or some other unit of measurement can economically use a computer system. Unfortunately, there is no rule of thumb. We have checked every major computer manufacturer and the answer is universal. It depends upon the individual applications involved. About the most that can be said with great assurance is that the amount of activity necessary to support a computer installation economically is probably smaller than you think."

And then he made what I think is a startling statement:

> "Certainly any company with an economical punch card installation should be investigating the possibility of a computer installation.
>
> "The decision as to who can use a computer economically can be made in a sound fashion. It rests on three factors which must be considered in every given circumstance. These factors are: (1) What do you want from the computer? (2) What sort of raw data have you and how is it organized? and (3) What can the computer system do?"[3]

Need for a Catalog of Available Equipment

I call attention to the comparative analysis of some of the leading electronic computers given in the appendix of *Data Processing by Electronics.* This analysis is not complete. It doesn't have an evaluation saying which system is better. This has been attempted by various groups but not for publication. The difficulty is that which system is better depends on what you want it to do; and no satisfactory way of giving a sort of "consumers union report" on which computers are best for what purposes has yet appeared in print.

It has been suggested that the Department of Defense might perhaps develop a Department of Defense catalog of electronic digital computers; and we have established a project with this as an objective.

A Feasibility Study

The first thing to do, as I said, is to define and evaluate your own problem, through an internal data processing committee in your own organization with the support of top management. Top management should understand that you can't deliver results next month or month after next if you are going to make a compre-

[3]Ralph F. Lewis, "What the Decision-Making Executive Should Know About Electronic Computer Systems," *The Arthur Young Journal,* New York: Arthur Young Co., October 1955, p. 1.

hensive study. A substantial time is required before you can decide on, and put to work, a new equipment. Estimate at least six months for indoctrination and defining the problem and at least another six months for selecting and evaluating equipment.

Some of the people in other organizations who have made such surveys have started out with firm intentions of being completely objective, of programming their tests for each of the several available, apparently satisfactory, computers. They have, however, been pressed by top management to make an immediate decision and this has had the effect in some organizations of narrowing the decision to one of two manufacturers. In my opinion it is unfortunate when the field is so narrowed because some of the smaller manufacturers have produced gear which is more economical for some middle-sized jobs than that which is offered by the two leading manufacturers.

In any case, I think you should make a reconnaissance and a summary block diagram of your present operations without reference to one manufacturer's equipment. This would be a basis for making a tentative selection of tasks which you might initially apply to automatic data processing. Following this, with the approval of your policy committee or top management to the extent it is required, you should make a thorough and very complete description of the results required under present procedures.

At this point I would like to quote from a staff paper prepared for the Hoover Commission Task Force on Procurement. On the problem of rethinking systems and procedures for the new equipment, this staff paper said:

> "A prominent student of military logistics in a speech before a recent logistics forum characterized military inventory control as being 'long on inventory and short on control' and implied that the basic materiel control systems in use today essentially date back to Hannibal. Although such a summarization is probably an over-indictment of today's inventory control system, it has become increasingly apparent that current procedures are dangerously inadequate to support the high speeds and technical complexities of the modern tools of war. Recent developments in high speed electronic data processing systems seem to offer an effective means of eliminating this damaging disparity in speed between essential data gathering and control systems and the needs of the modern fighting machines which they support. It is imperative that we 're-think' present control procedures in the light of the capabilities of the electronic digital computer rather than merely using the new equipment to ac-

> complish a 'stage-by-stage' speed-up of the present paper flow processes. Otherwise we may be solving problems that don't need to be solved at all; problems which exist under old methods only because of the massive volume of data which sometimes obscured and were mistaken for the more basic problems."[4]

Then the staff paper recommended that more vigorous leadership be exercised by the Department of Defense and by the Secretaries of each of the three Military Departments to establish a dynamic program to explore the potentials of electronic data processing equipment and to guide and coordinate its installation for business type activities, including inventory control and requirements determination. As a result, in part, of these recommendations, more activity in the field of automatic data processing is under way in the Department now than ever before.

Rethinking of Basic Assumptions

The kind of rethinking which we are discussing includes not only detailed procedures but also organizational problems and basic assumptions underlying the procedures now followed. You ought not to overlook the opportunity to ask about each task "Why do we have to do this at all?" We have seen in some installations that because of pressure from management for haste they have figured out a way to put on one of the leading data processors a procedure producing reports the value of which is very doubtful. You also should ask "Why do it this way?" Be sure to indicate the places in the process where decisions must be made. Record the work volume, the number of documents, the number of transactions, etc., and the minimum, maximum, and average number of digits of information in each kind of document.

After you have prepared a detailed flow chart and statement of your problem, ask all the qualified manufacturers to give you proposals for the use of their equipment on your problem. Then evaluate the proposals which you receive on a critical and objective basis. Don't base your decision on speed of computation alone. Consider the effectiveness of the system as a whole in relation to your own problem as you have defined it.

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[4]Commission on Organization of the Executive Branch of the Government, Five Staff Papers Prepared for Task Force on Procurement, Vol. III, "Inventory Control and Distribution," June 1955, p. E76 and 77.

Experience of Insurance Companies

There is no one best mouse-trap in the data processing field, and here I would like to quote from the report by the Society of Actuaries on *Current Status of Magnetic Tape as a Recording and Data Processing Medium.* This report reflects the experience of the Metropolitan Life Insurance Company and seven other large insurance companies with the application of various electronic data processors.

> "Evaluating the relative merits of different magnetic tapes and associated electronic machines is a formidable task. Each supplier's machinery has some features which are superior and others which fall short of those offered by his competitors. If a potential user develops procedures which use the equipment in such a way that it makes maximum use of the excelling features of one type of equipment, his procedure design has placed that supplier in a favorable position. It is often possible to get the same job done by developing equally satisfactory procedures which make better use of the favorable features of another supplier's equipment. To make a fully objective appraisal, the potential user must design the best procedures he can for operation of company A's equipment. Then develop a different procedure best suited for operation with company B's equipment, and so on, and compare the results as to cost. Considering the number of suppliers now offering equipment of this kind, all apparently capable of doing approximately the same job in different ways, a considerable effort is involved in deciding which particular machinery is best suited. It may also be that the work done or the results obtained by the best procedures developed for different machines are not quite the same, in which case an additional factor complicates the comparison."[5]

Then, the Committee on New Recording Means and Computing Devices of the Society of Actuaries gives the pros and cons of several of these features which various computers offer without giving a decision as to whether it is desirable or undesirable. The features discussed are:

(1) Simultaneous read and write

(2) Density of recording on the tape

(3) Metal versus plastic tapes

(4) Dual recording (i.e. recording the same thing in parallel on two tracks)

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[5]*Current Status of Magnetic Tape as a Recording and Data Processing Medium.* Chicago: Society of Actuaries, June 1955, p. 18.

(5) Variable versus fixed word length
(6) Duplicate computations versus program checking
(7) Independent use of input and output units
(8) Provision of a separate tape sorter.

Each of these features is advantageous in some circumstances and each has disadvantages in other circumstances. A knowledge of these advantages and disadvantages will be helpful especially after you have determined what the circumstances are, what the problem is, to which you want to apply any data processor.

Comparing Requirements and Equipment

After such a study you can make a careful and detailed comparison of the requirements for the job with the capacities and capabilities of the equipment proposed. Don't overlook the training and service facilities offered. You may find it advantageous to obtain technical assistance from an objective source apart from the manufacturer of equipment, such as the services of the Data Processing Systems Division of the National Bureau of Standards.

In this connection, I want to refer to an outline developed by Norman J. Ream of the Lockheed Aircraft Corporation in Pasadena. Ream has made a detailed study of the problem of selecting equipment. This section is based in large part on his outline.[6]

The distinction between special and general purpose equipment is well known to you. There are some situations in which special purpose computers, while lacking flexibility, may be better suited to your jobs. Lease versus purchase you have probably heard argued and I will not take a position one way or the other here. I think the decision depends in your own circumstances on a careful analysis of the relative economics, not overlooking the obsolescence factor which has motivated most industrial corporations to let the manufacturer take the risk of obsolescence by renting the equipment instead of buying it. Under the heading of "Performance Criteria," Mr. Ream gives cost of rental or purchase, installation (including air conditioning, other site preparation costs and power requirements). There is a substantial difference between the power requirements of the middle-sized computers and the very large ones. For some of the tasks

[6]Norman J. Ream, "Organizing for an Electronic Survey" (unpublished outline for seminar), International Systems & Procedures Association, Detroit, October 10-12, 1955.

that you may have, I am sure you will find it more economical and quite effective to use a middle size instead of a large computer. By middle size, I am thinking of equipments such as the DATATRON made by the Electro-Data Corporation, or the IBM 650 or the Remington Rand File Computer, among others. Then, there is comparison of programming costs, which vary quite substantially depending on the *logic* of the machine, the auxiliary equipment required for the system, what kinds of input it has, card input, punched tape input, or immediate input as with UNIVAC from a typewriter. And in the middle of this series of criteria is the question of speed. Greater speed is gained with some equipment by multiplex operation so that you can, as I mentioned earlier, read and write simultaneously. Some of the equipments, specifically IBM, have a high speed rewind, and this for some situations is advantageous. The input and output devices are described in detail in the Haskins & Sells book and also are listed on a comparative basis in an article in *Electronics* for June 1955.[7] This gives comparisons of some 38 business type data processors made by 24 manufacturers.

Concerning capacities, you may have heard from the salesmen a great deal about the merits of *large memory capacity,* but you may find that a thorough study of your job will show that you don't need large memory capacity. Don't buy the biggest one just because you want the "Cadillac feeling."

On reliability, most of the computers that we are talking about have adequate reliability in the sense of freedom from undetected error. The merits of built-in checking versus program check are discussed in the Society of Actuaries report referred to above.

In terms of efficiency (i.e., the maximum amount of productive machine time out of the time which is scheduled) you are in a better position on that score if you don't take the first model, the first unit delivered of any equipment. On the other hand, you may by being more cautious miss an opportunity to get a machine at a bargain rate, as the Bureau of Census with their first UNIVAC.

In terms of the problems of programming and operating, there are substantial differences in the personnel complement required for some of these equipments. Some decisions that have been made within the past six months on the selection of one or another computing system have turned heavily on the fact that one

[7]John M. Carroll, "Electronic Computers for the Businessman," *Electronics,* June 1955, pp. 122-131.

manufacturer's equipment required a smaller number of operators to operate on the fully assigned job. This was true, for example, in the Treasury job which George Stickney describes elsewhere.

Ream suggests concern with the flexibility of the equipment, the relative efficiency in handling different types of problems, whether the machine is sequential in its approach, or whether it is random. Random access equipment is coming on the market. You have heard about the RAMAC (IBM type 305) which IBM has made but has not yet offered for general distribution, although pictures of this equipment have appeared in the trade publications. I think it is only a matter of months until they will be available and will provide random access to a very large number of digits of stored information.

The availability of the equipment is also a factor which you will take into account because I think it will be true for a good many years to come that the equipment which you can get within six months or a year, is going to be equipment which was designed a year or two ago, and if your organization is willing to wait another 18, or 24, or 36 months, you can probably get something which is designed currently. I am not by this remark suggesting that it is desirable to wait. In some ways it is like the problem of selecting an airplane for the Air Force, by the time you get them built, they are obsolescent in the sense that better ones can now be built.

Ask the Man Who Owns One Now

So much for a quick run-down of some of the criteria in comparing equipment. One of the criteria I didn't mention was the analysis of present users' comments. I think that only by a first-hand conversation with people who are using equipment, will you get really critical comment. It is my experience that the users will put in print for technical magazines generally only their favorable experiences; and in cases where they have made mistakes or where the equipment has been something less than completely satisfactory, users are naturally quite cautious about recording their own errors, and they are not always sure whether the error was the machine's fault or whether the error was their own fault. Perhaps this will continue so, but I do recommend that you talk to the man who owns one. In no other way can you get the information which will be most helpful in deciding whether that is the gear for you. The manufacturer's reputation in terms of the dependability of his equipment and the availability of satisfactory maintenance service is one on which you can get rather complete information from present users.

You can get valuable information from attending the professional conferences. There was, for example, at the Association for Computing Machinery Conference in Philadelphia in September 1955, an excellent paper delivered by a representative of the Chrysler Company entitled "Application of an Electronic Data Processing Machine to Inventory Control."[8] Chrysler set out with the idea, which I have discussed earlier, of programming their job on several different computers. They investigated in detail the Sperry-Rand product and the IBM product and then they got under pressure from their top management and were pushed into a decision to put in one of them quickly and they have put in the IBM 702. And apparently in the process they have made very substantial savings through improvement in the system to which they will apply the computer.

The experience of Metropolitan Life Insurance Company has been written up in the report of the Society of Actuaries which we have referred to and quoted from, and in some detail in an earlier 1952 report of the Society of Actuaries.[9]

Recommendations of Kelly Committee

In this connection I want to quote from the report of the advisory committee chaired by Dr. Mervin J. Kelly, the head of the Bell Telephone Laboratories who with a group of four other outstanding specialists, Professor Robert Anthony of the Harvard Business School, Sam Alexander of the National Bureau of Standards, James W. Pontius of General Electric Company, and John F. Chesterman of Bell Laboratories, made a study of the programs of the three Military Departments for applying automatic data processing. In essence, this report of the Kelly Committee concluded that the Department was doing some good things but should be doing more of them and should be doing them faster. It had a high opinion of the caliber of the people in the Departments who were doing this work but said there were far

[8]Robert P. Beals, "Application of an Electronic Data Processing Machine to Inventory Control" Chrysler Corporation, Parts Division, Centerland, Michigan.

[9]*A Report on New Recording Means and Computing Devices.* Chicago: Society of Actuaries, September 1952.

too few people engaged in this program in comparison with the job to be done. This was in part apparently the result of a failure on the part of some people in the Department to recognize the need for the rather complete and arduous studies required.

> "In all three departments, there seems to be a tendency in some groups to underestimate the magnitude of the task involved in the survey of a given operational area in contemplation of or preparation for the application of automatic data-processing. The Committee noted that some groups in the three services confuse the acquisition of equipment with the end-product of productive operations. A complete and comprehensive survey of a data-processing system application will include an investigation of the basic reasons for the operation, the need for the end-product, the management concepts involved, organizational structure and relationship, and similar fundamentals. Such a survey will, in effect, represent a re-thinking of the operation in the light of present circumstances and obviously represents a sizeable undertaking. It should be noted that business and industry are having to face up to the same considerations, and it appears that the only sure way in which the magnitude of the problems can be fully appreciated is through actual experience. To some degree, at least, the free interchange of information between the services, both as to plans and attainments, would be very helpful as a partial substitute for expensive and time-consuming experience.
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> "The Committee also gained the impression that there was a tendency to short-cut the difficult and sometimes arduous application survey by the comparatively simple expedient of programming present data handling procedures for electronic equipment. This is understandable, particularly if the effort required for the application survey was underestimated. Finding progress slower than expected, the survey team tends to lower its sights and skips over a full re-evaluation in terms of fundamentals. The advocates of a short-cut approach argue that some of the benefits of the automatic system are gained more quickly and the faults of existing procedures can be eliminated later, thus adjusting them to the characteristics of the new equipment and taking full advantage of its capacities. The Committee recognizes this approach also has its advocates in business and industry where there is a compelling motive for minimizing the risk during the transition period. The Committee nevertheless believes that this short-cut approach should ordinarily be avoided."[10]

[10]U. S. Department of Defense, Advisory Committee on Electronic Computers for Defense Business (Dr. Mervin J. Kelly, Chairman), "Report to Assistant Secretary (Comptroller), Department of Defense," May 27, 1955. (Prepared for official use, but not available for general public distribution.)

I would like also to refer to some good work which has been done in the Navy Department in terms of the development of criteria for determining when an automatic data processing system is justified.

A Bureau of Supplies and Accounts Instruction issued in July under the subject "Electronic Data Processing Systems" contains a program for the development of applications in the Navy Supply System.[11] The justification which they recite as an inclosure to this instruction is as follows: "Justification for specific manufacturer's equipment will be submitted to BuSandA. BuSandA will place all orders for equipment. The justification should reflect such criteria as follows:

"(1) The problem to which the proposed installation is directed has been completely and carefully defined. This definition should include the end-product, the organizational structure or relationships involved, and similar fundamentals. *In effect, it should represent a 're-thinking of the problem' in the light of new equipment capabilities.* [Italics not in original source.]

"(2) A block diagram of the procedure and computer program proposed for solution of the problem has been developed and such a block diagram submitted for review.

"(3) A basic program for application of the equipment to the problem has been developed or is in the process of development. There should be evidence that the program will be completed and tested before the time the equipment is received.

"(4) Satisfactory evidence should be submitted to show that the requirements of the program have been compared to the capabilities of the equipment that is proposed and that the equipment will satisfactorily handle the program. Information as to reasons for selection of this equipment also should be presented, if feasible.

"(5) The basis upon which the equipment is to be acquired, i.e. rental or purchase, the amount involved under either basis and the anticipated delivery date.

"(6) Provisions made to house and support the computer and operating personnel, the installation, alteration or building costs involved, and the estimated date the accommodations will be ready.

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[11] U.S. Navy Department, Bureau of Supplies and Accounts, BuSandA Instruction 4400.16, July 11, 1955, "Electronic Data Processing Systems; BuSandA program for development of applications in the Navy Supply System." (Prepared for official use, but not available for general public distribution.) For another Navy publication on electronic digital computers, see U. S. Navy Department, Office of Naval Research *A Survey of Automatic Digital Computers*, November 1954. 109 pp.

"(7) Evidence should be submitted to establish that (a) the installation of the equipment will result in direct savings with estimates of amounts, or (b) the installation will result in indirect savings with estimates of amounts, or (c) if no direct or indirect savings are anticipated, that the installation will perform the operation involved or produce the end product faster or within a reduced time cycle with appropriate justification of the need for speed in relation to the additional costs, or (d) the installation will perform some function which could not be performed by any other means and that this function is needed with justification of the additional costs, if any.

"(8) Satisfactory evidence should be presented to show that personnel needed for the installation and operation of the system are available, or will be available, and that they are trained or their training will be completed by the time their services are needed."

I think this is an excellent statement of the considerations which most of you will be going through before you reach a decision as to whether an electronic computer is what you need in your organization and, if a computer is what you need, which one is the one best suited to your problem.

PART III

CASE EXAMPLES

Editors' Note

To most problems we can turn to history and comparative experience for leads as to what to expect from alternative actions we may propose to take. In electronic computer applications the experience is very thin and even this meager experience has been but slightly documented.

The Federal Government has pioneered in the use of electronic computers both for scientific and management purposes. It is primarily to government, therefore, that we must turn for the lessons of experience which may help to make future applications in industry, business and government more successful. In this section are four case studies. Three of them report experience with installed equipment. The fourth describes a feasibility survey and the study and selection of equipment.

POTENTIALITIES AND PROBLEMS OF ELECTRONIC DATA PROCESSING

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Role of the Census, and Need for Data Processing Equipment

The facts gathered and published by the Bureau of the Census enter into important governmental decisions at every level—national, State, local—ranging from the apportionment of seats in the House of Representatives to the determination of the salary of the teacher in a rural school. Similarly, they guide business in decisions and in administration such as analysis of markets and sources of supply, establishment of sales quotas, and location of stores and plants.

The first U. S. Census was taken in 1790 and found a population of 3,929,214. One thin book of scarcely more than pamphlet size held the published results of that census. The Seventeenth Census of Population of the United States in 1950 numbered a population of more than 150,000,000 and the published figures on the number of people and their characteristics occupy 52 bound volumes and more than 80 paper covered bulletins. The subjects covered range from the number of inhabitants, recorded in 1,428 pages in Volume I, to occupation and industry, income of the population, and the number and kinds of families. Concurrent with the 1950 Population Census were a census of housing from which many characteristics of the dwellings our people occupy were tabulated and a census of agriculture which enumerated the farms of our nation, their products, acreage, facilities, and many other types of information.

Other major censuses include the Censuses of Manufactures which were begun in 1810, Censuses of Agriculture and of Mineral Industries initiated in 1840, Censuses of Distribution begun in 1930, Censuses of State and local governments begun in 1850. The first Census of Housing was in 1940. Most of the censuses other than population and housing are taken every five years. Also, Foreign Trade Statistics have been compiled since the beginning of our nation. From this list one begins to get an appreciation of how our growing economy has demanded more and more basic facts.

From little more than a count of noses for less than 4 million persons in 1790 to these tasks represents a tremendous increase in workload. This need for more and more data is still not all of the story. These demands are accompanied by demands for information on additional subjects, and by pressures to minimize the time lag between the collection and publication of information. Our bureau has tackled these problems of demands for more information and of timeliness on several fronts. One of these is through sample surveys. Through such surveys, we are able to enumerate a small but representative sample and to publish results of high reliability in a relatively short time after the data have been collected. Our regular recurring sample surveys for information about population, manufactures, and business now constitute much of our work. They go on month after month regardless of whether we are engaged in one of our big complete census activities or not.

Another main string to our bow for meeting the pressures for publishing our data on as timely a schedule as possible is our unending endeavor to obtain more efficient equipment to use in converting the masses of facts which come to us recorded on pieces of paper to orderly, well labelled tables which classify and summarize these facts. This is the effort which led to our early participation in the development and application of punched card equipment and to our use today of high speed electronic data processing equipment.

Applications of Electronic Computers to Census

Shortly before the end of World War II, we at Census were visited by Dr. John Mauchly and Mr. J. Presper Eckert, who at that time were on the faculty of the University of Pennsylvania. They told us about the electronic computer—the ENIAC—they were building for the Army and suggested that similar but still more advanced equipment might prove valuable to us. On this visit they were interested only in learning about the nature of our problems and it was clear to all of us that until the war ended no significant effort could be expended to develop equipment for civilian use. From time to time until the war was over, we met with Mauchly and Eckert to discuss Census problems.

Once relieved of their war responsibilities, these men devoted much of their time to the research and design aspects of a general purpose data processor for our use. Also, our attitude at Census changed from one of casual curiosity to serious interest. Because we recognized that at Census we were ill equipped even to understand, let alone to pass judgment on, electronic designs we sought the assistance of our sister agency in the Department of Commerce—the National Bureau of Standards.

With Census funds the National Bureau of Standards awarded a study contract to Eckert and Mauchly in September of 1946. Through their study, which was completed in August 1947, the original design proposals for a UNIVAC System were prepared. In June of 1948 a contract for a UNIVAC System was awarded to Eckert and Mauchly, and on March 30, 1951, the first UNIVAC built passed acceptance tests and was accepted by the Government for Census use. Thus, in April 1951, just as the tabulating load of the 1950 Censuses of Population, Housing and Agriculture was reaching its peak, the Bureau put the first UNIVAC system into service on data processing.

During the year prior to acceptance of the computer, we had prepared the instructions or "programs" for its first job. This application consisted of one phase of the tabulation work of the 1950 Census of Population. The work of compiling the Population Census is so tremendous that doing only a part of one major phase of the work on the computer still provided an exceedingly large work load. Consequently, when we accepted delivery we immediately put it to work 24 hours a day for seven days a week on this operation. It continued working primarily on this one job for a period of about 14 months. This operation was carried through with the manufacturer providing the maintenance service, but with Census staff doing the programming and operating the computer. We did hire and arranged for training of engineers during the preceding 18 months, but these were lost to others who could pay higher salaries before we got very far along in the operation.

In this first application the central computer operated as well as could have been anticipated. But the auxiliary equipment which converted data from punched cards to magnetic tape and the equipment which translated the results from magnetic tape to readable form, were at that time no match for the computer in either speed or reliability. Moreover, no one then had any real experience in using such equipment on large scale tabulating problems. We should add that in this first application we originally over-estimated the amount of work that could be accomplished by the computer—and we believe this type of experience has been repeated elsewhere. In any event, although the UNIVAC did handle what might be considered a large job when viewed alone, it processed only a small part of the mammoth 1950 Census of Population and had very little effect on the number of people we hired. Nevertheless, in addition to providing valuable experience, it did make a contribution and helped us to close out the job in a more orderly fashion, by taking up more and more of the load during 1952 as our temporary workers left the job. Also, we made some of the time on our computer available to the Atomic Energy Commission and to other defense agencies.

By 1953, we began to use UNIVAC on our continuing current work. We now use UNIVAC to tabulate our Current Business Survey, our Current Population Survey, and our Annual Survey of Manufacturers, and are taking steps to apply it to our Foreign Trade Statistics program.

We have found our equipment to be extremely versatile. During most of 1953 and 1954 the Census work load we had been able to convert to the computer did not require the full capacity of the one UNIVAC System we then had. However, the equipment was never idle and continued to operate around the clock. Many agencies including the Atomic Energy Commission, the Air Force, the Social Security Board and others brought work to our machine. We supplied them with computer time at cost. One minute the equipment would be completing a tabulation for our sample survey of population and five minutes later it would be computing numerical solutions to complicated systems of mathematical equations for the Atomic Energy Commission.

In planning the 1954 Censuses of Business and Manufactures we found that we could apply our computer with considerable effectiveness to the tabulating and other important phases of the clerical work on these censuses. However, we found that the remaining time available on our first computer, even after stopping substantially all service work for non-Census applications would not be sufficient, and in fact nearly the full time of a second UNIVAC would be required. We knew that the Internal Revenue Service was interested in obtaining about 40 hours a week on a computer, and were considering renting a UNIVAC. The two agencies found it was to the advantage of each of them to jointly purchase a computer. Significant economies could be achieved through the operation of both computers as an integrated activity at one location. Thus, by merging the Internal Revenue Service's requirements with ours we were able to purchase a second computer with the expectation of returning the cost to the government in a period of about 2½ years. The installation of the second computer was completed on February 1 of this year. The two UNIVACs occupy the same room at our office in Washington. To the best of our knowledge we are the only organization in the world with two large-scale electronic data processing systems installed side by side. We operate both of them 24 hours a day, 7 days a week.

Beginning early in 1955 processing for the 1954 Censuses of Business and Manufactures was initiated. This is a complicated job involving reports from more than 3 million establishments. We anticipate, with the use of the computers, to complete the compilation and publication of the Census results on a considerably faster time schedule than has been feasible in earlier censuses. Some of the types of work done on these censuses are included in the illustrations below. On large scale temporary work such as these censuses, we find that the application of this automatic equipment not only enables us to produce more timely statistics at lower cost but it also has the important effect of leveling off our requirements for temporary clerical help.

Capabilities and Versatility of the Equipment—Some Illustrations

In addition to their high speeds, one of the most striking features of large-scale electronic computers that distinguish them from conventional punched card and other office equipment is the fact that they can do a sequence of operations automatically, one step after another, without manual intervention and therefore are able to carry through any completely specified clerical operations, no matter how simple or complex. Also, the particular operation that is performed at any particular stage can be made to depend upon the nature of the results obtained in preceding stages of the process. These devices cannot, of course, exercise any judgment, but can follow precisely the instructions they have been given. More than that, with appropriate checking circuits in the equipment or in the instruction program these computers can carry out such operations with far greater accuracy than we have been able to approach in accomplishing large-scale operations by other methods. Thus, they have tremendous flexibility as well as high accuracy for accomplishing many different types of jobs.

Of course, a computer frequently does make errors, but when an error is made the computer recognizes it and stops for the operator or engineer to correct the difficulty. Frequently it is necessary, after a failure, to go back and repeat the processing of a work unit from the beginning. Sometimes this requirement of perfection is a disadvantage in work that does not need to have such high accuracy, but which may have to be started over in order to carry through accurately a programmed sequence of operations. Errors can be allowed by permitting operator intervention when the computer stops, but may be difficult to control.

The versatility of our data processing equipment has proven very helpful, particularly in view of the fact that our work at Census varies significantly in character. For example, let us briefly compare processing of a complete census with processing a sample survey. Many of the operations are common to both kinds of investigation. The original reports are examined for internal consistency, the characteristics of the population enumerated are classified and a set of tables presenting the results of the investigation are prepared regardless of whether 100 percent or only a small sample of the population being studied are included in the investigation.

There are also important differences between complete censuses and sample surveys. Obviously the complete census may involve tremendous numbers of observations, a fact which places heavy demands on the equipment, for putting data into the computer. Also many detailed tabulations are made, placing heavy demands on the output of the computer, and on the printer which converts the results to readable form. A small sample survey will not require such heavy input and output, but may involve more computing than is required for a complete census. When we select a sample we strive for maximum reliability per unit of cost. To accomplish this we may, now that we have computing facilities to handle it, end up with a sample design which involves a complex method of estimation. The ability of our electronic data processing equipment accurately to apply complicated estimating formulas for sample surveys permits the use of techniques which we were unable to use when we tabulated with punched card equipment. Sometimes, also, large numbers of arithmetic operations—additions, multiplications, squaring, root extraction, etc.,—are necessary to compute measures of reliability of sample statistics. The computers are extremely well suited to accomplishing such computations.

A quite different kind of work is involved in examining for internal consistency the reports from the more than 3 million establishments covered in the 1954 Censuses of Manufactures and Business. If these reports were all complete and self-consistent and if we were smart enough to foresee all the problems involved in classifying them, and if we made no errors in our office work, the job of getting out the Census reports would be laborious but straightforward. Unfortunately, some of the reports do contain omissions, errors, and evidence of misunderstanding. By checking for such inconsistencies we eliminate, for example, the large errors that would result when something has been improperly reported in pounds instead of in thousands of pounds. Perhaps one-third to one-half of the time our UNIVACs devote to processing these Censuses will be spent checking for such inconsistencies and eliminating them.

For example, we request bakers to report their production of white bread to us in thousands of pounds. Most of them observe and follow our instructions. We know, however, that some respondents will report in pounds or hundredweights or some measure other than the thousands of pounds we request. Since we also request the total value of white bread produced we can compute the average unit value for each report. In effect, we instruct our UNIVAC that the value range for white bread is between $50 and $300 per thousand pounds. The UNIVAC divides the value reported by the quantity reported and compares the result with the range we have specified. If, for a particular report the average unit value is less than $50, the UNIVAC determines whether the average unit value lies in the range 5 cents to 30 cents. If it does, the evidence is that the respondent reported in pounds instead of thousands of pounds in which case the UNIVAC divides the quantity reported by 1,000 and automatically corrects an error in reporting. If the checks can not be satisfied the report is listed for human inspection and correction by a specialist, perhaps by communicating with the respondent, before we include it in our tabulations.

Similar checking procedures are applied to the approximately 7,000 product lines for which we have reports. In a like manner we check to see whether such relationships as annual man hours and number of production workers, or value of shipments and cost of labor and materials, are within reasonable limits for the industry and area involved.

Sometimes a respondent gives incorrect or incomplete information about the kind of business in which he is engaged and this might result in errors in the classification system on which our tables are based. Here again, our UNIVACs are instructed to apply checks designed to detect such errors. For example, the computer might determine for an establishment classified as a jewelry repair shop, that employees' salaries amounted to less than 10 percent of total receipts. For this kind of service trade, expenditures for labor usually represent the major item of expenses and less than 10 percent for salaries is uncommonly low. Our computer would list this case for inspection, and a review of the report might result in a change in classification from "jewelry repair shop" to "retail jewelry store," for example.

The foregoing are illustrations of relationships we examine to determine the quality of reports to us. These checks are quite numerous, and frequently very complex.

In the past we have done a smaller amount of this kind of checking by hiring, and training enough clerks to perform these routine checks on every report. Most reports are reasonably straightforward and complete, so that a clerk may develop a tendency to read carelessly. Now that we have put our computers to work making these checks, we find them doing this sort of thing tirelessly and without forgetting any of the special rules that come into action only rarely. The ability to carry through such complex procedures along with the more usual types of tabulation operations makes the computer particularly effective for some of our work.

Numerous other illustrations could be cited. It should be emphasized that generally in our most successful applications of the computer to data processing, we succeeded in assigning to the computer operations that formerly had to be done manually, either preceding or following what was previously done on punched card tabulating equipment.

Selecting Appropriate Applications

One of the important problems a potential user must face is that of determining the applicability of a computer to his particular problem. We do not know a simple rule of thumb method for answering the question of applicability. We find that the savings through the application of computers to clerical work varies widely depending on the nature of the job. On some jobs small in size the work of preparing instructions for the computer can exceed the work required to do the job by less automatic methods. Also, some of our operations that involve only comparatively simple manipulation of data can be accomplished with greater economy either manually or on punched card equipment than on our computer. For example, one may have a set of records that needs to be placed into sequence on the basis of an identification code, say of 6 digits. A few punched card sorting machines that cost much less to maintain and operate than a large scale computer can sort cards into sequence on such a code at considerably less cost than would be involved by using one of our computers to accomplish the sequencing at their present state of development. Jobs involving large amounts of such sorting and only limited additional operations may yield little or no gains when placed on a computer, or may cost considerably more than if done by alternative methods.

The work in Foreign Trade Statistics which is presently programmed for the UNIVAC is an example of work on which we get comparatively small gains. The important items are: first, a description of the commodity; second, identification of the foreign country; third, identification of the U. S. port of import or export; and fourth, fifth, and sixth, the quantity, weight and value of the commodity.

Tabulating these data involved sorting them in sequence by commodity, country, and port and then cumulating the quantities, weights and values for like shipments. This is a big job because there are approximately 1,200,000 different shipments of different commodities in our international trade each month and not because the operations involved are especially complex. We discovered that although our computer can do the sorting more accurately than we are able to do it with punched card equipment, the estimated cost reduction was small as compared with cost reductions we can effect in tabulation of the 1954 Censuses of Business and Manufactures where the computer does clerical operations that could not be done efficiently on punched card equipment.

On a number of what we regard as successful applications of the computer to the compilation of data we have found that for selected types of operations the computer has resulted in reductions of cost of from 25 to 75 percent. For example, about $55,000 of the funds appropriated to our Bureau for fiscal 1953 was to defray the cost of tabulating our Current Population Survey on which the government's monthly estimates of employment, unemployment and other characteristics of the labor force are based. For fiscal 1955, the first full year this was done on our electronic data processing equipment, our appropriation from the Congress included about $28,000 for this same work, or just about half of what it was two years earlier, and a more complex tabulating job was being done. These types of gains are on the selected phases of the tabulation work which were transferred to the computer.

Far greater gains are achieved on some operations such as mathematical computing involved in some of our sampling work, or in measuring and adjusting time series for seasonal variations. Many operations that would be of prohibitive cost to carry through except on a very limited basis on alternative types of equipment become inexpensive and feasible.

The cost comparisons from which these ratios of gain are computed are direct operating and maintenance costs and do not include an allowance for the capital costs of the computers. The Census Bureau computers are owned, and appropriate capital cost is not easy to assess in view of the fact that the computers are maintained on such a basis that they will continue in service indefinitely, subject of course to displacement by obsolescence. On the other hand, in the types of application we have made we have found that the capital costs can be returned through reduced costs in as little as 2½ years on a successful large-scale application.

The advantage or gain from the application of a computer to a job depends, of course, on the skill with which it is used, and on the state of development of computers. Advances in computer design are being made that will, we think, make computers economical for types of work for which they are not now as economical as available alternative methods.

It is not essential to have a system at hand to evaluate the probable performance of an electronic data processor for a particular application. Equipment suppliers can be depended upon to provide accurate information on the rates of speed at which their equipment is designed to operate. Good approximations to theoretical time for a given problem can be based on these quotations. Of course these estimates of theoretical time represent minimum time. To them must be added allowances for machine down time, faulty operations time, and other factors which operate to make actual performance take more time than the theoretical minimum. Here it may be unsafe to place complete dependence on the testimony of the equipment supplier. There seems always to be a strong tendency to underestimate time that will be lost, at least in early applications.

There is, however, an evergrowing body of experience being accumulated by users of these equipments. It has been our observation that organizations using high speed electronic data processing equipment both in government and in private industry are quite willing to show their records of equipment performance to anyone they believe has a legitimate and serious interest. Efficiency of the equipment varies on differing types of jobs and methods of computing of performance vary. Nevertheless, with a modest amount of effort, a potential user can obtain and understand data which will enable him to apply reasonably satisfactory factors to convert estimates of theoretical time to probable actual time.

Of course, if the right collection of components for an application being studied is available, a pilot test represents the best way of arriving at an estimate of a particular system's ability to accomplish a specific task. But as indicated above, if a pilot test cannot be made it is still possible to make useful forecasts of probable performance.

State of the Art and Outlook—From Viewpoint of a User

One widely discussed facet of the whole domain of automation is the rapid rate of progress that has been and is being achieved. Each year sees its announcements of faster, larger, more versatile equipments. This indicates a good, healthy state of affairs. However, waiting for next year's equipment because presently available equipments may soon become obsolete is not justified, in our opinion, if one has a good application.

We have found that we can do much of our work at the Census more efficiently with equipment available today than we were able to do it with the tools previously available to us. We look forward hopefully to the time when future models will make it possible for us to increase our efficiency even more. Our objective is the most work of good quality per dollar of expenditure. When we can satisfy ourselves that the continued use of our present equipment will cost more than installing new equipment and converting to its use we will try to acquire the new equipment.

Many of the components of systems now available are less efficient than we would like them to be. This is particularly true of input and output equipments. There have been remarkable achievements in these areas, but they have not kept pace with the speeds with which the main computing elements can manipulate data internally.

On the output side there are in use today printers capable of typing lines of 100 to 150 characters each at a rate of 10 lines per second and suppliers are promising devices which will be twice as fast. Although these speeds sound impressive, they are slow when compared with the rates of speed at which modern computers can manipulate information. This lack of balance and the need for faster printing equipment has been recognized by the engineers in organizations operating in this field and much research and development is currently being actively pursued. We believe it is safe to predict that great strides will be made toward better solutions of this problem in the next few years.

Input preparation usually originates with a human being depressing the buttons on a keyboard. Obviously this proceeds at rates completely out of balance with electronic speeds. At Census, most of our input is recorded on magnetic tape through the sequence of first manually key punching cards and then running the cards through a card-to-tape machine. We used a staff of nearly 2,000 key punch machine operators for almost a year to transcribe the information we collected in the 1950 Censuses of Population and Housing from the enumeration forms to punched cards.

If the full potential of modern electronic data processing equipment is to be realized better and faster methods for recording the original information on a medium usable as input to the data processor must be provided.

Here again, the problem has been recognized and research and development aimed at better solutions is under way. Several laboratories are actively trying to build "typewriter readers." This effort is an attempt to create a device capable of automatically reading typewritten information. When this can be done rapidly and accurately, it will be easy automatically to transcribe typed information to magnetic tape. Much of the information collected for Census purposes is recorded in long hand, however, and some means of transcribing data recorded with a pen or pencil would be extremely helpful. In an attempt to solve this problem for us, engineers at the National Bureau of Standards have developed a device called FOSDIC which we are now using experimentally. FOSDIC is a name consisting of the initial letters of Film Optical Sensing Device for Input to Computers. To apply FOSDIC we use a properly designed form to collect information in the field. Next, microfilm copies of these forms are passed through FOSDIC which transcribes the intelligence recorded on the FOSDIC form to magnetic tape.

Information must be recorded on a FOSDIC form by the position of a mark rather than by conventional letters and digits. In many respects a FOSDIC form requires marks similar to the marks that the IBM mark sense punched card requires. As many of you may know, the IBM mark must be made with special lead or ink which deposits an electrical conductor on the form. Furthermore, the positions in which marks may be made are rigidly specified for mark sense cards as are the overall dimensions of the form that may be used.

FOSDIC is designed to eliminate many of these restrictions.

First, almost any marking instrument may be used. Second, it provides flexibility in form design in the sense that the designer of the form can decide where marks are to be made. Lastly, any paper size up to 14 by 20 inches can be used.

Currently we are regularly employing FOSDIC as a standard unit in processing a small segment of our work at the Bureau. Primarily, this is research since we are attempting to evaluate and improve FOSDIC at the same time we are using it to perform regular work. Results have been extremely encouraging. So much so that there is a strong possibility that we will use this method for solving our input problem during the 1960 Decennial Censuses. In this event, it seems quite likely that about 8 FOSDICs operated by about 75 to 100 people in 1960 will do the work we used almost 2,000 people to accomplish for the 1950 Censuses.

Summary

Automatic electronic data processing equipment has contributed significantly to the efficiency with which some of our work at Census is accomplished. It is not, however, a panacea for all kinds of paper work. Careful analysis of applications and comparisons with alternative techniques will show that for some kinds of work it is uneconomical to contemplate the use of the newer devices while in other cases spectacular economies can result. Furthermore, there are areas where equipment improvement is needed and can be expected. Some of these improvements will be in the central computing element. From our point of view, however, the more significant ones will relate to the peripheral input and output devices which are sorely needed to bring these functions into balance with the tremendous rates of speed at which modern electronic computers can manipulate data.

LOGISTICS APPLICATION IN THE AIR FORCE

SAUL HOCH

The United States Air Force Logistics System

While all are aware that logistics in the Air Force is a task of somewhat imposing proportions, a few statistics may be helpful in establishing the true magnitude of the problem.

Supplies and equipment in Air Force warehouses are valued at over $10 billion; over 1,200,000 items are listed in Air Force catalogues with 15,000 new items entering the system and 7,000 items leaving the system or undergoing revision every month; over 140 types, models and series of aircraft must be maintained in efficient operating condition, compared with up to 10 types, models and series of aircraft normally operated by a commercial airline; over 300 customers—the air bases and overhaul facilities—are scattered over the far reaches of the earth. The Air Materiel Command is the agency in the Air Force charged with furnishing the materiel and maintenance support needed to keep the Air Force in combat ready condition. To do this requires the spending of many billions of dollars a year, the annual moving of 4.5 million tons of materiel, the handling of 42 million line items of requisitions, receipts and other inventory transactions, the employment of over 150,000 people.

While our system works and works well, as was demonstrated in Korea—it is expensive in terms of time, materiel, manpower. Further, with the advent of the nuclear age and with the sharply increasing cost of our weapon systems, new and stringent demands are being placed on the logistics system as never before. The technical breakthroughs which have occurred in our weapons must, for combat effectiveness, be matched by similar advances in the field of logistics. This means among other things, that a data flow system must be developed that has at least three major attributes—it is highly responsive to demand, it makes most effective use of available resources and it can expand quickly in times of emergency.

The first of these attributes—responsiveness—is most closely associated with the factor of time. In a military operation, time is of the essence. It is not only essential for maintaining the combat readiness of aircraft; it has very significant cost implications. The shorter the pipeline for filling demand, the less the cost of keeping the pipeline filled. The shortening of the pipelines by one month can mean hundreds of millions of dollars. It is interesting to note that in analyzing the time elements involved in the supply pipeline, it has been found that actual movement of materiel consumes only about 20% of the time; the remaining 80% of the time is paper flow. Thus, while we can make substantial improvements in the materiel handling time by extending the use of airlift in logistics activities, we will not thereby alter the larger problem. The *major* problem is the paper pipeline, and it is to this problem that I turn my attention.

The second desired attribute of our system—the effective use of our resources—is one which has become more and more difficult under our present system. The increasing complexity of our weapon systems has brought thousands of new items into our system. Keeping track of this inventory, projecting the demand for the myriads of items required to maintain weapon systems, and distributing these items in the most effective manner are activities whose difficulty increases in geometric progression. At the same time, the increasing cost of our weapon systems and their support prohibits us from meeting the situation by building massive stockpiles of expensive supplies and equipment, in order to assure us of having what we need when we need it. Perhaps a major reason that this problem looms so massively is the inability of our current system to obtain, digest and utilize the mass of data necessary to perform these activities.

The third of the desired attributes—expansibility under emergency conditions—is one that is now tied to the ability to obtain and train large numbers of clerical personnel. Even at the present time, qualified clerical personnel are difficult to obtain. In times of emergency, this difficulty can be expected to magnify many times. Furthermore, the training problem is a serious one. The Air Force manual of supply procedures is a ponderous document, and can not be easily absorbed in a short period of time. The rate with which these procedures undergo revision to meet changing conditions makes it difficult for even our experienced clerical staff to keep abreast of the situation. Thus, our clerical staff is relatively inelastic—an undesirable condition for an operation which must be very flexible to be most effective.

Another element should be considered here, in connection with human clerical activities. Because of the mass of data which flows in the logistics system, the problem of accuracy of data is a formidable one. Throughout the present system, multiple transcriptions and consolidations inevitably introduce inaccuracies which result in substantial losses of time and money. Under our current system, utilizing conventional data-handling equipment, such inaccuracies can not be greatly reduced; in fact, they should be expected to increase.

Electronic Equipment for Logistics

In order to meet these problems, the Air Force, through the Air Materiel Command, has instituted a program to revise our current logistics system, a program which is strongly oriented towards electronic data processing equipment. We are well aware of the fact that these equipments are not panaceas—that they have definite limitations, that their effective use requires long and arduous planning, systems study and programming. However, we do feel that their data handling capability exceeds by several orders of magnitude the capability of current equipment; that the state of the art is such that current EDPE is being surpassed almost as fast as it can be produced, so that limitations are constantly being overcome. In short, we feel that they represent almost our sole hope in our effort to maintain control over our data handling problem.

We recognize two different programs for the use of these machines. On the one hand, we wish to proceed as rapidly as possible to utilize the capabilities of the equipments. This requires that our current system be analyzed for areas of profitable and desirable machine application, and that we immediately begin the work of systems analyses and revision and programming to place these areas on machine. On the other hand, we wish to carry out a program of long range research which utilizes the powerful mathematical and statistical tools just now being developed to meet the exacting demands of our future Air Force. This type of work requires technique development and systems design which may not be ready to put into operation for some time to come.

Considering first the short range aspects, there are obviously in a system as massive as ours many areas immediately susceptible to machine operation—so many, that it is well beyond the capacity of any one office or one machine to cope with all of them effectively. This is particularly true in an operation which functions under the principle of decentralized management, as is the case in the Air Materiel Command. Thus, the task has been divided among the 15 U. S. depots which constitute the field management divisions of the Command, and each of the depots has set to work to discover areas for EDPE application. This is being accomplished by means of a small select group at each depot, constituting a data processing office, which serves as a repository of EDPE knowledge and works closely with the various operating elements of the depot in performing the necessary systems analysis. As progress is achieved, the data processing offices are expanded to furnish the required programming assistance, although variations of this particular pattern exist in several of the depots. An office has also been established at the Headquarters, Air Materiel Command which, in addition to performing a similar function, coordinates the work in the field in order to prevent unnecessary duplication of effort and to insure that the progress achieved in each of the depots is made known to every other depot.

Equipment-wise, we now possess a UNIVAC, situated at Headquarters AMC, Wright-Patterson Air Force Base, Ohio, and an IBM 702 at our Oklahoma City installation. We are further negotiating to obtain five more large scale computers which will be placed at five of our other installations sometime in 1956. These sites were selected because of the type of item managed by the installations, the volume of activity, vulnerability features and other considerations. All of the remaining depots will be allocated time on these equipments to debug their programs and run various computations. Our experience with these seven computers will inform us if there is a need to install large scale computers at all of the other nine installations, or if we can perform an effective service for them at the seven computer sites. We are also installing IBM 650's at most of our depots to serve one or more of the following functions. At installations not scheduled to receive large scale equipment, they will serve to assist in current operations and, to some extent, as test beds for applications to be run on large scale equipment positioned at other depots. At installations scheduled for large scale equipment, they can serve as interim equipment and later as adjuncts to the large equipment, if warranted.

Examples of Logistics Problems for Large Scale Computers

A few examples of the types of problems which are already running, or are about to be placed on those large scale computers which we already have, may be of interest. There has been developed for implementation at Oklahoma City a technique for computing requirements for aircraft engine spare parts which represents a significant improvement over our current methods. Very briefly, the technique, which has already been programmed for the IBM 702, achieves the following:

(1) It permits the maintenance and use of data which could not be handled effectively or in many instances, could not be handled at all under our present system. For example, it collects past usage of parts in engine overhaul by engine type, model and series. This results in greatly improved projections of demand, since it permits extension of past experience against future overhaul programs for specific engine types, models and series. In the past, data on overhaul parts usage were imperfectly collected against engine type and model at best and, in the case of parts applicable to more than one engine type and model, in grosser aggregates. This, of course, inevitably resulted in much poorer projections.

The technique also permits the maintenance and use of data on interchangeability and "substitutability" of parts. This is important in the determination of available assets to meet future requirements, and is much too involved a procedure to be handled effectively with conventional equipment. It will also be extremely important when used in connection with another EDPE application—the processing of requisitions, where it can be used to fill requisitions with substitute items in the event of shortages or to deplete stocks of older items which are eventually to be replaced by new, improved versions just entering the system.

(2) The technique also develops repair schedules for those engine parts which are themselves reparable. This is an integral part of the requirements computation, and takes into consideration the expected generation of items in reparable condition and the time necessary to repair these items back to serviceable condition. It is an extremely important part of the computation since it reduces the number of new spare parts which must be procured.

(3) It also permits, through a functional code, the drawing together of all items in any specified engine or engines performing a particular function. This is particularly useful in attempting to estimate spare parts requirements for new models of engines about to enter the system and for which there is no past parts consumption experience.

(4) The computation is scheduled quarterly, as opposed to an annual computation under our present system. Usage rates are computed using two years' experience, but each quarter they are up-dated on a moving average basis. Time series of rates are printed out in order that trends may be noted and provided for. This is completely impractical using current equipment.

(5) The technique also provides the foundation for expansion into other commodity and functional areas.

A second example of an EDPE application is one which has already been programmed by the Dayton Depot, and is now operational on the Headquarters AMC UNIVAC. This is a relatively simple tape look-up operation, which up to now has been a particularly bothersome bottle-neck to the Dayton Depot. The problem involves the examination of long lists furnished by aircraft manufacturers recommending those electronic spare parts which should be in the system to maintain their aircraft for one year after delivery. The parts, which may easily number in the thousands, are normally printed in order by manufacturer's part number.

The Dayton Depot must match each part number against a master cross index file of about 250,000 items to see if that part number has ever in the past been given an Air Force stock number. If so, the manufacturer's recommendation must be matched against prior Air Force experience, and a decision made as to the quantity to be accepted as the most likely requirement. This must later be matched against available assets to determine the amount actually needed from outside sources. If no stock number has been assigned, and a determination has been made that the item should be purchased, a request for a stock number must be submitted to Headquarters AMC, and care must be exercised to insure that no other request concerning the same manufacturer's part number, appearing on another list, is submitted while the original request is still being processed by Headquarters AMC.

As now programmed, the master file is on tape. The lists received from the contractors either are received in the form of cards, or are card-punched. The cards are then converted to tape and run against the master list. Where a part number has previously been stock-numbered, a print-out shows the part number, stock number, the contractor's recommendation, and previous Air Force experience on that stock number, the latter being computed from a replacement rate on the master tape. Where no match occurs, a list of such numbers is printed for consideration as to whether purchase should be made. If such items are required, a request is made for an Air Force stock number. This request is remembered by the machine, and no subsequent requests can be submitted on the same part number. The importance of this simple machine procedure can be seen from the fact that normal policy provides for the contractor's list to be accepted for procurement as submitted, unless the analysis just described is completed within a prescribed period of time. The deadline was frequently passed under the manual system, despite Herculean efforts to prevent it.

Space does not permit a fuller description of the many other applications which are already programmed, or are in an advanced stage of programming. Suffice to say they include such applications as the estimation of complete engine removals for overhaul through the application of actuarial techniques; the complete processing of requisitions including the updating of balances, the automatic production of shipping orders and back orders and the concurrent development of all types of historical data to be used for statistical reports of various types; technical failure data to indicate whether our parts are lasting as long as they should and also whether we are using better parts than are necessary for the specific applications under study; budget preparation; procurement status reporting; and so on.

Long Range Research

Now, all of these applications are, as was stated earlier, designed to obtain an immediate improvement in our capacity to perform the AMC mission. The other aspect of the use of electronic data processing equipment, future systems design, has, we hope, an even greater implication for Air Force logistics. In the long range research program that is now being carried on by the Air Force, we hope to take fullest advantage of the ability of these equipments to utilize the tools of operations research, linear programming, probability analysis, Monte Carlo techniques, mathematical model formulation, etc. This work will lean very heavily upon the electronic data processing equipments which have been discussed earlier, but its scope will not be limited by their current capabilities. Many of the techniques require so great an amount of computation for real-life problems that our current equipment is not satisfactory. But, as mentioned before, on the horizon equipments can be seen which show every possibility of having the capacity to satisfy the demands of these new techniques.

As an aside, I might mention here that a major reason that the Air Force has not at this time dealt with one equipment manufacturer exclusively is that it feels it is very desirable to keep several manufacturers interested in its problems. The competition which is thereby promoted can only serve to accelerate the improvement of current equipment and the development of new equipment, and thus further our progress in the field. We realize that having different equipments reduces the ability to utilize programs developed at one installation directly on the equipment at other installations. However, we have been assured that engineering-wise, there is no particular difficulty in taking data from a tape used on one equipment and converting it to the tape of any other machine. Further, while the programming will not be compatible, the systems analysis generally will be, and this represents the bulk of the work necessary for a machine application. Thus, we feel that the lack of programming compatibility is not as significant as might be imagined at first consideration. Additionally, we feel that it is much more than offset by the advantages of keeping several equipment manufacturers interested in our problems.

In order to show how these new techniques are applicable to Air Force problems, I should like to present a few examples of studies now in progress, but probably some distance in time from implementation. The first of these studies is a stock distribution problem.[1] It employs the device of building a linear programming model, and because of the amount of computation required in a real situation, would be used only for an item which is both high cost and high volume. The objective is to fill requirements at bases or overhaul shops from available assets, whether in serviceable or in reparable condition, or from new procurement. This is to be done at minimum cost, where the cost employed includes transportation costs, base repair costs, depot repair costs and new procurement costs. The mathematical model considers explicitly transportation times, procurement lead time and repair times in addition to the costs cited. The model computes, automatically, redistribution schedules, repair schedules, and procurement schedules for a time phased program.

In order to prevent transient or short term effects to dictate

[1]See Appendix A for detailed description.

actions which may not be optimum for the long range program, the model is computed as far into the future as firm program data allow. Despite this long term look into the future, action on future expectations would be deferred as long as economically feasible in order that changes in program or usage rates may be provided for through frequent re-computations. We are currently developing new techniques for reducing the computational load associated with these re-computations. We hope that these techniques will enable us to allow the computer to decide when new re-computations are necessary.

Other studies of interest are currently being performed by the RAND Corporation of Santa Monica, California. This is a research agency which performs a considerable amount of mathematical and operations research for the Air Force. Members of its staff have performed a number of studies on the nature of demand for aircraft spare parts. An interesting conclusion they have arrived at is that the demand for many aircraft and engine spare parts does not seem to be adequately predictable from flying hours—the conventional device for requirements projections. Rather, the demand appears to be more random in nature, depending mainly on the number of those aircraft in the system on which that part is used. The probability that the part will be used in any month generally appears to follow a Poisson distribution, where the shape of the distribution is determined by the average past usage per aircraft-month.

Using the principle of estimating demand by probability, RAND has constructed a mathematical model to permit the computation of minimum cost procurement and repair schedules. The model takes as its objective the making available of specified average number of aircraft in mission-ready condition—this to be accomplished at minimum cost. It introduces a new concept—a depletion penalty, which is a cost assessed for *not* having an item, and is based essentially on the cost of the complete aircraft to which the spare part is applicable. Using marginal analysis, this cost of not having the item is measured against the costs of obtaining or possessing the part. These latter costs include the procurement cost, repair cost, obsolescence costs and holding costs, with additional penalities imposed whenever procurement or repair must be expedited in order to meet a requirement which available assets or routine procurement or repair will not fulfill. The model is an outgrowth of the one described earlier. However, it presents a major computational burden for high volume items and certain data gathering difficulties, all of which make it somewhat more abstract than the model previously discussed.

As in the case of the short range applications, there is not enough space to discuss in detail more of the work that is going on in this area. However, there are studies in progress which cover such subjects as maintenance scheduling and support requirements; utilization of probability functions in the development of mobile spare part "kits," where the kits are weight limited and the selection of items is to be such as to afford maximum protection against "stock-outs"; the "complete aircraft model" which determines the quantity and schedule of entry into the system for new aircraft in order to maintain a desired average number of mission-ready aircraft; and so on.

Organizing for Planning Computer Use

The final subject with which this paper concerns itself is the existence of our concurrent programs for long range research and short range applications, a situation which provokes a whole series of problems. Our experience in the past year and a half has shown that attempting to do both by the same people is not wholly satisfactory. The tendency is almost irresistible for the pressures of current commitments to take precedence over the long range effort—to absorb its resources and to divert its direction. At the Air Materiel Command, we are even now restudying our organizational approach to systems design to determine whether revisions should be made in our current methods.

It appears to me that this dilemma is bound to be experienced by any organization, in government or out, planning to use high speed data processing equipment. These machines can and should be used to assist as soon as possible in the problems of management and of day to day operations. At the same time, the equipments have a potentiality which is generally beyond that which can be immediately utilized or is immediately obvious. It is important that resources of personnel and equipment be allocated to exploring this potentiality in order that the full benefits of these equipments may be realized. This, however, has organizational implications. My own personal views on the principles which should be followed in developing an organizational pattern which permits both long range and short range programs to operate with minimum impingement on one another are as follows. Let me emphasize, however, that these are my own views and not necessarily the official position of my employers. These principles, to my mind, are just as valid in industry as they are in government. They are:

(1) The organization should provide for a long range planning group which operates directly under top management and is in no way under the supervision of the operating elements of the organization. This is vital if the integrity of long range research is to be preserved. Placing long range research under the supervision of the operating elements will inevitably limit the scope of the research effort. Further, the pressure of current commitments will cause the gradual subversion of the long range efforts to the more immediate task of meeting these commitments. This is particularly likely in view of the high caliber of personnel necessary for performing research work.

(2) Where operations function in a decentralized manner, the long range planning effort should be largely concentrated at the headquarters element. The decentralized elements of the organization should, however, provide focal points for the review of long range concepts and techniques for feasibility from the field point of view, and for the carrying out of tests of the long range concepts and techniques. This concentration of the long range effort in a single place permits the optimum use of the very highly qualified, very hard-to-get talent engaged in research work. Furthermore, by the physical proximity of the persons engaged in the program, the ideal of a truly integrated system is made less difficult of attainment. Stated in a negative way, it is my opinion that long range, conceptual research is extremely difficult to perform on a decentralized basis because of the dilution of available personnel resources and the difficulty of adequate coordination.

(3) As long as equipment and programmers are scarce commodities, electronic data processing equipment should remain under the control of (although not necessarily operated by) the long range group, even though the equipment is used for both long range research and current operations. This is desirable in order to prevent the equipment from being completely pre-empted by the pressures of current operations, and thereby denying adequate access to the equipment by the long range effort. It is also desirable because the dynamic state of the art places these equipments in a developmental, rather than a stable, environment and control by the long range group increases the likelihood that the benefits of improvement will be foreseen and properly planned

for. Finally, consideration of the highly specialized programming required for the new mathematical techniques, will be thereby insured. This implies that all machine programmers should be attached to the long range group, because this is the most effective way to control the equipment.

(4) Short range applications are and should continue to be the responsibility of the operating elements. Programming and technical advice should be furnished as necessary. In the case of programming, this will ordinarily involve the assignment of one or more programmers to work directly with operating personnel from the point of initial determination that a problem is a profitable machine application. It also appears very desirable to give operating personnel some training in programming because this knowledge will assist them greatly in formulating their problems in such a way as to facilitate actual machine application.

(5) A coordinating device such as, for example, a high level coordinating committee should be created, composed of senior representatives of each of the operating elements, and a representative of the long range group. This committee should have the following responsibilities:

(a) It should coordinate short range planning among the various operating elements and determine the priority of effort to be assigned to various proposed machine applications. A committee such as this, operating properly, would discover any inconsistencies, or incompatibilities, existing among the individual short range planning activities of the various operating elements. Further, it would provide for common source data collection, where the same basic data are used by several of the various operating elements in different ways and for different purposes.

(b) It should coordinate long and short range planning so that short range planning will be compatible with long range objectives.

(c) It should provide the means for obtaining data needed for long range research from the operating elements, as well as the assistance of the subject matter knowledge and experience that reside in the operating elements. It should also provide the means for informing the operating elements of the direction, progress and results of long range research.

This I believe will provide the modus operandi for optimum progress in both programs.

Perhaps the major point that I would like to make is that I feel those people who have the courage to allocate scarce personnel and equipment resources to longer range attempts to extract the full benefits of EDPE—despite the pressures of current commitments and the temptation to apply all available resources to meet these commitments—will be more than amply rewarded by their foresight.

LOGISTICS APPLICATION IN THE AVIATION SUPPLY OFFICE[1]

REAR ADMIRAL F. L. HETTER, SC USN, COMMANDER V. A. BLANDIN, USN, AND LIEUTENANT COMMANDER W. V. CROWLEY, SC USN

Rear Admiral Hetter

The Aviation Supply Office

I was very happy to accept the invitation of Professor Hattery to participate in these sessions, because I feel that we can all benefit from an interchange of information about our experience in this fascinating new field. When the Aviation Supply Office first investigated the possibility of utilizing electronic data processing equipment as a tool of inventory control, we were deluged with claims and counter-claims from manufacturers of this equipment. At this time we received valuable help from Mr. S. N. Alexander of the National Bureau of Standards and from many of the fine people on his staff. We were thus able to get an unbiased view of the entire field so that we could formulate sound ideas as to the type of equipment best suited to our needs.

As a result of our work with the National Bureau of Standards, I had the opportunity to present the Navy supply case at a seminar of the Office of Naval Research. At that meeting we broke our problem down into quadrants.

(1) The accumulation or *collection of information* at the consumer level.

(2) The actual *transmission* of these data to a control point.

(3) *Assembly* of this material at the control point (and this included the actual library work of putting these data into usable form).

(4) The *data processing* at the control point.

Now I'll try to give you a brief picture of how electronic data processing machines serve the Aviation Supply Office in the management and inventory control of 400,000 plus items in the aviation supply system. My associates, Commander Blandin and

[1]The opinions or assertions contained herein are the private ones of the officers involved and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

Lieutenant Commander Crowley, will give you, first, a brief rundown on a supply system dealing with dynamic engineering technological advances; and, second, an outline of ASO's use of the IBM-701 and 702.

The Supply Function

Supply is an essential part of our National Defense. Some time ago President Eisenhower set forth four considerations as the pattern of our National Defense structure for the future:

"(1) The *threat* to our security is *a continued and many-sided one.*
(2) True security for our country must be *founded on a strong and expanding economy* readily *convertible* to the tasks of *war.*
(3) We should *base our security upon military formulations which will make maximum use of science and technology.*
(4) The *United States has reason to be deeply concerned over the serious effects which a sudden attack could inflict.*"

These *four points* are the *guide post* which the ASO has been following in order to increase efficiency and reduce the expenditure of manpower in the supply support area. There are many problems in Naval Aviation Supply. Among them are:
(1) The economies of manpower utilization.
(2) Raw material availability.
(3) Industrial production capabilities.
(4) And this is the most important—inventory management. This is the area over which ASO has the most control and the most influence. Commander Blandin will now give a brief presentation on some of the technological advances which create the climate for modern aviation supply.

COMMANDER BLANDIN

Aviation Technological Advances Affecting Spare Parts Support

In discussing the technological advances in the aviation industry as considered in the military development and operational area, it is necessary first of all to look at the reasons for these technological advancements and study the pressures that exist in the military for as rapid advancement as is possible. The military requirements picture you read about every day in the newspapers may not impress you in the way we hope to impress you today. The main topics in the newspapers concern the stresses and strains in the diplomatic field that affect the safety of this country. The same stresses and strains are reflected, as in a mirror, in the military requirements of the United States.

We look at it in much the same way as any competitive organization in the civilian economy. We have a goal to attain and that is, to be supreme in both equipments and in training of personnel. Our competitor is not as conducive to revelations of his strategy and tactics as we have between Macy's and Gimbel's, and the competition is much greater in view of the stakes involved. Therefore, the advancements in the technology of aviation are extremely rapid and in many cases calculated risks must be taken in order to take advantage of the technological brilliance of the United States.

Advanced research and development in the aviation industry that is reflected in today's aircraft and armament was actually provoked and initiated by severe world diplomatic tensions as early as 1935. In 1938 we became universally aware of the world threat of the dictatorships in the European continent and the realization that the Germans at that time were far superior in all phases of aviation. Through the years since 1938 there were many component factors that have been involved in research and development, not only in the airframe itself, but also in the power plants, the accessories and the electronics equipments. Today we have a highly specialized and highly technical group of components that make up the aircraft.

Technological Stabilization

It is also interesting to note the wide disparity between technological stabilization of civilian consumer goods and the military equipments. Civilian consumer goods have a very definite and logical trend, because they must be made to sell at a high volume or to a selected customer. Stabilization of these items falls into three basic categories. It must perform to the public taste, it provides simplicity of operation, and has ease and inexpensiveness of maintenance.

Technological stabilization when applied to military operations and the military weapons presents a very different requirement. First of all, the weapon must perform to military operational requirements set forth by our top strategic and tactical planners. The combat organization of the Navy depends on the implementation of these requirements. Secondly, the military weapon as it is produced and operated must also be logistically feasible. Logistics feasibility depends upon our ability to manufacture quality-wise and mass production-wise; our technical ability to maintain and operate; and our ability to provide materials and spare parts when and where needed.

These three problem areas are irrevocably interlaced since the processes of manufacture induce new problems that must be solved by personnel training and supply support.

We require training of the operator. A good example; our present Naval Aviators going through the Naval Aviation Cadet Program spend approximately two years in their training for operations at a cost of approximately $75,000. In the maintenance field we have schools throughout the United States for personnel who are trained specifically in these highly technological electronics equipments and power plants. We have a double problem in that training personnel is one thing and retaining the personnel within the military establishment for any period of time after they have reached a minimum of capability is extremely difficult.

Supply support must consider a world-wide picture of logistics support with movement by train, truck, aircraft and ship. When we consider the world-wide operations of the Navy and the other military services, it dwarfs any other distribution function of even the largest of the civilian industry of the United States or even in the world.

The Old and the New

Discussion of generalities on this subject is necessary for a basic understanding of the problem. However, let's take a look at the actual weapon, its peculiarities and evolution.

As an example, I would like to compare the products of a very well known aircraft manufacturer and I don't want it to be misconstrued that this is an endorsement of their product. However, it is a very good example of the rate of growth of the weapon in the aviation industry.

The F6F, a fighter plane built in the year 1942 by the Grumman Aircraft Company, was a composite of all the requirements expressed by the combat aviators in the fleet during the first part of World War II. The Navy realized we were woefully weak in combatting the specialized aircraft flown by the Japanese Navy. This particular aircraft was produced approximately six months after it was first laid down on the drawing boards. It is an example of the production genius and imagination of the engineers when really put to the task. The F6F is a part of the family of the F4F, F6F, F7F, F8F and the F9F which was the first jet aircraft built by Grumman. The F9F series came into service in 1947 after being initiated in 1944. The F9F series has grown into the latest of the series which is the F9F-8 and I would like to draw a comparison between the F9F-8 which was introduced into the fleet approximately a year ago, 1954, and the F6F which was introduced into the fleet about twelve years ago.

It is significant that these two airplanes have approximately the same envelope; length and wing span are about 30′ x 30′. The weight differential is more revealing; the F6F is a 10,000 pound article and in the F9F-8, a 20,000 pound article. The speeds involved, comparison-wise, is 200 knots for the F6F and over 600 knots for the F9F-8. Take-off speeds have increased approximately 25% while the landing speed has increased by about 15%.

Concerning the power plant: the reciprocating engine horsepower is about 1800 horsepower and the turbo-jet produces five to 7000 pounds thrust; a ratio of about one to three, in view of the fact that thrust is not directly relatable to engine horsepower. Temperatures involved in the operation of their power plants are 500° F. in the cylinders, while the operating temperature in the same comparative location, the combustion chamber of the turbo-jet, is about 3000° F. The altitude limits of the two different aircraft are 20,000 ft. for the F6F and in the jet aircraft is over 40,000 ft. Electronics equipments for the F6F in the second World War consisted of three sets of electronics equipments, generally in the category of a radio-receiver-transmitter, a radio altimeter and basic navigation equipment. However, in the jet aircraft we are engrossed in systems of electronics equipments, such as the communications system, navigation system, the gun laying system and the bombing system. A direct and explicit comparison between the F6F and the F9F electronics components is beyond the scope of this discussion.

In the foregoing, we have discussed general differences between the two aircraft and from these differences we can infer a number of things.

The altitude differential between the two aircraft brings into focus the absolute requirement for an efficient, lightweight and completely reliable oxygen system. An inoperative oxygen system can negate the high altitude use of the jet aircraft; a tremendous drain on the combat effectiveness of the type.

All-weather and night combat requirements depend entirely on the flight instruments and combined electronics systems; a requirement which was not met in the aircraft of World War II.

Increased wear and attrition rates are inherent with the high temperatures and large temperature differentials involved in the power plant and aircraft operation, the increased landing speeds and weights, and the number of pilot-aids installed to enable the pilot to master the tremendously increased forces to which he and the aircraft are subjected.

The situation existing in the aviation field reminds me of the quotation, "Necessity is the mother of invention." This simple sentence compounds itself towards infinity as we progress in the aviation world today. Its application to the system of aviation supply support finds a wide open field. Greatly increased sensitivity and reaction to operational needs, coupled with the necessity to stay on the black side of the ledger, are the fundamental problems.

These fundamental problems are being attacked through the use of high speed Electronic Data Processing Machines which will be the next subject of discussion.

REAR ADMIRAL HETTER

The ever-increasing number of items that ASO must have on hand to support the rapid advances of this country's engineering genius has created the need for better and more efficient ways of handling and processing extremely large and unwieldly masses of technical supply data. That is our major problem—*MASS.* To make sure that we have enough of the right parts in the right place at the right time, ASO must accumulate and analyze data that are current and usable on a two billion dollar inventory.

Our customers are gypsies. They buy from us about 500 million dollars worth of parts annually. Eighty-five per cent of these sales are confined to fifteen per cent of the inventory. The remaining items are military insurance items that must constantly be available to support the Military Defense Program.

During the past ten years we have developed a centralized inventory system. Four times each year our activities report to us their stock status. With the conventional EAM machinery, we have been unable to speedily assimilate this information, analyze these data, and project future requirements nearly as well as we want to do. It became more and more apparent that some speedier methods for inventory management must be introduced.

Several years ago, ASO began to explore the possibilities of the "electronic computer" in the supply management of the ASO inventory. Our chronology in the introduction and the use of these electronic machines will now be discussed by Lieutenant Commander Crowley.

Lieutenant Commander Crowley

The PURS System

As early as 1943 Naval Aviation Supply Inventory Managers recognized that one of the major weaknesses in their logistics system was the inability to relate rapidly and reliably the technical and supply characteristics and current assets of thousands of aviation spare parts to the operational programs of the Naval commanders, and, at the same time, be properly considerate of the fiscal restrictions of a peace-time economy. As a result of this situation a system of determining aviation spare parts requirements known as the Program/Usage Replenishment System was evolved. This system is composed of two major computation phases:

PHASE I

Part (*a*) From a large reference file of stock numbers which contains all known technical and supply characteristics of each item of supply, such as the application or applications of the item to an aircraft equipment, engine or airplane, or the procurement lead time, the data needed for the particular type of requirement being calculated are taken. In some cases as many as 200 references are made to each stock number. This reference file has been partly on punched cards and partly on tape for the 701 operation. All of this information (the equivalent of about 20 million punched cards) will eventually be on 702 tape.

Part (*b*) From the usage factors established through statistical analysis the usage factor for each item is taken.

Part (*c*) Past and planned operating schedules of aircraft are calculated and injected into the computations.

The Phase I calculations then reduce to the basic formula:

Operations X Usage X Application = Gross Calculated Requirements for each item as of a given date.

PHASE II

This phase consists in taking all system assets such as on hand, expected receipts from contractors, and anticipated returns to the system through overhaul and repair, which have previously been written on EDPM tape, and applying them to the gross requirements previously calculated. The result is a net requirement or excess for every item at every station, as well as for the entire system.

This system is now employed for calculating net requirements for procurement and distribution for 120,000 line items. Within 90 days it is intended to begin to extend coverage to another 80,000 items and eventually it is expected that we will be able to absorb up to 350,000 line items on present EDPM equipment.

There are two significant aspects surrounding the development of the PURS System:

First: It is a very scientifically devised system of determining requirements, and with a few minor modifications and the availability of more rapid communication equipments, technical supply inventory managers may be able to double their efficiency and more importantly, be able to advise the military commanders on very short notice of the logistical implications of deployment decisions.

Secondly: It has proved to be peculiarly adaptable to EDPM application even though mostly developed prior to the time that EDPM was being seriously considered for this type of work.

Installation of an Electronic Computer

In 1948 it also became patently obvious that existing punched card machine systems were inadequate and cumbersome for the processing of these PURS calculations in a timely manner. Exploratory investigations into computer capability and availability were begun which were to terminate in the decision to install an IBM 701 in the Spring of 1954 to absorb the calculations for as many line items as possible. The 701 was selected at this time for the very good reasons that:

1. It was available on a rental basis and it was yet impossible to determine what the eventual electronic data processing requirement would be at ASO.

2. It had a larger memory or storage capacity than other available hardware.

3. The manufacturers agreed to provide programming on a contract basis to put the 701 in operation.

I might add that it was fully realized that the 701 would have to be replaced by a data processing system which was more flexible and more capable of processing masses of data rapidly rather than performing extensive mathematical calculations.

In July 1953 an organization to coordinate problem definition with contractor programming staff, to guide personnel recruitment and training, and to direct preparation of physical facilities was created. This group was sufficiently trained by February of 1954 to successfully program for budget calculations for Fiscal Year 1955.

By April of 1954 sufficient contract programming was completed to produce the gross requirements calculations. The net requirements were extended on conventional punched card equipment until December of 1954 when programming was completed for the production of net requirements on the 701. Since January 1955, then, we have been producing these calculations for 120,000 line items of material. On 1 November of this year we transferred 701 operations to another location so that the 702 could more quickly assume responsibility for productive work.

The direct benefits of 701 operations to the Aviation Supply System may be stated as follows:

1. The opportunity to work closely with electronic machines has provided empirical experience with computers which we believe is as yet unequalled anywhere in inventory control work.

2. An actual reduction in our stock replenishment cycle of from 15 to 20 days has been effected.

3. Increased operating efficiency has resulted from the discovery and correction of many data errors and logical errors of procedure which had existed in the system.

4. Punched card equipment time in the amount of 12,000 man-hours and 12,000 machine hours per quarter was freed to be applied toward preparing more data for eventual electronic processing.

5. Programming errors of commission and omission discovered in the 701 programming have been used to improve 702 programming efforts. We expect 702 programs to be at least twice as efficient as the original 701 programs.

Program for an Improved Computer

In January 1954 programming for the 702 was begun. Since the 702 had the capacity to do a more efficient job for us than the 701, it was only logical to expand the scope of the job as much as possible. Therefore, the 702 job has been expanded to include:

1. Calculation of the monthly deployment schedules used in requirements determination for most of our 450,000 items. This was formerly a manual computation.
2. The establishment and maintenance of the entire technical reference file on magnetic tape. This was formerly maintained on punched cards.
3. The inclusion of Life-of-Type procurement calculations during regular processing. This factor was formerly applied by adjusting the machine computations manually.
4. Use of many techniques of programming to check possible machine, programmer or data errors. These include procedures at certain intervals, file and tape identification, and many others.
5. Expandability features to eventually assume these calculations on from 300,000 to 400,000 line items.
6. Expandability to produce catalogs rapidly and accurately.
7. Expandability to obtain financial management by-product information such as line item budgets, stratification and disposal reviews.

The difference in scope of the 701 and 702 operations may best be described by the following:

701 has 64 active machine runs and 60,000 instructions.

702 has 93 machine runs and 117,000 instructions.

Management Problems and Recommendations

Future innovations in supply management which can improve the power of electronic equipment in a centralized system are transaction reporting for high cost and medium cost items, and automatic redistribution of medium and low cost items. These system improvements must be accompanied by improvements in communicating stock status information rapidly and accurately to the control point.

EDPM operations have been proved by ASO to be flexible in meeting catastrophe situations. At various times we have transferred 701 operations successfully to 3 different remote sites. With duplicate tape files of information and machine capacity, operations can be transferred on very short notice.

The principal problems of successful EDPM introduction into an organization still seem to lie in the area of management understanding and appreciation of the potentialities and requirements to exploit these potentialities. The most efficient EDPM installation will be the one where:

1. The entire system to be mechanized is examined as a totality.

2. Procedures and management policies are altered to take full advantage of EDPM.

3. The organization responsible for EDPM implementation has authority to obtain resolution of problems in situations where several departments or divisions are concerned.

The ASO organization responsible for EDPM utilization is the Electronic Processing Branch of the Integrated Data Processing Division. The current staff consists of 33 of which 16 are programmers and coders and 17 are EDPM operators.

Working programmers were recruited primarily from within ASO and some supervisory programmers were hired from outside. Selection was by aptitude test and interview. This method has proved very successful at ASO. Operators were recruited from Navy machine accountants and were trained essentially the same as the programmers and coders. In this area day-to-day experience had to be heavily relied on.

The difficulties in obtaining completely valid input data, completely defined problems and integrated system planning are still with us. Once you have committed part of your system to EDPM, that group must be consulted on the possible ramifications and costs of every future system change contemplated.

The problems of inexperience and lack of recorded experience in this field have doubtlessly resulted in longer programming time than might otherwise be necessary. Since it takes about a year to make a good programmer, we can expect faster programming and coding in future applications.

Machine time scheduling and timing have been particular problems in determining the eventual loading of our 702. We know we must develop about 5000 tape reels of information during the quarter, but the timing is determined by the type and density of the data being processed. Since this changes from quarter to quarter we will not know how much excess time is available, if any, until we have run a quarterly cycle of work. Also 701 experience has shown that we were never able to average better than 50% good production because of machine maintenance time of 20%, machine error of 10%, and data error 20% over a 19 months period.

Indications are thus far that 702 time will be initially divided into 60% production, 20% maintenance, 15% data error and 5% machine error. With experience and some program modification we anticipate eventually 75% productive time.

One fact emerges as a certainty in the relationship of people to office automation. The demands on all people involved, from top management on down to the junior machine operator, in thinking, planning, training, will be beyond that ever before existing if maximum economical utilization of EDPM is the objective.

Rear Admiral Hetter

Summary

Automation, or the use of electronic machinery in inventory management is not necessarily the "open sesame" to perfect inventory control. However, it has been ASO experience that the proper use of Electronic Data Processing Machines has materially increased the effectiveness and the efficiency of supply support. One point which I want to emphasize is that the machines in this automation age are no better than the capability of the personnel who introduce or "program" the information into the machine. Electronic Data Processing Machines do not eliminate the necessity for human judgment. However, by speedily processing the mass of routine decisions, they free our technicians for concentrating on the "unusual" or exceptions which always exist in any system. The electronic data processing machines are merely a slave of management, and like any slave will reflect the personality and the capabilities of the master. ASO is continuing to explore and refine the use of automation in supply management.

TREASURY DEPARTMENT CHECK RECONCILIATION PROJECT

GEORGE F. STICKNEY

Background

The joint accounting improvement program was instituted by the Secretary of the Treasury, the Comptroller General of the United States, and the Director of the Bureau of the Budget in December 1947. The program is a government-wide cooperative effort to make government accounting of maximum usefulness. Its purpose is to provide a basis for better management in the executive branch; give the Congress better information for acting upon appropriations and other legislation; and to give the public a clearer picture of the financial condition and operations of the Federal Government. This cooperative action led to the passage by the Congress of the Budget and Accounting Procedures Act of 1950, which incorporated the basic aspects of the program in permanent legislation and placed, for the first time, specific responsibilities for accounting, auditing and financial reporting in the Federal Government.

From the inception of the joint accounting improvement program, one of the major fields of work has dealt with simplifying and improving procedures and operations relating to government disbursements and collections. A major segment in this area concerns the issuance, payment and reconciliation of more than 350 million checks drawn annually on the Treasurer of the United States by more than 2,000 government disbursing officers.

While many improvements were made in the disbursements and collections area during the first few years of the program, it became apparent at an early date that there were real potentials for savings by integrating the check reconciliation operations presently performed by the General Accounting Office, as a function of external audit, with the payment operations of the Treasurer of the United States. This contemplated a reorganization of the payment function of the Office of the Treasurer of the United States in accordance with the following principles:

1. It should be a function of accounting and internal control on the part of the Treasury Department, which is charged with

disbursement and custody of the public funds, to effect a proof of checks paid in relation to the checks which are issued.

2. The General Accounting Office, from the standpoint of its responsibilities in connection with accounting systems and independent audit, and the Treasury Department, from the standpoint of its operating responsibilities, should be in complete agreement on the procedures necessary to accomplish such proof of checks paid and the incorporation of these procedures into the accounting system of the Treasury Department as an integral part thereof.

3. In the light of a revised system of accounting and internal control by the Treasury Department, it should be possible to eliminate the present detailed reconciliation of checking accounts of disbursing officers as a function of independent audit, substituting therefor reliance upon the effectiveness of internal control as reviewed in actual operation and the furnishing of such data as may be required for comprehensive audit purposes.

Two plans were developed for integrating the check payment and reconciliation functions. One plan was based on the use of check-issue cards (duplicates of checks issued) to be produced by the disbursing officers and furnished the Treasury for matching with paid checks as an integral part of the paying operation. The second plan involved the use of "block" controls representing summary totals of the amounts of each 1,000 block of checks issued to be reported to the Treasury by disbursing officers and used as controls over the amount of payments.

In order to develop the full potential of each plan, two experiments were initiated. One was conducted in the Federal Reserve Bank of St. Louis during 1950, utilizing check issue-cards for the Army allowance and allotment checks. The second experiment, conducted in Washington, D. C., utilized "block" controls for checks issued by the Treasury disbursing officer for Civil Service Retirement payments. Valuable experience was gained through these experiments and it was the consensus that the results justified further consideration of the desirability of integrating the check payment and reconciliation function. (It is noteworthy to observe that during this period of experimentation, many individual procedural areas were explored with resulting improvements to the existing systems.)

A major consideration in reorganization of procedures was the question of what type of mechanical equipment would provide the most efficient and economical system. Before making any recommendations, it was decided to explore the possibility of utilizing electronic equipment to perform these functions.

The Project

In June 1953, the Secretary of the Treasury, the Comptroller General of the United States and the Director of the Bureau of the Budget appointed a joint committee to conduct a comprehensive study of the possible use of electronic data processing equipment for the payment and reconciliation of government checks.

The joint committee's assignment and work program were developed as follows:

Scope of Assignment

1. Determine whether the use of electronic data processing equipment for an integrated payment and reconciliation function, including related check claim processes, was practicable;
2. Develop the proposed system, in detail;
3. Recommend the manufacturer whose equipment it considered best suited for the system; and
4. Present for consideration the proposed course of action, including a time-table and financial considerations.

Work Program

1. Develop in detail the present requirements for the clearance, payment and reconciliation of government checks drawn on the Treasurer of the United States;
2. Present to manufacturers of electronic equipment specifications for an integrated plan of operations, inviting manufacturers to submit proposals contemplating the use of available equipment or equipment under development;
3. Evaluate the various proposals submitted by manufacturers;
4. Develop a plan for implementing the committee's recommendations, including a detailed operating procedure, budgetary considerations, and a time-table for conversion; and
5. Determine the effect of the proposed changes in the organizational structure, financing and operation of the disbursing agencies, the Audit Division of the General Accounting Office, the Check Payment Division of the Office of the Treasurer of the United States, and the Federal Reserve Banks and Branches.

The Survey

The committee's general approach in carrying out its work program is described briefly in the following paragraphs.

Development of requirements for the clearance, payment and reconciliation of Treasury checks under present procedure. A detailed analysis was made of present procedures for the issuance, clearance, payment and reconciliation of Treasury checks as well as the procedures for handling check claims as a basis for developing specifications for performing these functions.

Development of a plan for utilizing electronic equipment to perform the payment and reconciliation of Treasury checks. Based on analysis of present procedures and the experience gained during the period of experimentation referred to above, a proposed plan was developed for utilizing electronic equipment to integrate the payment and reconciliation functions on a centralized basis. The plan was developed in some detail including step-by-step procedure, all of which was outlined in chart form. At this time, a review was made of the present cost for paying and reconciling checks, and sufficient cost analysis was made of the proposed plan to conclude generally that electronic equipment had very definite promise and should be fully explored.

Presentation of the plan to manufacturers of electronic equipment. In the fall of 1953, the Fiscal Assistant Secretary of the Treasury addressed a letter to fifteen manufacturers of electronic equipment, acquainting them with the project and inviting them, if they desired, to submit firm proposals by December 31, 1953, for an integrated system of check payment and reconciliation utilizing equipment available or under development at that time. They were requested to give consideration to the program from the standpoint of either centralized or decentralized operations.

In September, 1953, a two-day symposium was held and attended by representatives of interested manufacturers. During this meeting, a detailed discussion was had with respect to the entire program. Following the symposium, the committee held individual meetings with those manufacturers' representatives requesting further discussions.

Working relationship with manufacturers. The committee worked very closely with various manufacturers for over a year. During the course of this cooperative work, many techniques were developed for improving the various proposals. This information was made available to each manufacturer. Based on discussions and meetings with the various manufacturers' representatives, it was decided to extend the time for submission of proposals to January 25, 1954, with the understanding that manufacturers might present amendments to their proposals at a later date if the committee had not completed its study and evaluation of the various proposals submitted.

Working relationship with Federal Reserve System. Early in the spring of 1954, the committee met with representatives of the Federal Reserve System to acquaint them with the study and to review in general terms the principles of the new plan. Discussion was held on the procedural changes and cost factors which would affect Federal Reserve Banks.

One of the principal factors which was developed for consideration and further analysis was the proposition of issuing a card check prepunched by the manufacturer with the issuing officer's account number and check serial number to be used in lieu of the present 25 million paper checks issued annually. Under such a procedure, the issuing officer would not punch the amount into the checks. More specifically, such a plan contemplated that the issuing officer would continue to prepare checks in the same manner as heretofore and that the amount of such checks could be punched by the Federal Reserve Banks as a part of their normal clearance and collection process. The development of this proposition enabled the committee to consider the practicability of electronic equipment for *all* checks drawn on the Treasurer of the United States.

Establishment of criteria. The committee, with technical advice from representatives of the National Bureau of Standards and the National Security Agency, established the following principal criteria to assist them in determining the manufacturer whose equipment it considered best suited for an integrated system for payment and reconciliation of government checks:

(1) Reliability and efficiency of equipment
(2) Cost—purchase versus rental
(3) Direct labor requirements
(4) Cost of supplies (tape, etc.)
(5) Maintenance and service requirements
(6) Specifications for installation (space, electricity, air conditioning, etc.)

Evaluation of manufacturers' proposals. Proposals were received from five manufacturers and a detailed analysis was made of each. During the course of analyzing these proposals, numerous meetings were held with the manufacturers' representatives. As a result of this work, three proposals were amended to take advantage of significant savings in time, controls, and processing techniques. These three proposals were practically identical so far as principles of procedure were concerned.

It is significant to note that all manufacturers finally proposed a centralized operation. It was determined that decentralization of any of the functions under the proposed plan would be prohibitive from a cost standpoint.

One of the three acceptable proposals had to be disregarded inasmuch as the equipment would not be available for at least one year subsequent to the availability of the equipment of the other two manufacturers.

Tests were conducted on the equipment proposed by the two remaining manufacturers, utilizing paid checks in the file of the General Accounting Office. These tests were conclusive that procedures could be designed to perform an efficient and economical integrated payment and reconciliation function, utilizing electronic techniques.

Estimated savings. In order to arrive at a sound basis for estimated costs, a step-by-step procedure under the new plan was developed. Each step was tested on electronic equipment and was timed to determine how much equipment and how many personnel would be required to operate the new system.

Based on this detailed study, the committee estimated that following one year of conversion from present procedures to the new plan of operations recurring annual savings of $1.7 million in appropriated funds would be realized. This is in addition to over one-half million dollars' annual savings in operations of the Federal Reserve Banks, 90 percent of which, under present policy, will inure to the benefit of the Treasury. Practically all of the savings in appropriated funds will occur in the General Accounting Office (estimated savings to Treasury is $25,000 annually) representing the present cost for performing a separate reconciliation of over 300 million checks annually. The present force of about 755 employees in the Treasury and General Accounting Office will be reduced to about 270 employees under the new plan which, it is estimated, will be completely installed by July 1, 1957.

The committee made eight recommendations, all of which were closely related. The following, which is quoted from the Committee's Final Report, summarizes the conclusions:

> "*Recommendation No. 1:* The check payment function of the Treasurer of the United States should be reorganized under an electronic data processing system to provide (a) proof of checks paid by comparison with checks issued, and (b) development of the necessary data, including outstanding checks, for the reconciliation of disbursing officers' checking accounts.
>
> "*Comment:* Procedures have been designed and tested to account for check payments in direct relation to amounts of checks issued, as a feature of internal control. These procedures provide for (1) earlier disclosure of certain discrepancies for which either disbursing officers or the Treasurer of the United States are accountable, and (2) development of outstanding check data, both being an integral part of the function of paying and accounting for government checks. This makes it possible to eliminate the present separate reconciliation operation in the General Accounting Office, without impairing the effectiveness of the audit and settlement of government disbursing officers' accounts."

Equipment is scheduled for delivery to the Treasury Department in early 1956. It is estimated that the changeover will require about twelve months. The new system should be in full operation by June 1957.

PART IV

SUGGESTIONS FOR MANAGEMENT

Editors' Note

In this section much actual experience is reflected in suggestions for management concerning the key problems which are faced by any organization. When one brings together distillation of the experience of the Census Bureau, Metropolitan Life, U. S. Steel and the Department of Defense, he has tapped most significant available sources. Other authors in the section speak both from personal experience and from study of other installations.

A debt is owed to these contributors who have been candid about their own problems in order that others may profit. The editors are deeply impressed by the thoughtful and sincere effort of the contributors to be helpful to others in the field.

COST CONSIDERATIONS

GEORGE P. BUSH

Cost considerations in relation to electronic computers have immediate significance to any executive because his two principal goals are either cost reduction or a better product. This applies equally in business as in the Government, in the latter case "product" being interpreted to mean "service." In the computer field cost considerations are based upon complex situations and problems, decisions upon which are often of far reaching consequence. Much also depends upon the configuration of the organization at the time first consideration is given to the possible use of EDPS.

Having the above in mind we shall consider some of the costs which may be encountered, endeavoring to discuss them in a sequence from inception of probable need through the following order:

Considering the needs of the organization.
Making choices between the alternatives.
Procurement, installation, and operation costs.
Personnel costs.
Other costs.

Obviously, it is not possible to keep cost considerations as neatly categorized as this. For example, personnel costs may be reflected in the first three topics.

Considering the Needs of the Organization

How much will it cost us to find out if we need electronic data processing machinery? Management, being aware of the progress being made by computer manufacturers in connection with the development of equipment for data processing, will probably get together and set up an informal committee to report back with recommendations. Such a committee probably would come from the finance or comptroller's area. The work would not involve much cost because the additional responsibility is over and above the members' normal operating functions. Costs do soon come into the picture as the members of this committee make visits to various computer manufacturers' plants to acquaint themselves with the types of equipment being manufactured, or if they are sent to a manufacturer's school, or if they are sent to observe some applications, either nearby or afar, or to society meetings, or to institutes concerned with computers.

A new development arises when the informal committee makes studies of various operations within the organization to determine roughly which areas would benefit from the proposed installation of the machines. It is at this point that some consideration should be given to the budgeting of funds for electronic data processing, because if the committee report is received favorably, substantial costs begin. The committee will probably recommend the setting up of a full time detailed feasibility study group [1] to investigate the proposed use of EDPS in particular areas of the company's operations. This group should look not only at present operating practices, but consider modification of practices, procedures, and operations so as to obtain the greatest benefit from the proposed installation. Of course they will consider the greater accuracy and timeliness of all data in addition to the reduction of clerical costs, so that management can manage better. The cost of making such a study may range from $25,000 to $250,000[2] in tangible costs and there may be many unseen intangibles as the time of regularly occupied employees is encroached upon in various ways. If this investment of fifty, eighty or a hundred thousand dollars seems large—it is only a harbinger of things to come.

If the committee recommended against the purchase or rental of EDPS, then the money for the survey might be considered to be "wasted." But another way of viewing it is to consider that the committee developed a negative fact and thus saved the company from making an unwise and expensive investment in computing machinery at that time. On the other hand, if the committee advocated pursuit of EDPS, new costs are on the horizon in the form of more detailed studies of the business by the full time committee. These studies would involve statistics showing the volume of data transactions, time cycles, flow charts, organization and methods studies, communications, all of the elements of a thorough business study, including alternative methods of conducting the business or parts of the business. This might well take another $50,000 or more in tangible costs and might cover

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[1]For an example of a group engaged upon a limited application, see the Rockwell team's picture in *Dun's Review and Modern Industry,* October 1955, p. 59.

[2]*Ibid.*, p. 98.

a period of a year.[3] Outside consultants may be included in the committee at this point and provision should be made for their fees.

The committee may have recommended the outright purchase of machinery, if it is for sale, or the alternative of rental toward purchase, or rental or lease, or turning the whole program over to an institution such as Battelle or to a central commercial computing center. Facing these alternatives, it is prudent at this point to consult with the salesmen of the major computing machinery manufacturers. One now knows enough about the business, not to be "taken" by glib sales talk. Frankly acquaint the manufacturers with the problem and ask them to make a study (at no cost to you, of course). This may take some time as the functional characteristics of the business are weighed in relation to the operations which the machinery may be called upon to perform.

Making Choices Between the Alternatives

In considering the relative merits of competitive bids one should constantly bear in mind that any significant savings in costs will be confined to areas of *routine data handling.*[4] It is also important to recognize that for the most part companies who have invested in computers have found that they paid for themselves, or are on the way to paying for themselves.[5] In going to the manufacturers, one avails himself of the latest developments, the presumption being that the committee had already available to it such information as the booklet put out by Haskins

[3]Richard D. Dotts, in "Making a Decision For a Large-Scale Data Processor," at the American Management Association Seminar, April 22, 1955, reported a study that ". . . took nearly a year and just under 10,000 man-hours to complete . . .", p. 6.

[4]Consider at this point the admonition of Schmidt and Bosak: ". . . Although the machines will eliminate the need for much tedious, routine clerical operation, humans are still required to prepare and present the original data, prepare detailed instructions for the computers, and analyze the final results. The computer is only a tool which makes it more practical to use a mathematical approach to management problems . . ." C. W. Schmidt and R. Bosak in *Electronic Data Processing in Industry.* New York: American Management Association, 1955, p. 214.

[5]Consider for example: ". . . the machines have become capable of economic and efficient application to the huge paperwork activities of the federal government . . ." *Report of the Electronic Data-Processing Machines Subgroup, Report of the Business Machines Group, To The Task Force on Paperwork Management, Commission on Organization of the Executive Branch of the Government,* October 15, 1954, p. 1.

and Sells,[6] the Appendix to which describes the characteristics of fourteen systems, and the comparative data prepared by John M. Carroll,[7] which appeared in *Electronics* for June 1955 in which the characteristics of 38 systems, their costs, performance characteristics, storage devices or memories were tabulated.

EDPS prices range from $50,000 to more than a million dollars, depending upon speed of operation, memory capacity, and input-output speeds.[8] Rentals may range to $20,000 per month or more. It helps at this stage to soften the impact upon management by stating that the machines do not seem to wear out, but they do require some maintenance, and they do become absolescent, especially in such a rapidly moving field as this one.

Making choices between the many alternatives requires "close harmony" between the company's study group or committee and the manufacturers' representatives. The latter must learn many of the fine points of the company's business in order to properly specify that equipment which will perform best when installed. Costs begin to take shape as detailed proposals covering the equipment are prepared. It pays at this point to insist that the competing manufacturers "lay it on the line" in such language that comparison can be made by functions to be performed in terms of the cost for that function. Due to differences in electronic functioning and circuitry this may be difficult to achieve, but it does aid in enabling the committee and the management to be in the best position to judge the equipment of each manufacturer. An elimination process then ensues until costs and promised delivery dates narrow the choice to but one supplier. Of course there may be many variants to this rather simplified statement of procedure. As a matter of fact the process of making choices is infinitely varied and may engender much backing and filling. As stated in the Society of Actuaries report[9] dated June 1955:

". . . To make a fully objective appraisal, the potential user

[6]Haskins and Sells, *Data Processing by Electronics*, privately published, May 1955, pp. 65-113.

[7]John M. Carroll, "Electronic Computers for the Business Man," in *Electronics*, June 1955, pp. 122-131.

[8]An unidentified case reads in part: ". . . I spent some time with an executive of a large company a few weeks ago. He's spent five years studying and planning this thing and installing it, and it's cost them a half million dollars to get to the point where they're ready to operate it. That's just preparatory costs. . ." *Dun's Review and Modern Industry*, October 1955, p. 78.

[9]Society of Actuaries, *Current Status of Magnetic Tape as a Recording and Data Processing Medium*, Report of the Committee on New Recording Means and Computing Devices, privately printed, June 1955, p. 18.

must design the best procedure he can for operation with Company A's equipment, then develop a different procedure best suited for the operation with Company B's equipment, and so on, and then compare the results as to cost. Considering the number of suppliers now offering equipment of this kind, all apparently capable of doing approximately the same job in different ways, a considerable effort is involved in deciding which machinery is best suited. . ."

Some plain talk in this area is furnished by Robert W. Burgess in the Congressional *Hearings, Automation and Technological Change,*[10] especially the interrogations.

There are some considerations of cost which should be made concurrently while considering alternatives. The cost of a computation is related to the use of the most suitable computer to the problem at hand. This implies that there might well be a variety of computers at hand, or that certain problems be farmed out to save costs. Furthermore, in computing the capacity of a computer, costs can be reduced by giving due consideration to its maximum load in terms of the maximum frequency per time period. In some instances costs would be trimmed by buying machinery with less capacity and farming out the peaks to a commercial central computing laboratory. Another consideration is that where there is enough computational work to be done to justify the purchase of a computer, costs may be reduced by farming out certain problems that may be more cheaply done extra-murally. This may concern the factor of time, or lead time, during which one or more of the elements of the computational groupment is under procurement and/or installation.[11, 12]

Some general conclusions related to computer cost considerations in the utility field have been stated succinctly by J. W. Balet.[13]

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10 U. S. Congress, Joint Committee on the Economic Report, Subcommittee on Economic Stabilization. *Hearings, Automation and Technological Change,* October 14-28, 1955. Washington: Government Printing Office, 1955, pp. 86-96.

11 For considerations, including costs of EDPS in the smaller office see Ralph W. Fairbanks, "Integrated Data Processing for the Smaller Office" in *Office Management,* June and July 1954, pp. 18-19, 78 ff. and 33, 78 ff. respectively.

12 An example of a detailed analysis of some cost considerations is contained in Part III "Estimated Savings and Budgetary Requirements" in *Electronic Processing United States Treasury Checks,* A Report of the Joint Government Committee Representing the Bureau of the Budget, The General Accounting Office and the U. S. Treasury Department, Under the Joint Accounting Improvement Program, September 1, 1955, pp. 24-33.

13 J. W. Balet, "General Accounting in a Public Utility," in *Electronic Data*

Procurement, Installation and Operating Costs

When the decision to procure has been made, it should be remembered that there are certain costs involved in this area: contract writing, legal, inspection, payment and guarantees, to mention a few. Also there may be some losses as one shifts over from a large card system to an electronic system. There may be a loss in terminating leases. Decisions need be made to hold some equipment for standby, or to sell it, etc.

A next cost to be considered is that of the site upon which to install the equipment. Maybe the site is "free" in that the space is already owned, but questions of both adjacency and remoteness enter the picture when security and joint use are factors. The following topics may also arise: high cost urban versus suburban versus country-side sites. Then comes the cost of a building, either a new one, a renovated one, or an enlarged one. In the latter two instances there are for consideration the alteration costs, such as for walls, air ducts, water pipes, power circuits, gas pipes, heating, painting, flooring and many other incidentals. Some idea of the costs involved can be gained from Carroll's tabulation[14] which states that space requirements range from six to 1250 square feet. However, a large computer with its supporting equipment may require 4,000 square feet of floor space, the equivalent of a building 50 x 80 feet, which might well cost $80,000 plus. Savings in space up to 50% are claimed for the transistorized computers. Aside from the IBM 608, much of this is for the future, but such a basic saving in costs should be given consideration.

Turning next to power, we note from Carroll[15] that the power requirements range from 1 kw to 125 KVA depending upon size. As much as 90% saving is claimed for the transistorized equipment. Such a possible saving deserves most careful consideration. Large amounts of power usually call for a special power transformer to be installed, heavier cables, switching equipment, fire protection, and related items. Air conditioning is required with most EDPS. Sometimes this has a variant in water cooling. Whichever or both, they require power, a large size one requiring 40-ton capacity. Add this factor when determining the over-all power demand. The power company will usually assume the

Processing in Industry, New York: American Management Association, 1955, pp. 204-205.

[14]John M. Carroll, *ibid.,* p. 125.

[15]*Ibid.,* p. 125.

costs down to the building's exterior conduit, but not always if the building is remote. Interior wiring costs may total $3,000 for a large size computer. Air conditioning may be modified by the factors of siting or climate or transistorizing, as transistors do not need the cooling which banks of vacuum tubes demand.

Another cost is involved in the additional communications facilities provided in an effort to speed raw data or processed data to the central data computing center and to the machine, with the least possible time lag. Also for consideration is the continuation of an adequate communication process whereby the results of the computation are transmitted to management, either centralized[16] or dispersed. There are so many variants that no estimate of costs can be given.

Let us now assume that we are ready to move in the equipment. Much depends upon the contract specifications. They should be specific as to the F.O.B. point, insurance en route, cartage and drayage, crane service, labor crews, breakage, time delays, responsibility for the total job. A case has been reported of a large computer which cost $220,000 to prepare the site,[17] move in the equipment and install heavier electrical wiring.

After the installation, the next step is to get the machinery into operation. It will need debugging, so as to isolate and remove all malfunctions. This may take as much as two weeks. A next care is to see that sufficient spare parts are available, just in case. Judgment is needed so as to have sufficient spares to avoid costly shutdowns, yet not to have too large an investment in spares. Some spares deteriorate while in storage, while others become obsolescent. Sometimes the cost can be cut by a pooling-of-spares agreement with other users of similar machinery in the vicinity, if any. Since certain spare parts are costly, such an arrangement is highly desirable. Supplies of various kinds should be kept on hand: tapes, paper, carbons, vacuum tubes, etc., for all items which are consumed in the course of operations. Lumping together the amortization of the spares and the purchase of supplies, we can visualize costs for a large size computer that approach $1,000 per month.

Now let us prepare some problems for our machine to go to

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[16]The factors concerned with centralized and decentralized management are discussed by Robert M. Smith, "Decentralized Management Not Threatened by Data Processors AMA Told," in *Office Management*, April and May 1955, pages 18-21, 34 ff. and 26-29, 34 ff. respectively.

[17]Dotts, *ibid.*, p. 6, also reports $85,000 for preparing the site at Pacific Mutual Life Insurance Company.

work on. This brings us face-to-face with some decision-making on costs. First of all there are costs involved in systems analysis and programming. It has been said that the cost of computer planning and program setup approximate the initial cost of the computer equipment. This is startling. Estimates of the cost of preparing machine instructions may vary from $1.00 to $10.00 per instruction word, but this latter term may be the equivalent of several words in English. Costs of preparation of a single problem for use by digital computers may involve the services of experienced persons to the extent of 5 to 10 man-years of effort. The costs for a single problem are said to have been $100,000. A more usual cost for a typical problem, however, is in the range from $1,000 to $10,000. It should be recalled that many problems, once prepared, can be reused, or at least parts thereof reused. This is where a problem library can save on costs.

The costs of problem preparation may sometimes be lowered by using a cheaper, more inefficient method because of lesser coding costs, but care must be exercised to see that all the factors bearing upon the lower cost have been considered. Another possible saving may be effected when certain problems are solved on a fast machine with slow input—problems which have a large amount of computing per unit input and output. If convenient, such problems might well be farmed out.

The cost of problem preparation may sometimes be reduced by calling upon the experienced staff of a commercial central computing laboratory to assist with intricate problems, which they may have helped solve for a previous client. Sometimes problems get "hung up" in the machines and must needs be rescued, all of which takes time and costs money.

Proper problem preparation should be eyed in terms of costs at all times, primarily because the cost-per-hour of useful computation is the total cost of operating the computer for a year, divided by the number of hours of useful computing performed during the year. Thus, costs will be high when the computer is not in use 24 hours per day (less maintenance time) all year; or when its problems are not formulated so that it is operating at its maximum efficiency each hour.

Personnel Costs

The excellent chapter[18] by Robert B. Curry on "Preparing Employees for the Changeover" gives management many hints

[18]Chapter 13, herein.

as to what to expect in terms of personnel costs. There are certain costs that deserve emphasis here. The first one concerns the increased executive attention that invariably is a result of EDPS. Thus, costs can be expected to increase in the planning function area as either additions to, or replacement of, men are made. The introduction of EDPS places a premium on management skill at the planning level and this truism is found to apply at all the levels where planning takes place.

In a similar situation is business management skill, the costs of which can be expected to increase as men of increased talent are employed to cope with the more effective use of business information made available by EDPS. Some companies report the training of their own best managers. Coming now to a lower level in the company, to those engaged in the computational function, the pay rate should be that which is needed to hold such persons as are likely to be coaxed away. One might as well meet the issue without too much regard for past structured pay policies.

Training costs vary from one situation to another, some companies reporting that on-the-job training is much to be preferred for programmers, computer operators and procedures men. It costs less and the trainees know more about the business itself. Some training cost would be involved in setting up a modest library of books and periodicals.

While many companies and the unions advocate retention and retraining of persons who have been displaced by EDPS, it must be faced that in the short run this appears as an added cost. In the long run it may be a good investment. EDPS may bring labor troubles, which should be cushioned. Brace for it. Try to work it out with the unions, if there are such. Try to avoid the costs that are incident to low morale, absenteeism, slow downs, sabotage and strikes. Money should be budgeted for good employee relations so as to avoid most of this grief.

Another related matter is turnover. It costs money to have your good help hired away competitively. Sometimes a company may fail to realize that when a man leaves an investment that ranges from $200 to $75,000 is lost.

Other Costs

Under this heading are grouped certain costs that do not fit neatly into the previous categories.

Due to the tremendous capacity of a large scale computer, it is usually necessary to concentrate all of the work of one kind in one location to justify the cost and effort and secure the maximum results. This centralization of activities may bring with it varying costs depending upon the nature of the business. Related to centralization is the matter of communications. Low cost communication devices are needed to handle the large volume of data rapidly to the data processing center. Instead of short messages at slow speeds the system should handle lengthy messages at high speeds. Moreover, to reduce costs the message should be in a form which is immediately reusable in conversion to a machine sensible form.

Some accessories to the EDPS are needed such as: filing equipment with perhaps provision for classified materials, having in mind the accessibility of data before use, for possible rerun, and after present use appears to be over; data reduction facilities; and supplementary desk computation facilities. The costs are greatly variable depending upon the nature of the program. In the event that the preparation of reports is a function of the computing effort, provision should be made for these costs.

Obsolescence is a considerable factor in a field which is so dynamic and fluid. Greater speed, greater accuracy, greater reliability and lesser operating costs are continually affecting changes in design. Newer machines are equipped with greater memory capacity. Some machines with advanced techniques are tailored to more specialized tasks. In such a milieu the costs of prospective new equipment should be budgeted well in advance.

Standby equipment costs should receive some consideration, particularly in a cold war situation: duplicate tapes, raw data or semi-processed data. Also consider the possible costs of transporting classified data elsewhere for computation: express, courier, messenger, Brink's service.

Classified information may be an added expense, even though EDPS has no brain or consciousness. When "cleared" employees bring the classified data, operate the machine exclusively, then take the product and their basic data away with them, there is little added expense. Otherwise, such items as barred windows, gates, guards, registration, and incidental pertinent personnel costs must be considered.

Last, but not least, is the cost of public relations. If there is any doubt that this is a problem, read the Congressional *Hear-*

ings,[19] *Automation and Technological Change.* The concept of automation in its several forms has been exaggerated, bally-hooed, and lied about to such an extent that there are both real and fancied misgivings among many people. This needs fixing. Fixing entails costs. Costs can be reduced by an intelligent management by shoring up the integrity of the organization so that its morale is high, and stays high when the subject of proposed EDPS is bandied about. Sell the facts of EDPS internally, as Robert Curry[20] has suggested. Do your own part in keeping down the exaggerations, the bally-hoo, and the lies, thus sweetening the external public relations. All of this takes effort and money.

Summary

This chapter has presented some of the considerations which management should give to the costs of EDPS. The treatment is indicative, rather than exhaustive. Many of these costs are quite familiar to management, but others not. In this connection:

1. See if your company can use EDPS competitively. The cost may be high.
2. If determined positively, take a healthy interest in the matter personally and see that all in management follow suit.[21] This cost may not be high.
3. Hire talent, real talent, so that you may take full advantage of the increased potential which EDPS can bring. This cost may be high.
4. Give your employees the full treatment of the golden rule. This cost is relatively low.
5. In a competitive world, can we afford not to make a bold investment for increased efficiency of organizational effort? Consider a quote from Commander Goodwin,[22] U.S.N.: ". . . The Soviets have apparently surpassed the United States in the very important science of applied mathematics. Much of this success seems to have been made possible through the use of computers to solve complex problems. . . ."

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[19] U. S. Congress, *ibid.*

[20] Chapter 13, herein.

[21] This aspect is stressed by M. L. Hurni, "Must Management Change for Automation?", in *Advanced Management*, May 1954, pp. 25-28.

[22] Harold B. Goodwin, Commander, U. S. Navy, *Adaptability of Electronic Computers to Problems Affecting Economic Mobilization.* M54-38. Washington: Industrial College of the Armed Forces, May 4, 1954. Processed. p. 119.

PROCEDURAL CHANGES FOR ELECTRONIC SYSTEMS

JAMES T. SCOTT

For years, efficiency experts, systems men, procedures men, and now in the Age of Electronics, mathematicians, computer analysts, engineers and operations researchers have faced the problems of attempting to effect procedural changes. The literature of management on procedures and systems analysis is extensive. The profession of management consultation has largely developed from services in this field. We should all realize that the endeavor to effect procedural changes is quite difficult and there is no sure-fire or short cut way to accomplish it.

In many ways the problems of procedural change in the Age of Electronics are no different than they were in the pre-electronic era. There are the problems of status quo thinking at all levels. There is resistance to the procedures analyst who is still often viewed as the "efficiency man," who has had so much unfavorable publicity. In many instances there is a difficult problem to provide convincing evidence that procedural changes will result in improvements. And ever-present is the problem of the operational expertness of the staff systems analyst which takes the form of difficulties of communication and mutual understanding.

However, in other ways procedural changes for electronic systems pose new kinds of problems, or, at least, some of the old problems take on a higher degree of importance and difficulty. The nature of the current problems may be best illustrated by examples. Following is a case illustration in which I participated.

The company involved was a large steel producing company which had conducted an extensive study and analysis of present equipment and applications. The equipment was proven in before actual purchase by trial runs on the manufacturer's machines.

In the current illustration a study was undertaken to determine a linear programming model for a steel producing mill. Since the technique of linear programming had received considerable attention for application in the field of production planning and scheduling, it was felt that it might be useful in scheduling steel mill production effectively.

The complex problem that confronts steel men is that they not only have to cope with a maze of machines and processes in the manufacture of their products, but have the additional responsibility of producing according to customer specifications. Therefore, a unit of production, though quality perfect for one customer, may not fulfill the requirements of another. This necessitates many alterations in the manufacturing process.

Another complexity of steel producing plants is that they may integrate their various processing operations. For example, to produce cold roll steel it is necessary to employ a cycle of six steps:

1. All the raw material must be cleaned.
2. It is then placed on a rolling mill.
3. The annealing process.
4. The slitting process.
5. The pinch rolling process.
6. Final inspection.

However, these processes may not be performed in the same sequence. In some instances, for example, we may slit before we roll.

This makes it possible to integrate the processing of two or more batches for certain steps, even though the total processing formula is different. Since there are several pieces of equipment employed in the aforementioned processing elements, it is obvious that efficient scheduling becomes most complex. It involves controls to insure the correct sequence of operations for each order, the precise instructions for processing each batch on each piece of equipment, the most efficient load for each element of processing and piece of equipment, and completion of each order on target time. There are other factors involved such as the availability of raw materials, and predicted and actual down-time of equipment. Our problem is to relate all of these matters to cost which, although not the exclusive consideration, is the primary one. Even in instances in which an early delivery date may be more important than the lowest possible cost of manufacture, precise information about costs for alternative processing sequences is necessary as a basis for management decision.

Theoretically, the linear programming approach appeared to be a natural for this type of application. True linear programming is a powerful instrument if you have a relatively simple problem, and you possess the facility to feed information into the programming problem in a smooth, efficient manner. However, our problem was obviously quite complex, nor was the basic informational data readily available. Our objective is to be able to compare cost of steel production, but in order to achieve this, we must be in a position to determine the cost for each sequence of production, and embrace every machine involved. After taking these considerations into account, we ascertained our basic problem was *not the application of linear programming, but the necessity of a complete procedural change.*

To correlate data for our linear programming model, we would have to develop a new method for deriving cost and time information. Our present technique was not adaptable to the scope and freshness of information an electronic computer would require.

At this point of the survey, we did not attempt to conceive new ideas to solve our problems, but instead formulated objectives predicated on established concept, and commenced to develop a composite picture of the problems that confronted us. We did not permit the objective to prostitute our approach when the actual experience factors began to develop, but we did realistically adjust the ideal to absorb the improbabilities of a procedural change. This approach we followed because of our sensitivity to the resistances and costs which almost inevitably accompany procedural change. It is obvious that even in so important a matter as providing better and faster information for management decision, the less disturbance of existing procedures the better, taking into consideration the stated objective alone.

The concept was not too difficult to arrive at. We knew what we wanted. We desired cost through each particular machine and the time involved plus every conceivable way of going from our raw material to a finished product through a sequence of machines.

I would like to point out that the time and cost information that was available was excellent for the purposes that it was used and was derived in a most scientific and efficient manner. The problem, however, was that we had a computer available and we wanted to use it most efficiently and use it for the most powerful type of problem that we could. The existing system was not geared for this type of routine.

In a mathematician's jargon, the time and cost information that was available was in discrete form. It was represented by thousands of rate tables, which incidentally could be handled by a large scale computer. However, the "file maintenance" problem would be overwhelming. Therefore, in order to rid the time and cost equations of these costly and inefficient step functions, it was necessary to derive continuous functions that would approximate our original rates.

Anyone who comes from a scientific field and goes into a business field, as I did, is likely to think that business problems are relatively easy. A simple table, a few variables, and there is the answer. On the contrary, business-type problems are very, very difficult. If you are faced with hundreds upon hundreds of discrete rates, it is a most difficult job to determine a continuous function which will express these. The difficulty exists not only for the analyst; it also exists for all the people who are involved in the project. They find it difficult to accept the so-called "new fangled" techniques. These people must be sold. A selling job involves an educational process.

And the educational process is by no means easy. Can you imagine trying to tell an "old-timer" of the steel mills that a mathematician can tell him how to produce steel better and cheaper? There has been a great deal of skill involved in producing good quality steel and the principles and methods of Frederick Taylor have by no means been completely accepted. These remarks are not intended to be in any way critical of the men in steel. The reaction I describe is the natural one from men who are already proven experts to suggestions for the adoption of a technique which has all the mystery of mathematics dreamed up by persons who are not themselves expert steel men.

Even among top management, there is hesitance to accept the new methods. Many reasons may be involved in this hesitance including the realization of the extent of plant resistance which is likely to be encountered. Furthermore top management itself has probably come from the plant, thoroughly indoctrinated in the methods of the past.

However, after thorough explanation of the objectives, the methods and the potential contributions of the new technique and methods, there was really remarkable open-mindedness and acceptance of them.

To summarize, we first tackled the problem that seemed to lend itself to straightforward linear programming. In the middle of trying to solve the problem, we discovered that we had to re-define it. Our primary problem turned out to be the development of an efficient and fast method for deriving cost and time information. We went in to work on the newly defined problem, modified some of our original thinking as to how we would solve it and derived more efficient ways of arriving at the time and cost information. Derivation of the more efficient ways does not insure the acceptance and installation of new procedures. At this point the problems of procedural change are faced in full.

Not all of the final cost equations required enough computation to warrant using a high speed computer. One of the final cost equations, for example, we found could be ground out on a Friden Calculator. We could compute a total finished product cost in approximately 5 minutes compared to the present method which took something in the order of one hour and a half.

From experience with our first cost equation derivation, we possessed the technique for developing the others. We also knew that when the project was carried out to its completion, we had developed a method which would not only enable us to be able to derive cost and time information for a linear programming model but also discovered a method that would aid management in many other areas. We had an efficient method for revision of standards, for machine selection, and for a fast way of coming up with the cost of a new product once we knew the sequence that we had to go through to arrive at it.

In summary, to effect a procedural change, one must:

1. Have a concept.
2. Define the boundaries.
3. Tackle the problem.
4. Modify objectives and/or premises if study warrants it.
5. Present the findings.
6. Install the system.

The fundamental objective of any procedural change should be one of altering functions in order that the lowest cost (hidden or real) may be obtained, provided such alteration is consistent with sound management policies.

Each of the six steps has critical importance to success. A poorly conceived concept can distort the entire process, although unfortunately, it does not prevent carrying a project through to completion. It very likely will result in additional frustrations and resistances along the way, and finally in an unsatisfactory system after installation. In fact, it is the frequency of such failures in the early planning stages that accounts for much of the resistance which the systems analyst generally faces.

The analyst, too, must possess the same flexibility of mind and readiness to adjust his thinking to new concepts and new information which he hopes to find among the operating personnel and executives with whom he works. He must *always be ready* *to modify his objectives and premises* when the facts so dictate. And the facts may include human factors in the situation as well as physical factors.

Success in the final two steps, too, depends in large part on certain human factors. The procedures or systems analyst sometimes overlooks the importance of the human factor in the presentation of findings to line management. He should keep in mind that top management very likely:

(1) Does not have any emotional conviction in favor of the new system which the systems man often develops during the process of his survey.

(2) Does not have knowledge of the details of the situation.

(3) Wants a presentation of (a) the present, (b) the proposed and (c) the results to be expected, with substantive evidence of the latter.

(4) Is thinking of the persons *he* must sell on the new plan: colleagues, superiors, subordinate management, union officials, the production man, and perhaps others.

(5) Takes a personal risk when he approves the installation of a new system.

(6) Has a bigger universe to take into consideration in decision-making than does the systems specialist.

It is within such a context that the results of a survey should be presented to management for decision. Perhaps the basic presentation, whether written or oral, should be brief and graphic. If so, it should be backed by thorough and detailed documentation which may be examined if desired. Any evidence that the basic survey, the analysis, and the recommended changes have been slip-shod or short-cut casts a general pall of doubt over the entire survey and the validity of recommendations.

The installation phase of procedural change is the payoff. I have already commented on problems of installation. I would only like to add that the magnitude and significance of changes which are necessary to effect major computer systems make the problems much more difficult than most procedural changes.

Workers and worker groups may fear loss of jobs if the new procedures are introduced. Even top management officials may see the probable loss of power.

In summary, I would say that all of the problems normally associated with procedural change are present in the installation of new systems to include the use of electronic equipment.

There are, in addition, special problems associated with electronic equipment. However, they can be met by honest, thorough procedures analysis and alert management. When met, the results will be more than worth the effort. I believe there are especially great possibilities in the use of the techniques of operations research to management problems.

PERSONNEL AND TRAINING NEEDS

R. D. ACKER

The introduction of electronic computers to business data processing has raised many problems concerning the development of procedures which will carry out the flow of work and make best use of the capabilities of the computers.

An important phase of procedure development is the preparation of the specific instructions which are needed to guide a computer in carrying out the parts of a procedure. When we first began to become involved in planning for the use of electronic equipment in our organization we were confronted with a basic personnel problem. Should we employ personnel from outside our organization who were thoroughly trained in the use of electronic computers and the preparation of instructions for computers and attempt to teach them the life insurance business? Or should we select personnel from within our own organization and instruct them in the necessary electronic computer techniques for preparing programs and operating the equipment? We chose the latter step. This gave our present employees who have been with the Company several years an opportunity to qualify for jobs at higher salary levels. Also, we found this required by far a smaller training period.

In the earlier stages of development work there were few guides available to indicate the specific qualities required for personnel in the electronic field. As a result of this fact and also because of the newness of the problems to be met, the first group of people employed were chosen for their pioneering qualities. We chose high caliber people associated with development work for many years who were capable of carrying out original work with ingenuity and perseverance. These people were also required to possess a firm grasp of the fundamentals of the life insurance business and the particular objectives of our own company.

Associated with the choice of the original staff of personnel was the decision to use a general purpose digital computer, at first in but one area of the Company's work. The area chosen was one where preliminary studies indicated that:

(a) a profit might be realized;

(b) the necessary knowledge and experience would be gained for further application of computers;

(c) the failure in actual operations to meet expected schedules would not jeopardize insurance policy service operations but only internal statistical functions.

The original group of people selected for computer work were sent to the manufacturers' training courses covering programming and also subjects pertaining to details of operating and engineering. This group worked with manufacturers' representatives thoroughly trained in the general techniques of procedure development who had also studied computer applications to specific procedures which we prescribed. From this experience and operation of almost a year, we learned:

(a) Manufacturers' courses were too general for our use and contained a great deal of material for scientific application which we were not likely to use in our business.

(b) The application of digital computers to data processing was not sufficiently advanced for the manufacturers to be adequately aware of the problems that were met with in the life insurance business.

(c) The translation of existing procedures into machine language was not the only skill required. A broader concept of programming includes the development of procedures on an integrated basis from first principles; not simply the mechanization of what was done before.

As a result of this experience, we established a concept of the type of consolidation of separate functions to be sought and then began to extend the scope of our activities to place further areas of the Company's work upon electronic computers. This planning included the considerations involved in acquiring additional electronic equipment plus the selection and training of a larger staff. We decided to establish a number of project units, each one of which would be headed by a supervisor who would be assisted by a group of programmers. The idea behind a project unit was that the members of each unit would act together as a team in developing procedures for a specific area of the Company's business. Our concept of the duties of a programmer includes the ability to perform in the following three areas of work:

(a) Development and analysis of large scale procedures involving the use of a computer many times as a tool in the flow of work; this work to be done under the guidance of a supervisor.

(b) Preparation of instructions to carry out specific programs upon a computer and the necessary testing and proving out of such programs.

(c) Operation of the computer and other auxiliary equipment.

These project units are currently engaged in planning activities in connection with the development of new procedures to be placed upon a computer. Future responsibilities will include the actual installations of new systems and the training of the personnel to maintain going systems.

When our staff was expanded with the creation of the project units we chose our candidates for programmers from a group of relatively high-level personnel who had considerable experience in the Company. They were chosen with due regard to the fact that we did not intend to mechanize past procedures, but rather would develop new procedures for a computer from first principles. In selecting candidates the overall intent behind the program was to select older experienced employees with valuable insurance experience and re-educate them in the new electronic techniques.

First, a group of two hundred forty-five candidates were selected throughout the Company by a review of the Company files for those persons with the desired work experience and job achievement as reflected by the position levels attained. The following qualifications were considered in this selection:

1. A good insurance background based on practical experience plus completed work in insurance courses.
2. The ability to think in mathematical terms and grasp mathematical concepts.
3. Experience in procedure planning and analysis work.
4. College training with a major in mathematics preferred. (This was not regarded as an essential and several selected for the work are not college graduates.)

This group was invited to take a series of aptitude tests. The aptitudes measured were:

(a) Mental Alertness
(b) Quantitative Thinking Ability
(c) General Linguistic Ability
(d) Functional Mathematics or Mathematical Relationships
(e) General Mathematical Comprehension

The longest test used was the American Council on Education psychological examination. This test requires about one hour to complete. From it three scores are available. A score measuring Quantitative Thinking; a score measuring General Linguistic Ability; and a total score which is a measure of Mental Alertness. This test is published by the Educational Testing Service of Princeton, New Jersey.

The second test is known as the Faust-Schorling Test of Functional Thinking in Mathematics. This test requires no more than a high school knowledge of mathematics. It stresses mathematical relationships rather than just pure knowledge. It requires about 45 minutes to administer this test. It is available from the World Book Company of Yonkers, New York.

The third test measures Mechanical Comprehension. It is Part VI of the Moore Engineering and Physical Sciences Aptitude Test and requires about 12 minutes to complete. It is published for the Psychological Corporation, 522 Fifth Avenue, New York, New York.

After a series of interviews and a review of records of the personnel who ranked highest in these aptitude tests we selected the 38 individuals needed at this time to be given programming training and have available a list of other suitable candidates. After they had been given four weeks' training, the instructor rated the individuals and it was determined that four people rated as "excellent" and nine as "very good" were in the top 10% of those scored on the aptitude tests. The balance who were rated "good" by the instructor will succeed probably with some difficulty and they were in a class below the upper 10% scored in the aptitude tests. The correlation is not perfect but is a very strong index that the tests do indicate the abilities for which we were searching.

The 38 individuals selected are scheduled to receive the following types of training.

(a) An abbreviated course in computer programming. This is a specially designed four-week course which includes the elements of programming and a basic concept of programming which uses prefabricated subroutines and a master program to combine them. This type of master program is called a compiler and was specially prepared by one of the original group of programmers.

(b) A short course in computer logic of about one week, given to groups of two or three men at a time. This course was designed to teach the elements of the computer so that a programmer might be able to operate the equipment, particularly in the area of utilizing certain service routines relating to sorting, correcting, testing, etc.

(c) The study of procedure guides and other material helpful in the procedure analysis and development functions of a programmer.

(d) On-the-job supervision in performing certain elements of a project involving both procedure development and program coding as assigned by a project supervisor.

So far we can say that none of the 38 individuals has entirely completed his training, although most of the 10 selected in May 1955 (the first of three selections) have been able, under supervision, to do the procedure analysis and development work assigned and prepare the necessary computer instructions. Their progress is excellent. This group's accomplishments are enthusiastic examples of what can be done along the lines of retraining older personnel. The median age of this group of 10 persons is between 30 and 40, with one or two close to age 50.

With the 38 programmers already selected as a nucleus, we feel that should further expansion become necessary it would be practical to expand our programming force by adding others who do not have such a broad background. For example, we might use people without the experience background to serve as aids to the basic group in the more mechanical translation of procedures into machine instructions, or we might train others solely in the techniques of computer operation. So far, however, we have been endeavoring to develop a large group of "all-round" personnel.

PREPARING EMPLOYEES FOR THE CHANGEOVER

ROBERT B. CURRY

Introduction

You are well aware of the fantastic speeds, the unbelievable accuracy, the reliability, capability and versatility of not only the prospective, but of the present automatic data processing machines actually in operation today handling business applications. A year ago, or at most 18 months ago, there was hardly a business application worthy of mention on a computer. Today, it is a hopeless task to attempt an accurate inventory check of the number of business applications installed and planned. This story has been told and thoroughly retold by schools and universities, professional societies, manufacturers, management professions, and the pioneering companies and Government agencies; but it has been told most widely by the greatest of all spreaders of news—the Press. Unfortunately, it has been spread with glamourous exaggeration and characterized as a second industrial revolution leading on to a new prosperity.

This week, you are learning the meaning and full import of this coming revolution in the office, but for thousands of people who do not know or do not and will not take the trouble to learn, the terms Electronics and Automation give rise in their imagination to a new class of huge Frankenstein monsters of machines so much superior to man himself that ultimately we will all be destroyed by them. The word Automation alone has conjured up visions of automatic factories where machines will grind out products 24 hours a day without any payroll whatsoever. Automation itself is a modern bogeyman. A recent poll in Detroit revealed that automation was second only to Communism in fears for individual security. In another poll, a thousand factory workers replied 3 to 1 affirmatively when asked—if they favored the use of new and improved machines; but replied 3 to 2 against when asked how they felt about more automation. This surely illustrates the need for better public relations for automation and electronics in the office.

So much has been said and written on computers! But there is so much to say and to write that, in reality—relatively little has been said and written. This is particularly true with regard to *human relations* in computers and automation. Even here so little has been said and there is so much to be said that—like the mosquito in the nudist camp, you don't know where to begin.

Let me begin by quoting one writer[1] on this subject as he stated it—a year ago:

> "As automatic computers extend their operations into new fields of business and industry—and the process of automation reaches new heights, there becomes visible an area of problems which—as yet have received consideration chiefly *by avoidance*. This is the field of their human relations, particularly their labor relations, and the social changes that may be expected to follow from the new processes."

However, the host of problems of organizational adjustments and personnel displacements have been receiving increased attention. This morning's session on "Personnel and Training Needs for Electronic Data Processing" (Robert D. Acker, Metropolitan Life) vividly illustrated this requirement. In this phase of the human relations problem, much has been written. Wayne University and other schools have taken excellent comprehensive and constructive approaches to the problem of training personnel.[2] A great deal has been written on the education and training of programmers. Because of training and personnel needs, this side of personnel disruption in the changeover to electronics has been covered much more adequately than that of personnel displacement which has received scant consideration on the constructive side.

It should be emphasized at this point that my remarks on preparatory measures for the changeover are not a case study nor are they based on my organization's experience or plans. Rather, the measures described and set forth are attempts to state the idea rather than a specific application.

Preparatory Measures

In *preparing employees for the changeover,* the major concern is in the area of human relations. The time, effort and intelligence devoted to coping with the various aspects of that area will be directly reflected in the ultimate success to be achieved by the conversion.

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[1]Fletcher Pratt, "Human Relations of Computers and Automation," in *Computers and Automation,* December 1954, p. 6.

[2]Arvid W. Jacobson, Editor, *Proceedings of the First Conference on Training Personnel for the Computing Machine Field.* Detroit: Wayne University Press, 1955.

Glowing descriptions of a computer's high speed processing of a tremendous volume of data, and the benefits to be derived therefrom, all too often fail to take into consideration the necessary things to be done before a business can enter into the promised land of electronics. This omission is not too surprising when one considers that information regarding the fantastic potentialities of a particular computer are usually furnished by salesmen, who are never lacking in enthusiasm for the merits of the particular hardware they sell (for if they were lacking, they would not be salesmen long). Therefore, while being lulled by the siren song of happy days to come, a company or agency must not overlook the basic human angles of the problems to be met, and the steps to be taken between the time a computer is being considered or ordered and the time until it is delivered and the start button is depressed.

In this interval one of the most important facets of the problem is that of preparing employees for the changeover. Adequate steps in this direction, or lack of them, can be the difference between the organization's or agency's success and failure in good employee relations.

Let us liken our subject to the mother, who in preparing her daughter for the advent of a new brother or sister, found a very unreceptive child who did not want a baby brother or sister. The next day the mother asked if she had told any of her playmates about the new brother or sister. "No, I haven't." "Why not?" "Because I still think I can talk you out of it—that's why." *We,* as the little girl, cannot talk management, pregnant with a vast new tool, out of adopting mechanization in the office nor would we want to do so. What we can do and must do, however, is meet the psychological questions and quell unwarranted fears of employees concerned with the changeover to electronics.

The key to the human relations problem may be expressed by a single word FEAR. In some degree, more or less, it affects all personnel from the newest clerical employee even to some of executive rank. This frightening spectre of fear is fanned by the press, which constantly plays up accounts of job abolishments to result from each new installation of large scale automation equipment. Two weeks ago, *Business Week* carried a story on check preparation mechanization reducing the number of employees required from 750 to 350. With the continued talk that automation will destroy jobs, put people out of work, create a depression, comes a fear of losing one's work. In combating this fear, neither sharp words nor a patronizing attitude will convince anyone that automation is a boon rather than a threat.

Thus, it is to these fears that we must address ourselves in "preparing employees for the changeover." It will be recalled that in time of great economic stress, the President said—the only thing to fear, is fear itself. That is certainly the case in automation. The picture is not nearly as bad though as it has been imagined, (it couldn't be), and as others have said, much of the picture as painted is false. Facts are needed, and the facts have to be examined before blithely succumbing to such type of "fear" thinking. Positive action is needed, as well as rebuttal to common misconceptions of the results of automation.

Positive Actions

Positive actions include staff participation, understanding, communication and training.

The ultimate fate of the clerical worker at the hand of electronics is certainly open for considerable conjecture. It is no wonder that employees worry about what the effect will be to them personally when a company announces the acquisition of a large-scale computer. The older employees and more senior staff wonder about their future, their ability to change and to meet, absorb, and adjust to the radical departmental and procedural changes evolving from the changeover. Other employees may worry about job reclassification, downgrading, organizational and geographical relocation or even the actual loss of their present positions. Several authors have pointed out the tendency that increased office automation will have to degrade masses of semiskilled workers while creating a small professional elite of salaried employees.[3]

The introduction of a computer into a business or agency cannot help but have a radical effect on the present status of all personnel. Many will find their work procedures altered considerably or changed entirely. Some offices will be reorganized or consolidated. The channeling of tremendous volumes of data to be processed by a computer in a centralized location will usually mean the eventual relocation of some positions. The successful utilization of a computer must certainly, in time and over-all, effect a

[3]J. Douglas Elliott, "Will Electronics Make People Obsolete?," in *The Impact of Computers on Office Management*, Office Management Series No. 136, New York: American Management Association, 1954, p. 48.

reduction of personnel required in data processing. In some instances this may represent a substantial reduction, while in other cases it may be negligible, depending upon how completely mechanized and how efficient the former operations had been, as well as the efficiency attained with the newly electronified system.

Admitting then that a fear may exist in the minds of many employees and that they may have a reasonable basis for that feeling, what can be done about it? Certainly if nothing is done, a decline in employee efficiency and in the quality of work being produced will be the inevitable result. The most important thing that can be done is to fight fear with the most potent counter-weapons—facts. Since the procurement of a computer is always preceded by a detailed feasibility study, the signing of a contract would hardly come as a surprise to any employee of the company.

The staff should be informed at the outset of the intention of management to investigate operations to the end that electronic equipment is being considered or planned. Any press release concerning actual signing of a contract for a computer should be simultaneous with a complete announcement to all employees. The announcement should give details of the location selected for the computer and describe some of the work to be initially converted. It should be noted that the era of the push-button office is not yet in being, and that there will be more people than push-buttons for the foreseeable future. However, personnel should be aware that some positions will be eliminated, but that labor turnover will accommodate personnel cutbacks involved. Bringing the matter to the attention of clerical personnel as early as possible will serve to still fears which inevitably arise as to what is going on. In this connection, it is noteworthy that the best computers and the fastest of electronic communication cannot keep pace with the output or the transmission speed of the office grapevine.

Emphasis should be made that some of the main benefits to be derived from the computer will be the elimination of purely routine operations and general increase in the "interest factor" of work through the release of employees from the tediousness of repetitious tasks, enabling them to be reassigned to work of a more interesting and productive nature. At this time those departments which will be first affected should be listed.

Any industrial company large enough to acquire a computer will very likely have a union. Employees affected by the change-over should be informed of their rights under their particular union contract. Such benefits usually include the rights to transfer with their work, seniority displacement rights, severance pay and the right to re-employment as future vacancies occur. After the announcement, the employees will be seeking out their union representative. The company should be the first to tell them of their rights and let them receive confirmation from their Union representatives.

The organization should stress plans to accomplish personnel reductions wherever possible by normal attrition. A sound plan should be outlined for placing employees from abolished positions in vacancies in other offices whenever feasible. Many companies and agencies through the effect of personnel turnover alone have been able to assure that no one would be displaced who wanted to continue working. In many industries attrition plus growth factors in their expansion programs will completely accommodate any personnel savings in the changeover.

The cooperation of the staff is highly essential in the changeover. Just as in preceding conventional systems, successful change in procedures in electronic data processing are practically impossible unless the clerical staff is fully cooperative. Supervisors must bring in the clerical staff at the beginning and make every effort to secure wholehearted support by a full factual presentation of what is in store for personnel when automation becomes fully operative.

By setting forth facts to all employees at one time instead of allowing them to discover the news by rumor or second-hand information, the employees can face the future with some means of determining how they will be individually affected. With the facts in their possession, many of their fears will never materialize and others will be considerably lessened. The importance of providing effective communication of factual information from management to employees at this time cannot be too strongly emphasized. If the plan as previously outlined is properly administered, both management and employees will enjoy the numerous benefits to be derived therefrom. In contrast, however, some organizations have insisted the acquisition of such machines and the use of machine time be kept a secret.

With everyone informed of the proposed conversion, the next problem to consider is that of training; this consists of two main categories—general instruction and specific training.

General instruction is a program directed at making everyone within the organization *"computer-minded."* It is not just the rank and file, it is the departmental and sectional supervisory levels as well, that need a quieting of fears of job disruption. It is this group that frequently has extensive worries of whether they can make the grade in changing over to electronics. The purpose of a general training program is to acquaint all levels of personnel with facts about electronic computers, how they operate, what can be accomplished by their use and some of the preliminary work required to prepare data for computer processing. The program is to familiarize all employees with computer terminology and capabilities so they will more readily accept a procedural conversion, and to stimulate their thinking regarding other procedures which could be converted in the future. An organization with a suggestion system can call upon that medium to advantage for the processing of employee suggestions regarding changes in procedures involving use of an electronic computer.

In carrying out the program of general training, all educational media should be utilized. Periodic talks by computer users should be arranged for executives and personnel to acquaint them with accomplishments in related fields in other organizations. A glossary of computer terminology should be prepared and copies circulated to interested personnel. Some computer manufacturers furnish movies demonstrating their products. Others can be secured from accounting firms such as Arthur Andersen and Co. These films should be shown to employees throughout an organization with wide spread or complete attendance.

A library of books and other materials on the subject of computers should be started and added to as worth while material becomes available. A bibliography should be prepared and circulated to all officers and interested personnel as well as establishing the availability of these books. The library should also contain copies of at least some of the current periodicals: such as *Computers and Automation, Harvard Business Review, The Controller,* etc. A list should be circulated each month referring to articles of interest appearing in the various publications. A routing plan should be devised to insure that these periodicals will reach all executive and supervisory personnel. Other accounting firms issue publications from time to time which are excellent source materials.[4]

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[4] *Arthur Young Journal,* a monthly periodical, particularly August, September and October, 1955. Haskins and Sells, *Data Processing by Electronics,* privately published, May 1955.

Visits may be arranged whereby interested executives and key employees of departments most involved in the conversion may see other computer installations. Visits to computer manufacturing plants, installations and business service centers are likewise quite profitable.

The general training program should be designed to make everyone in the organization think in terms of computer applications and capabilities. Concurrently with a program of general training a program of specific training should be conducted.

Specific training should be available to those who will be preparing data to be converted to computer processing and to those who will operate under the new procedures. The first group will become the Procedures Analysts, Programmers and Coders. At this date of computer development, it is almost impossible to hire trained programmers and coders, and training is the only source of supply. On the subject of hiring trained programmers, it is illustrative to note that the national computer conferences have (according to the Wall Street Journal) taken on the air of hiring halls.

More illustrative perhaps is a recent statement of Dr. H. R. J. Grosch, who heads computer activity at G. E.'s Evendale, Ohio, aircraft gas turbine plant:[5]

> "For each of the next five years, the need for people to operate computers, that is to introduce information properly and maintain the machines will double each year. We have 100,000 such persons now, which would mean over *three million* needed, five years hence. We won't be able to train that many, so the worker shortage will be greater than it is now."

Management must, therefore, turn to its own personnel. The methods and procedures group of a company will form the nucleus for the task force required in preparing data for the computer.

It is assumed that in making the feasibility study some of the methods and procedures group would have been utilized. Since they will have some degree of familiarity with the planned conversion, these individuals should be immediately sent to school for computer programming.

By rotation every member of the methods and procedures staff should be sent to programming school. This should be done even though, of course, it is not planned to make programmers or

[5]Statement made at Joint Computer Conference, Boston, November 1955.

coders out of all of them. Only by receiving this specialized training can personnel of the methods and procedures department be properly qualified to evaluate procedures to be converted and to be able to prepare flow charts which can be utilized by programmers in actual coding.

Attention should next be directed to the selection and training of personnel for positions as programmers. Special aptitude tests to be used for this purpose are available from universities, vocational consultants and equipment manufacturers. Other tests may be secured from testing agencies and other computer users. Testing should be made available to selected young employees from each office of the company or agency. Final selection should consider not only the score attained but a very careful evaluation of the employee's abilities and attitudes within his present area of work.

Additional instruction can be supplied by obtaining specialized personnel from the manufacturer and from other computer sources to give short talks at intervals of perhaps once or twice a month. These speakers can discuss in detail those components and techniques not fully covered in the regular programming courses. Attendance at various computer conferences and seminars by members of the programming staff can also serve to keep them informed of new developments.

The importance of a continuing program of instruction cannot be too strongly stressed. It will be found that new developments will be available from the manufacturer or other users even before installation of the computer. New techniques will also be made public. This makes necessary a definite plan to keep the programmers, analysts, supervisors and department heads abreast of all new developments.

The next group to be considered for specific training are those who will operate under new procedures as a result of the conversion. To aid this group, procedural handbooks or procedural manuals must be prepared by the methods and procedures staff. These manuals must reflect the details of every procedure as it will be carried on after the conversion. Needless to say, any attempt made to put new procedures into effect will be abortive prior to the time that all personnel is sufficiently familiar with the new procedures.

In preparing its employees for the changeover, each user will find some variation for the specific preparatory measures enumerated. It should be borne in mind that this is only set forth as a guide. Each case must be handled on the basis of the individual company's or agency's circumstances.

I have not attempted to cover training for training's sake—only as a psychological element of the preparation of employees for the changeover. There is a great deal of reassurance for the staff to see and know how some of themselves—not outsiders—are being trained to adapt their work to the new machines.

Similarly, I have not attempted to cover executive leadership affecting intermediate supervisors but here again two-way effective and informative communication is a real requirement.

Department heads and supervisors should be kept informed as installation planning progresses. In addition planning should be made known to employees once a final determination is made in order to get greater cooperation and understanding. Actually, opinions, ideas and suggestions of the entire staff should be solicited before detailed routines are established, to achieve the full sense of participation. Many final decisions of necessity must be left to department and sectional supervisors.

Analysis of Fears

In addition to specific preparatory measures to achieve a smooth changeover, an understanding of fears, both real and imagined, of the employees should be grasped before attempting to cope with preparing employees for the changeover.

In this connection J. Douglas Elliott of the Detroit Edison Company[6] has in an excellent article explored some of the fears, problems and misunderstandings about the effect of these machines on employees and cites:

"Four basic fears and misconceptions concerning electronic systems which need clarification in our own minds, in the minds of all employees, as well as the minds of the public, are as follows:

(1) That the new electronic brains will truly become masters of men, reducing the worker to a subordinate position;

(2) That only a few high-priced, highly educated specialists, technicians, and mathematicians will be necessary to organize and operate the machines;

(3) That the few workers who are still needed will lose their individuality, with jobs reduced to simple repetitive tasks; and last, and perhaps of most concern,

(4) That wholesale layoffs will result when complete electronic systems are installed."

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[6]J. Douglas Elliott, *ibid.*, p. 49.

1. *Who are the Masters, We or They—*

Of course, Lewis Carroll in *Alice in Wonderland* was talking about something else and not about machines, when it was scoffingly said, "It depends on who is master, we or they." But are the machines masters of men, or men masters of the machines? This may seem strange to you at this time with your understanding of automatic-data processing systems and a knowledge of how *un*intelligent the machine really is, but it is still of real concern to the rank and file, the average worker and the public and to members of management itself.

The real fact of the matter is—the more complicated the machines have become, the more dependent they are upon man. Actually, the machines are so dumb you have to tell them to stop work; their intelligence is so low they do not know when they have finished a stack of work; that is pretty dumb by human standards. The plain and simple fact is the machine can make only those decisions you have planned it to make. If confronted with any you have not anticipated, it comes to a grinding, flashing halt. About that wonderful faculty of the machine's memory —it can remember only what you told it to remember. The inescapable conclusion is the machines will replace "muscles" but not "brains."

2. *Highly Skilled Specialists*

The second fear is that the operation of electronic data processing systems will become dependent upon groups of highly skilled specialists to—

(1) review and analyze jobs for the machines to handle (analyst),

(2) to prepare machine instructions (coders)

(3) to operate the machines (operator).

It is true that a considerable amount of training will be required to accomplish the above. However, it has been the experience of the organizations to date that the best programmers and coders are the company's or the agency's own staff who know the company policy, objectives, procedures and practices. It is merely necessary for such personnel of the organization to acquire a thorough knowledge of symbols and codes of the particular machine system.

Furthermore, the duties of the machine operators are quite comparable to those of a good punched card equipment operator—

monitored by a programmer who will watch the console and check for errors, machine stops, and system failures. Some specialized training will be necessary, but the services of an electrical engineer or mathematician are not required to operate the data processing systems.

3. *Loss of Individuality*

The third category of fear is that the machine installation will so debase an employee that he will lose his individuality and become a robot. The exact opposite is true. The robot's part of the work will be mechanized as the use of machines will eliminate voluminous amounts of small repetitive tasks. The replacement of these tasks eliminates mediocre jobs and brings new but fewer jobs with these jobs requiring greater responsibility, understanding and initiative in order to work with the new machine. John Diebold has stated that automation actually may have an effect opposite from "debasement."[7]

4. *Personnel Displacement*

The fear of large employee dismissals is more real in that it has an immediately prospective economic impact in contrast to the psychological impact of preceding fears and misconceptions. Here, since management of a company or an agency has become convinced the electronic machine will pay for itself or even make money, you cannot at the same time assure the staff there will not be a reduction of employees.

In the planning and analysis work, however, there is usually a considerable increase in work not only preceding installations but later also because such activities with automatic data processing systems are never complete.

In the actual data processing operation, a reduction in manual manipulation and paper processing is expected and inevitable except in a few cases where a computer is installed purely for new work.

Also, more machine operators per unit of equipment will be needed on an electronic system than in a normal tabulating machine installation. Because of the high cost of machines, users cannot afford to have them undermanned. Sufficient help adequately supervised will have to be available to keep the machines

[7]John Diebold, *Automation.* New York: D. Van Nostrand Company, 1952.

running at all times, continuously for one shift and sometimes on double or triple shifts.

However, one of the major attributes of electronic data processing systems is the ability to develop information and reports of extreme importance to management but which without office automation were previously either prohibitively expensive or too time-consuming to be accomplished reasonably and timely enough for administrative consumption. In this area alone a large amount of additional workload is automatically generated, frequently far exceeding the workload eliminated by electronic handling of data. Management has known how much information and reports have cost, but has not known, although it has been suspicious, of the cost of not having pertinent information. With data processing electronically, additional work will be undertaken heretofore not contemplated but which requires additional and higher capabilities of the personnel.[8] Actually while the machines are causing significant changes in the work force, the mechanization is creating a net increase in jobs, not decrease in jobs.

While a computer works its wonders without the aid of a crowd of little men and women sitting inside it operating thousands of calculating machines, it is nevertheless true that people are still needed on the outside to carry on a business, even after a computer is in operation. The picture of *Before* and *After:* A thousand desks for clerical workers with manually operated machines, in contrast to a few black (or rather gray) boxes full of wires, tubes, relays, resistors and other electronic components—is merely a figment of the manufacturer's advertising and the salesman's broad generalizations and to a degree to management's own picturization born of wishful thinking.

Summing up, it becomes more apparent that the completely automatic office made up of only sexless and shapeless machinery will not become a reality. Actually, there are still going to be a lot of people around and in some areas of work more than before. Any significant savings will be confined to areas of routine data handling. The pictures you see of huge rooms filled with electronic machines with a couple of beautiful blondes and one engineer sitting at the console are strictly for the manufacturers' advertising and management consumption.

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[8]Cuthbert C. Hurd, "Business Applications of Large Computers," in *Tomorrow's Technology—A Symposium.* Published by the Southern Research Institute, 1955.

Economic and Social Aspects

In *preparing employees for the changeover,* the social and economic implications cannot be ignored but must be developed in order to dispel the over-all fear and misconception of automation. Much has been said and written on the technological advance and the increased standard of living resulting from automation; that for every job eliminated by technological improvements, more jobs are created in new and allied fields. Public attention has been further focused on this matter by the recent Congressional Committee investigation of automation.

We ought to be able to accept history as proof of the point rather than debate any further on economic theory. Over the centuries, man has accomplished an amazing industrial miracle. He has surrounded himself with luxuries and greatly lengthened his hours of leisure; but no machine he ever devised has made humans obsolete. One outstanding example of automation that none of us here is too young or too old not to have seen in our lifetime is the dial telephone system. Recently, a little boy from Washington visiting in a southern farm asked how they could get telephone numbers without a dial and, being told to just pick up the receiver and tell the girl what you wanted, he asked: "Gee, do you have everything as modern as that!" Now, we would naturally assume that dial phones must have thrown thousands of telephone operators out of work, and some of the current writing and talking on the subject of automation would seem to confirm that assumption completely. But the latest Federal census, 1950, shows that the number of telephone operators in this country had increased by 79% in the previous 10 years.[9] And still the telephone company is advertising for more operators.

However many total people are employed, though, it is tough to convince Mary Smith, an *ex*-payroll comptometer operator, and Betty Whoosis, a former file clerk in accounting that electronics and automation do not result in unemployment. It should be conceded here and now that the fear of technological unemployment is a very real one to someone who is laid off when a new machine arrives. He knows and cares about only one thing, that he does not have a job.

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[9]U. S. Congress, Joint Committee on the Economic Report, Subcommittee on Economic Stabilization. *Hearings, Automation and Technological Change,* October 14-28, 1955. Washington: Government Printing Office, 1955, p. 80. See contrary testimony by Joseph A. Beirne, p. 340.

However, technological unemployment is only temporary and the answer must be provided by management and labor and the element of time.

Management more and more is accepting its responbility in the expense of reeducating displaced personnel in newer techniques, retraining them in new fields, reassigning or assisting in employment transfer for employees so that they may continue to earn a livelihood and to support the community in which they have lived. The fact that DuPont has 35,000 persons employed on products new since 1951 is truly significant! The chemical industry, too, with all its built-in mechanization is increasing at a 10% per year rate compared to a national over-all average of slightly less than 3%.

While management suspects labor of resistance to change and to some extent justifiably so, labor suspects management of unreasonableness. The solution lies in cooperation of both labor and management in facing the over-all problem.

One thing that must be considered and relied upon is the need of time to assist in technological changeover. Fortunately, it will take a considerable period of time, at least 3 years, to accomplish even the basic aspects of a change from a manual accounting to an electronic data processing and the full effect will be as long as 5 to 7 years. During this interval, management and individuals must work with, rather than against, the forces of nature. There was no insurmountable pain in the coming of the automobile—even though blacksmiths and buggywhip manufacturers started going out of business.

MANAGEMENT EXPERIENCE IN THE CENSUS BUREAU

DONALD H. HEISER

The responsibility of the Electronic Systems Section of the Bureau of the Census is that of keeping the installation of two UNIVACs and auxiliary equipment supplied with working programs and workable data from New Year's to Christmas with the minimum of lost time and the maximum of output.

I would like to mention briefly the size of our operations as measured by several standards and to discuss with you some sample problems that are typical in the operation of large scale data processing equipment.

Our equipment includes two UNIVACs, each with 8 Uniservo (tape handling) mechanisms, three card-to-tape converters, two of which are Census owned and one of which is on rental from Remington Rand, three tape printers, capable of reading information from magnetic tape and transferring it to a printed page, two of these are Census owned and one is rented from Remington Rand, one Unityper, which accepts information from a keyboard and transfers it to magnetic tape, and one film to tape converter that we call FOSDIC, which transfers information from a microfilm copy of enumerators' documents to UNIVAC tape.

The Electronic Systems staff includes between 50 and 60 people who are engaged in programming research and training, equipment maintenance and repair and equipment operation and control.

We occupy approximately 11,000 square feet of floor space, which is divided into almost 4 equal parts to cover these four functions: 1. Operation of the two central computers, 2. All maintenance operations and operation of auxiliary equipment, 3. Office space for programmers in the central group and administrative and record-keeping personnel and 4. Storage space and cooling equipment for both UNIVACs.

The budget for the current fiscal year is $460,000, which includes salaries of staff referred to above, maintenance, repair, and parts for all of the above equipment, with the exception of the two rented items where the maintenance is included in the rental price, a small amount for tape replacement and a small amount for equipment improvement. The budget does not include amortization of original capital expenditures nor does it include services such as space rentals, power, lights, etc., as provided by General Services Administration.

The current workload is sufficient to keep two UNIVACs occupied full time 7 days a week, 24 hours a day and we are currently purchasing time from another UNIVAC installation. We are also negotiating for the possible purchase of UNIVAC time from other sources to meet the peak requirements of the current Economic Censuses.

Since the acceptance of our first UNIVAC in the spring of 1951, our lives have been full of problems and headaches. Some of these problems, of course, we had expected and were partially prepared for. Others were entirely new and consequently were the cause of a great deal of activity and effort. Some of these early problems are representative of those that are still being encountered in the operation of large scale computers; others are problems that may have been solved by now, but will serve as examples of the unusual or unexpected type of problems that seem to continue to arise.

The use of this kind of equipment brings new problems, however, and in addition puts new faces on some old problems. A requirement to be met in applying computers is that very detailed and explicit instructions must be provided to the computer before it will proceed through any operations. A computer, for example, doesn't even know when to start or when to stop except when explicit directions covering these elementary functions are included in the instructions prepared for it. This applies not only to a complete task but to hundreds and sometimes thousands of subparts within subparts which when executed in the proper sequence by the computer result in the solution of a complex problem. The preparation of these lists of instructions known as "programs" involves personnel with varying degrees of skill ranging from the principal programmers, who must be thoroughly familiar with the application as well as the characteristics of the computer to be used, to less skilled personnel, who must be skilled in applying the computer instructions to accomplish specific results but who need only be capable of filling in the final details in small pieces of a total program and need not necessarily understand how the pieces they prepare fit into the large mosaic which makes the whole.

Staffing

Many of the personnel needed to perform these functions of general and more detailed programming need not necessarily receive an extended education on these specialized areas. Persons of good educational background and with aptitude (but not necessarily professional training) in mathematics, sciences, engineering, and related fields or who have demonstrated ability in planning punched card procedures can be trained in the essentials during a period of several weeks. They can acquire experience over a period of several months or perhaps a year that will enable them to perform effectively in this specialized field.

The requirement for personnel to prepare programs is supplemented by a need for operating personnel. Much has been printed in the popular press about how automatic and self contained these devices are. You may have heard how internal checking facilities, or checks for accuracy which are included in the instruction "program," can insure against incorrect results. The very existence of these facilities suggests that sometimes checks are not satisfied. When this occurs there must be human intervention by an operator. The art today has not reached the point at which these equipments can be left unattended for periods of even an hour unless the user is willing to take a great risk that during a major part of that hour the computer will just be stopped, waiting for the operator to press a button or take some other action to start it again. Because of the high cost of lost time and the need for fairly frequent operator intervention to identify and correct difficulties or supply additional input material it is important that operators of large scale computers be more highly skilled and trained than is necessary for more traditional office equipment.

In addition to operators there is a need for maintenance personnel. Here as with program preparation a wide range of skills is required ranging from engineers who know the design of a computer to far less skilled technicians.

Thus, these new data processing facilities create job opportunities for programmers, operators and maintenance personnel while they take over routine clerical tasks. Practically all of our staff now working in these various positions represent persons with appropriate background and aptitudes who were working in the Bureau of the Census prior to our acquisition of the computer, and who have been trained and have developed the necessary experience while on the job in the Census to carry on effectively in the new type of function. We have had to hire from the outside only one or two who were already experienced in one of these fields. For a fixed amount of work an electronic data processor may sometimes effect a net reduction of substantial proportions in the total personnel required. The reductions, however, will be in the number of employees needed to perform routine work.

Assignment of Responsibilities

The organization and assignment of responsibilities for various aspects of a computer installation deserve some attention. We have followed an approach in which a central Electronic Systems operation is established with responsibility for (a) operating and maintaining the computer, (b) allocating computer time, (c) providing leadership and training in the development and application of programming techniques, (d) developing new areas of application, and (e) operating auxiliary equipment such as the printers and the devices for converting from punched cards to magnetic tape. On the other hand, actual preparation of programs is the responsibility of our user divisions with guidance and assistance from the central programming group. Similarly, the user is responsible for bringing his work to the computer at the beginning of the period he is scheduled to use it. He in turn expects to find the computer in operating condition and an operator to assist him with his work.

This approach seems to work quite well. It effectively educates the staffs of the divisions about the computer, and we believe it is more effective than completely centralizing the computer service, with the customer simply stating his problem and the computer group programming and putting it on the computer. It certainly has spread understanding of the computer, its capabilities and limitations, among the staff of our Bureau. This also has the effect of providing a much larger staff to draw upon when we have large temporary expansions of work for major censuses. Professional, procedural or administrative people in the divisions control flow of work to and from the computer, and learn to successfully program for the computer. At the time we started operations in Philadelphia we recruited four electronic engineers that we intended to "expose" to UNIVAC logic at the plant in Philadelphia, with the hope that these people would serve as the nucleus group for the maintenance operations with Census Bureau personnel. At this time we were using as operators a number of expert clerks who had been selected from the Philadelphia office of Census operations. As time went on and we needed to recruit additional staff, our search was in the direction of finding experienced technicians with electronic repair or maintenance background, who may have come from trade schools, television and radio repair shops and the like. These people we trained in the field of UNIVAC logic and maintenance and we also used these people as the operators of the equipment. This group, in addition to supplying the necessary logic and technique for keeping the equipment in operating condition, were also used to keep the equipment fed with work during the time that the equipment was operating satisfactorily. Incidentally, this was the method of operating most of the large scale computers that had been put into operation up to that time. This seemed to be a reasonable way of operating our UNIVAC. However, as time went on, we were faced with the extreme difficulty of finding technically qualified maintenance personnel.

Another factor concerns the addition of a Second UNIVAC. Our operations were now becoming so large that we could afford specialists in the two areas of operations and maintenance. Consequently, we have recently relieved our maintenance staff of the responsibility of operations of the equipment and we are developing a staff of operations people whose main responsibility will be that of operating the equipment, which includes mounting and demounting magnetic tape, operation of the control switches, preparation of the operations logs and the like. Our present maintenance staff consists of about fourteen people, ranging from grades GS-5 through GS-12 [1] and the present operations staff consists of about twenty-three people, ranging from grades GS-3 through GS-13.[2] To qualify as a candidate for a position on our maintenance staff one needs to have a certain amount of experience or training in the field of electronics, but this experience and training need not necessarily be in the field of computation. If a man has mastered the fundamentals of electronics, we feel that he is good material for training in the logic and operating process of UNIVAC equipment.

Our first maintenance engineers were sent to Philadelphia, with the hope that they would learn UNIVAC maintenance by working alongside the Eckert-Mauchly people, who were engaged in con-

[1]Starting salary range: $3670-7570.
[2]Starting salary range: $3175-8990.

structing and debugging UNIVAC equipment. There was little formal training effort expended during this time, presumably because the manufacturers considered it to be more important to get the equipment delivered than it was to train maintenance staff for customers. However, our trainees did make reasonably good progress and in fact did so well that they were able to get positions elsewhere at salaries above those that Census was able to pay. We eventually lost them all.

At the time we moved the first UNIVAC out of Philadelphia to the Census Bureau in Suitland, we had been reduced to one engineer and were in the process of training a small group of technicians in UNIVAC maintenance. A few of these people were hired from outside the Census Bureau, but several were taken out of the Census Equipment Maintenance Shops and were trained on-the-job in UNIVAC maintenance.

Because of our unsatisfactory experience up to this time in obtaining an engineering staff, we started working on the preparation of a special contract for engineering personnel. There was a precedent for the contract arrangements inasmuch as the maintenance of the equipment had been done, partially at least, on a contract basis with the Eckert-Mauchly engineers during the twenty-one months of operation of the UNIVAC in Philadelphia. After a great deal of effort and discussion with Bureau of Standards and Department of Commerce personnel we finally worked out a contract which permitted us to hire, at the equivalent of a super-grade level, an expert UNIVAC engineer who had been trained with the Eckert-Mauchly group in Philadelphia. The contract has been renewed twice with this man and he is still our chief consulting engineer. Even though we have been paying him an unusually high rate for his services, we feel that the return has been well worth the investment.

Our UNIVACs are turned on for 168 hours each week. This means that we must have the machines manned for operations or maintenance 21 eight hour shifts each week. Our people, like most people, are used to working five 8 hour days a week and there are certain rules and regulations which prescribe their hours of duty. Because there are 21 shifts of machine-time each week and five shifts of man-time each week, we have become accustomed to speak of four shifts of operation. It would be nice if there were four definite shifts of operation. However, this is not the case. Consequently, there must be considerable juggling of assigned hours in such a way that the 21 shifts of machine time get covered by the equivalent of four groups of maintenance people and four groups of operations people. In general, most of our people prefer to work the daylight hours—five days per week. There are occasions when some of our people for some reason or another prefer to work the off-shift time. Maybe the man prefers to work the midnight shift because he is going to school in the day or evening, or maybe he prefers the evening shift in preference to rotating. In the scheduling of our personnel, we attempt to first locate those people with preference for off-shift assignments, and then to assign the remaining people on a rotating basis to cover the remaining positions. We take care of Saturday and Sunday requirements by scheduling for some people two off days in the middle of the week. Our present engineering staff includes two Grade GS-12 Engineers, one Grade GS-11 Engineer, and one Grade GS-7 Engineer; and a staff of technicians, Grades GS-5 through GS-9. We have a chief maintenance technician on duty at all times, and it is the responsibility of this man to continue the scheduled maintenance work when it falls in his shift of duty and to provide emergency service for the UNIVAC and auxiliary equipment as it becomes necessary during time scheduled for productive operations. After a great deal of effort we have finally classified this position as Grade GS-9, Electronic Technician; we now have four people operating in this capacity, although only two of them are presently qualified according to Civil Service standards. The other two are performing a satisfactory job, but because of insufficient time in grade or the absence of some other qualification, are not now permitted to enjoy the Grade GS-9 salary. So we have problems both in the limitations of Civil Service job classification standards and personnel qualifications standards.

In the past few months we have enjoyed an unexpectedly low turnover rate of technical personnel, but we are presently becoming a little jittery again, believing that we are about to be faced with a new series of resignations. Computers are now being purchased by many non-government concerns; and there is a growing field of electronic construction and development in the Washington area. Both of these fields seem to be able to pay more money in general than we are able to pay, and some of them are able to offer more attractive working hours than we are able to offer. Some stigma is attached to the term "maintenance." We find a number of people who are more attracted by the glamour of electronic construction and development than by the routine duties of UNIVAC maintenance.

Physical Facilities

In the same way that we are somewhat restricted by personnel standards, we are also restricted by purchase and procurement procedures. To run an efficient computer operation, it is necessary, of course, to have adequate power, operating area, cooling facilities, supplies, replacement parts and the like. Most of these items fall in the area of someone's else responsibility. With respect to space and electricity, the General Services Administration is responsible for supplying the space and the power for the regular sort of Government activity; but when special services and extra facilities are required, there is a considerable amount of arranging and negotiating necessary to accomplish the desired results. One UNIVAC requires something over 100 kilowatts of electricity. This amount of power is not generally available in an office building at one location, so it was necessary for us to arrange for the construction of a transformer vault and installation of a transformer to supply the necessary power.

The first eight or nine UNIVACs that were constructed depended on their cooling to be accomplished by the circulation of a tremendous amount of air through the central computer and power supply cabinets. Preparatory to the installation of the first UNIVAC at the Census Bureau, it was necessary to negotiate a contract that would cover the installation of adequate air moving equipment, sufficient power, and power regulating equipment, and suitable operations signals and alarms. Since we were to install the UNIVAC in a government building, it was necessary that we go to the Public Buildings Administration and acquaint them with the requirements as best we could learn from the suppliers of the equipment.[3]

The Public Buildings Administration people had to study the problem and work out a plan for the modification of the building and the installation of the necessary equipment. For this we paid a fee. The work developed by the Public Building Administration resulted in invitation to bid and award of contract for the installation of two large squirrel cage blowers, conduits, holes through the floors, an entirely new transformer room, a 750 KVA trans-

[3]The equipment manufacturers' installation manual was not published until some months later.

former, and suitable connecting cables and power control equipment. To push 30,000 cubic feet of air per minute through the bottom and out of the top of the UNIVAC, it was necessary to cut two 30-inch square holes through a ten-inch concrete slab. Other smaller holes were necessary to provide for air ducts and electrical cables.

One of the specifications of the building alteration contract called for the hole cutting to be done in such a manner as to cause no interference with the regular operations in the building. It was assumed that suitable drilling equipment would be procured and that the holes could be bored with little or no interference to people in the neighboring areas. This turned out to be a false assumption. After trying various pieces of equipment and ways of getting these holes through the floor, the final result was that the holes were cut by compressed air jack hammers on a weekend and the contractor had to clean up almost the entire back half of the whole wing in the Census Bureau to get rid of the concrete dust that was everywhere.

With the completion of the building alterations and provisions of power and cooling facilities for the first UNIVAC, we thought that with all this experience we would be in a good position to facilitate the installation of a second UNIVAC when the time came. However, by the time we got around to purchasing our second UNIVAC, the manufacturers had installed a modified system of cooling equipment. It is still necessary to circulate air through the electronic chassis in the UNIVAC; but the circulation is now enclosed in the system and a network of cold water cooling coils has been arranged to keep this circulating air at a reasonably low temperature. Consequently, it is not necessary to cut 30-inch square holes through concrete slabs to install the present cooling system, although some smaller holes are still necessary for electrical conduits. Instead, it is now necessary to provide rather elaborate water cooling arrangements.

Before installing our second UNIVAC, we again had to develop specifications, invitations, and award a contract for the installation of water cooling equipment. We now have installed in the basement of the first wing of Federal Office Building No. 3, about 90 tons of cooling equipment and we have attempted to arrange this equipment in such a way that the failure of any one component would not cut off all the capacity; rather, there would be, by a valving operation, half the total capacity available to the UNIVAC area. In addition to having the second UNIVAC served by the cooled water from this system, there is also a 25 ton air-handler that cools the operating area around the UNIVACs and auxiliary equipment, and there are the two auxiliary pieces of equipment, each of which has its own cold water cooling requirements. In event of cooling equipment failure, we usually are able to keep the UNIVAC supplied with sufficient cold water, although we may have to suspend operation of the card-to-tape machine or the high-speed printer during time of shutdown of the cooling equipment.

The maintenance of the cooling equipment is still a problem for which we are searching for an adequate solution. When air conditioning equipment is installed in a government building, it is by past practice, the responsibility of the Public Buildings Administration to maintain. However, the Public Buildings Administration, in equipping itself for the responsibility of maintaining air conditioning equipment, has not felt it necessary to give the service necessary to keep a large scale computer in operation around the clock. We are currently drawing specifications for the maintenance of the cooling equipment which will probably result in a year's contract with some firm qualified in the air conditioning business to keep our equipment adequately maintained. Perhaps during this period of contracted maintenance our people in the UNIVAC group or the Public Buildings Administration will have the opportunity to get the necessary knowledge and experience to continue the cooling equipment maintenance with government personnel.

Spare Parts and Supplies

One step toward minimizing lost time due to equipment failure is the maintenance of adequate inventory of spare parts. Spare parts inventory as originally recommended by the manufacturer included some $40,000 worth of material. This material was divided into two categories: expendable and non-expendable spare parts. The expendable spare parts list included such items as electronic tubes, fuses, resistors, and the like. The non-expendable spare parts include major components such as chassis, motors, mercury tanks, and the like—all that were thought necessary on short notice but which in general could be repaired at a later time.

Because of a large recommended inventory of spare parts and limited operating funds, three of the UNIVAC owners in the

Washington area established an arrangement whereby it would be unnecessary for each to install all of the spare parts. The arrangement provided that all of the spare parts in the recommended list would be in one or the other of the three Washington installations although not necessarily in all three of them. For example, the Census Bureau has never invested the $7,000 necessary to purchase a standby mercury memory tank because at least one of the other UNIVAC installations in the Washington area had stocked a memory tank. Likewise, there are some items that the Census Bureau stocks that the other installations did not stock for themselves. The really expendable items of course were stocked and will continue to be stocked by all three installations.

Even though we attempt to establish a respectable working inventory of spare parts there continue to be occasions when something goes wrong, and we need some piece of material on relatively short notice. Our procurement people in the Census Bureau, like other normal activities, are in the habit of working eight hours a day, five days a week. But, since three-fourths of the operating time of a large scale computer is outside of this normal 40 hour-week, a great number of problems and special handling operations fall outside the normal hours of the procurement people.

Procurement people, of course, are equipped to provide service according to regular procurement standards; but these standards were not designed to provide for procurement of equipment for large scale computers, nor were they designed to provide service on a few minutes notice. Needless to say, we have had a number of problems in this area.

We have also had difficulty in procuring parts and materials from the only known source of supply, the manufacturer of the UNIVAC equipment. For one reason or another, perhaps the pressure of delivering new computer UNIVACs to new customers, the UNIVAC people have not always been in a position to supply spare parts or emergency service on immediate demand. On occasion we have had to by-pass our own procurement people and local factory representatives by telephoning emergency requests directly to representatives at the Philadelphia plant, and once went so far as to send one of our programmers to Philadelphia in her own plane to pick up a part. I believe our longest down-time period due to difficulty in getting a replacement part was something like 32 hours, and there have been perhaps eight other lost time periods of a few hours due to delay in getting spare parts.

Magnetic tape is a problem and probably will be for some time to come. Most large scale computers use a plastic tape with an oxide coating as a medium for introducing instructions and data into the system and for recording results produced by the system. The UNIVAC system, however, uses a metal tape which is not available from any other source of supply. Metal tape is a phosphor bronze base with a plating designed to give good magnetic recording and reproduction. Metal tape costs three to four times as much as the same footage of plastic tape. It, however, is thinner than plastic tape; and, therefore, one reel can hold more material than the same length of plastic tape. Recently, plastic tape developments have produced a material called mylar which has sufficiently good durability and tensile strength to make a good base for oxide coating for computer magnetic tape uses. We are currently experimenting with the new mylar magnetic tape, and we believe that we may develop an arrangement whereby the mylar tape and metal tape may be interchangeable.

There are reasons for wanting to use plastic tape other than just the fact of lower cost. The original contract with the UNIVAC people provided for an arrangement which would permit the Census Bureau to purchase up to 5000 reels of metal tape. By the middle of 1952, the Census Bureau had taken possession of approximately 2000 reels of tape, and we were already having difficulty in getting additional tape from the manufacturer. However, a manufacturing facility had not been supplied to take care of both the Census' anticipated requirements and the requirements of the other customers whose demands at that time were becoming pronounced. The manufacturer later increased production facilities, and as of the early part of this year was stocking a relatively large amount of tape in Philadelphia. As the demands of the Economic Censuses, which we were about to process, indicated that our inventory would have to be expanded to several thousand reels larger than we then had, we notified the supplier of our estimated requirements and we were assured there would be no difficulty in meeting them. As a matter of fact, for several months they were able to make delivery on all metal tape ordered on reasonably short notice. However, the inventory of spare tapes was exhausted in Philadelphia this last summer and our own calculations seemed to have been somewhat short of actual requirements, so that during the past three or four months we have been fighting a disturbing shortage of sufficient magnetic tape. Tape, of course, is reusable; but if the information that is stored on the tape is to be retained for some other use, this tape will be tied up and not available for current processing work. To help get around the difficulties of short tape supply, we have packed tapes in an attempt to reduce the amount of total number of reels necessary to store certain information so that the blank tape at the end of the reel is made available for storing information that was already stored at the beginning or front of another reel. This, of course, takes valuable UNIVAC time and requires some arrangement of suitable controls and records to keep tab where the information was stored.

Tape as originally delivered to the UNIVAC was coated with a thin film of oil to reduce the friction and wear of tape over the reading and writing head and also to provide a protective coating against corrosion. However, experience with oiled tape showed that we were going to have to replace the $1,200 writing heads rather frequently unless an improvement were developed. This improvement turned out to be the installation of a thin film of mylar plastic tape between the reading head and the metal magnetic tape. The function of the mylar spacer, which moved across the head at the rate of ten inches per hour, was designed to absorb the wear that the heads otherwise were taking. Prior to the installation of the mylar we had replaced some 11 heads due primarily to the effect of magnetic tape wear on the head. However, the installation of the mylar spacer was not the complete solution to the problem. The mylar spacer itself, because of the static charge that it developed, was an excellent attractor of dust and dirt in the air, which the blowers in the tape unit were pumping through a hole directly behind the magnetic head. The oil on the tape, too, seemed to have an affinity for dirt; so, that a complete tape cleaning and deoiling operation was necessary after the installation of the mylar spacers. This was accomplished on our inventory of 2,000 reels in Philadelphia. Since then we have manually cleaned exceptionally dirty tape as it has developed. But as of now we do not have an organized tape cleaning program. We continue to operate with the tape clean or dirty as best we can. We have a number of tape breakages which are repaired as they develop. The tape may break in the middle, in which case we have to splice it and identify the spliced area by punching small holes on either side of the area which serve as signals to the reading and writing mechanisms to suspend reading and writing in the area between the holes. Broken clips and broken leaders occur, and these, too, are replaced by our technicians. Folds develop in tape which do not interfere with the mechanical processing of the tape through the tape units, but the fold itself may produce an area where it is impossible to procure good reading and writing characteristics. When folds are encountered, they are also identified by holes punched on either side.

Program Planning and Coding

For the most efficient operation of a program on a large scale computer, it is important that the details of a program be well planned out in advance; that they cover the exceptional situations as well as the general; that they provide adequate coordination between the various steps of the overall program and that there will be suitable checkpoints or means of establishing the adequacy of the program prior to its use in a tight production schedule. I would guess that to date the Census Bureau has expended something between 60 and 80 man-years of programming effort. A year ago we had in the central programming group 8 programmers—most of them with a great deal of programming experience. However, the problem of preparing programs for the Censuses of Business and Manufacturers created a demand for a much larger number of people to provide adequate operating programs. The central programming group conducted a training program which resulted in UNIVAC programming techniques being given to 50 or 60 employees of the Census Bureau who were already operating in the subject matter divisions and in the fields that were to be covered in the new censuses. This training program was quite successful and there are now in the Census Bureau 25 or 30 good programmers engaged in translating the requirements of their own subject fields into UNIVAC instructions. Our own central group has dwindled to 3 persons partly because of the necessity of detailing some of the people in it to cover the immediate requirements of the current Economic Censuses. The intended function of the relatively small central programming group is that of providing guidance and training for people newly recruited into the field of UNIVAC programming; to provide a source of information and a point of dissemination of new techniques and procedures developed in the group or in other UNIVAC installations; and to conduct research in the area of new programming techniques to meet general requirements, new programs to fit to new equipment, or to evaluate proposed improvements to existing equipment and to develop requirements for new features to be added to existing equipment.

Even though we have a number of people who are experienced UNIVAC programmers at the Census Bureau, we believe we still have considerable to learn about predicting UNIVAC capacity, program time requirements, and so on. We still fail on the side of underestimation of time necessary to produce operating programs, and UNIVAC time necessary to process the data after programs are developed. We are learning in this area, but as of the present, we do not have adequate standards for making good estimates of program requirements.

Scheduling

There are a number of problems in scheduling time on the computer. Some programs operate on a very tight time schedule and must be processed a short time after the receipt of the data. Our monthly current population survey is a good example. We attempt to produce final results from UNIVAC within 3 or 4 days of the receipt of the data to be processed on punch cards. The whole month's operation takes something less than 40 hours of UNIVAC time but it is necessary to coordinate card-to-tape operation, UNIVAC time, printer time and the time of the subject matter people who must be present to give immediate answers to subject matter problems that may arise in the processing operation.

Other jobs, particularly those requiring much more time and lasting for longer periods, can be scheduled in such a way that the bulk of the work is done in a routine manner during weekends or night shifts when it is not necessary for subject matter people to be in attendance. Since maintenance of the computer must be fitted in with requirements of the operating programs, we have established some general rules which we use to guide us in establishing the monthly schedule of time assigned to each of our customers.

Even after we have established what seems to be a reasonably good schedule for the following month, there always seem to be a number of problems and emergencies which arise that require special attention. When these do arise, it is necessary to do some juggling with the assigned time and attempt to get some degree of mutual agreement on a revision in the time schedule. If this results in a customer not having to come in to run his program early Sunday morning, he is generally happy but if it requires that we change his assigned time from Friday day shift to midnight Saturday night, he is occasionally not very pleased with the new arrangement.

It may be interesting to note that when we were selling a large amount of our UNIVAC time to customers outside the Census Bureau, the scheduling and rescheduling of time seemed to be easier to accomplish than when we have to reschedule only among employees of our own Bureau. This must be due in part to the fact that people without a computer are anxious to get time at almost any cost or hardship but that the people with the computer think the tool should be used to serve their needs and conveniences rather than enslaving them to its own unreasonable hours of operation.

Auxiliary Equipment

I would like to discuss a few problems in the field of auxiliary equipment. At the time we took possession of the first UNIVAC we also took possession of two devices designed to translate information from IBM punch cards to UNIVAC magnetic tape. Instead of using card reading units that were already in existence and doing a good job, the UNIVAC engineers undertook to build a new card reading device that would read the cards, short edge first, a column at a time so that the information could be transcribed to magnetic tape a column at a time without the need for a storage device that would have been required if the cards were fed broad side first on conventional equipment. The objective is understandable but the result was by no means a success. However, we did struggle along with these two card-to-tape converters and were successful in converting several millions of cards to magnetic tape. There was a great deal of down time on these pieces of equipment and in general we had to process all of our cards at least twice to get acceptable tapes for processing on UNIVAC. This means that we were using a three quarter million dollar testing unit to establish the adequacy of the output of a 40 thousand dollar unit and we were wasting additional UNIVAC time in attempting to salvage card-to-tape output that was almost good enough. The UNIVAC people have developed a new card-to-tape converter which feeds cards in a conventional manner, stores the information in memory and, after having transferred the information from memory to the magnetic tape, it rereads the information stored on tape twice—once to establish its readability and certain relations between good signals and bad signals and once to match what has been recorded on the tape back against a set of data stored in memory from a second reading of the card. This unit has turned out to be a reliable unit although it has two limitations over that of the older unit. One is that the speed has been reduced to provide for the time necessary to start, stop, and reverse the tape after each card. The other is that the number of cards that can be stored on one reel of tape is now of the order of only 5,000 whereas over 10,000 cards could be converted to one reel of 1,500 feet of tape on the Mod-1 converter.

We still have a problem in procuring adequate high speed printing equipment. Three years ago, we let it be known around the industry that we were interested in equipment with greater printing capacity and we provided certain broad specifications for equipment that we thought might meet our needs. These exploratory efforts resulted in an invitation to bid on our specifications for a printer to meet our requirements, and award of a construction contract to a company in Summit, New Jersey. At the time this award was made, we were confident that it would produce a new printer that would meet our requirements, and well ahead of any other source of printing equipment. We were partly wrong in that there is now on the market a respectably good high speed printing device which reads UNIVAC tape, while our own printer will not be delivered to us at the Census Bureau until sometime after January 1, 1956. We believe that our contract with a competitor was at least partially responsible for an earlier delivery of the Remington Rand printer that is now used in several UNIVAC installations although we are still quite confident that our own printer, when installed, will have certain features which will make it much more useful to us.

I have previously mentioned the effort to standardize the use and interchangeability of plastic magnetic tape with metal magnetic tape. Because of certain methods of production in the plastic tape plants, the tape comes to us on a reel that is seen frequently in the audio recording business. This reel has a larger capacity for tape but more important it has a different inside mounting hole diameter. Our own engineers have developed a new reel mounting chuck that is capable of accepting the standard 8 inch UNIVAC tape reel as well as the new 10½″ plastic tape reel. In developing this new chuck capable of accepting either type of reel, our engineers have also succeeded in developing a clamping arrangement that required no special nor additional finger movements to engage the reel on the servo. The mounting operation is simply to push the reel on to the chuck and the dismounting is simply to pull the reel off the chuck. This saves only a few seconds for each reel mounted but it is nevertheless in the direction of making more efficient use of the equipment.

There are a number of non-maintenance areas in which we would like to have our electronic engineers and technicians spend time. Not only because these areas need development but also because the engineers and technicians themselves like the development sort of work which is a good relief from their routine maintenance duties. However, the limited number of qualified personnel and the heavy work schedule have meant that we could afford very little time to be spent in the development area. Engineering development has always taken second priority to that of keeping the maintenance staff trained and the equipment in operation.

Conclusion

Having listed a number of problems in the operation of data processing equipment, it is evident that this is an excellent area for operations research. There is an opportunity for experts in the field of statistical analysis and evaluation to apply their techniques to solving the recurring problems in the operation of large scale equipment.

The Census Bureau has pioneered in the use of large scale data processing equipment. Some of the problems described above are due to the lack of experience by the manufacturer, government service agency, and the Census Bureau itself. Many are continuing problems, however, and have been presented that other users may profit by our experience to achieve maximum success in the utilization of this important equipment.

ORGANIZATIONAL EFFECTS

WALTER FRESE

Formal organization structure is one of the more rigid aspects of administration. Changes in organization structure are infrequent in most organizations because informal adjustments are usually sufficient to accommodate changes in demands on the organization. This is particularly true in those instances in which the changes affect only a single unit of organization.

The introduction of electronic data processing systems, however, requires such basic changes in personnel and procedure that changes in formal organization structure must be expected. In addition, substantial changes in working relationships between organizational units should be anticipated. The data processing center itself requires the establishment of a new organizational unit and it may change substantially the nature of units with which it is closely associated such as punched card processing units and report preparation units.

Assuming that these generalizations are correct, a new order of interorganizational cooperation and teamwork is required. A highly flexible approach to organizational adjustment to the new system is essential.

Certainly these observations seem to be applicable when EDPS is introduced into accounting operations. Traditionally, the functions of budgeting, accounting and auditing have been separate processes. Fortunately, trends of recent years have led to integration of these three processes and the concept of financial operations for maximum usefulness to management. As George Stickney has noted, it was only in 1949 that the major Federal agencies embarked upon a joint accounting improvement program in which the chief budget, accounting, and auditing agencies participated.

The emphasis of this joint accounting improvement program has been on developing accounting as a useful management tool in each of the many diverse areas of management responsibility in the Federal Government. A corollary objective has been to eliminate or simplify central accounting and control processes. Many improvements in Federal accounting from both of these viewpoints have been made since the program began. The development of an electronic data processing approach to the payment and reconciliation of Federal checks is one of the most dramatic accomplishments of the program. It involves the application of new techniques to mass accounting and auditing processes which, while they affect all agencies of Government, can most effectively be performed on a consolidated basis for the Government as a whole.

The payment and reconciliation of checks directly involve both the Treasury Department and the General Accounting Office. About 755 (under the new program 270 employees will be needed) persons are directly involved in present operations for payment and reconciliation of checks in these two agencies. Of this number about 370 are engaged in operations pertaining to the "payment" of checks in the Treasury Department and 385 are involved in processes pertaining to the "reconciliation" of checks in the General Accounting Office. Under the electronic data processing system, the processes of "paying" and "reconciling" checks are brought together in one integrated system in the Treasury Department.

It is significant to point out here that while there has thus been, in effect, a transfer of processes from the General Accounting Office to the Treasury there has been no real transfer of functions. The General Accounting Office will continue to audit and settle disbursing officers' accounts, based on reconciliations of checks paid against checks issued, and other factors. It will, however, be relieved of the necessity for going through the detailed work involved in reconciling individual paid checks against related check issue records, etc., since this will be performed as one part of the integrated electronic payment and reconciliation operation in the Treasury Department. Assurance that adequate controls are built into the Treasury system, as a result of cooperative systems development work and periodic reviews of procedures in operation, provides the basis for eliminating the many detailed processes now performed in the General Accounting Office in connection with its function of auditing and settling disbursing officers' accounts.

It is thus obvious that this change in basic approach to the performance of functions and the related transfer of detailed operations, reduction of personnel and general change in procedure will have a very significant organizational impact on both the General Accounting Office and the Treasury Department. In the General Accounting Office it will, of course, mean the complete elimination of the present large-scale mechanical operations (on conventional punched card equipment) for reconciling card checks as well as the clerical processing involved in reconciling paper checks. In the Treasurer's Office where the new integrated operations will be established, a complete reorganization is involved. In the Check Payment Division of the Office of the Treasurer of the United States, the Bookkeeping Branch with 15 employees is eliminated; the Card Check Branch with 49 employees is eliminated; the Electric Accounting Branch will be increased from 15 to 50 employees; the Examining Branch with 61 employees is eliminated; the Proving Branch with 69 employees is eliminated; the Reconciliation Branch with 7 employees is eliminated; the Sorting Branch with 44 employees is eliminated and the Statement Branch with 82 employees is eliminated. However, several new branches are formed: Receiving Branch; Electronic Branch (Data Processing); a new Reconciliation Branch; Files Branch, Control Branch and a Messenger Branch.

The organizational influence extends far beyond the Treasury Department and the General Accounting Office. For example, provision had to be made for significant and fundamental changes in the processing of Federal checks by the 12 Federal Reserve Banks and 24 branches. These changes were all in the general direction of simplification. Among other things, the new procedures make it possible to eliminate (1) transfers of various checks from one Federal Reserve Bank to another; (2) the sorting and arranging of checks according to disbursing accounts, serial number, etc.; and (3) the preparation of statements (including listings of paid checks) for various disbursing accounts. These changes stem from the fact that under the new procedures all checks are "paid" by the Treasurer of the United States at the central point, whereas under present procedures most of them are "paid" by designated Federal Reserve Banks acting as agents for the Treasurer. This centralization of "payment" is made possible by use of the electronic data processing procedures for an integrated payment and reconciliation operation and would not be feasible, because of the large volume involved, with present techniques.

In order to achieve the new system, it is also necessary to deal with the problem of integrating the procedures for preparing the checks with the basic changes that had been worked out in the processing of the checks after they had been disbursed. While the procedural changes in this area are not great, they involve the procedures for 3,000 disbursing accounts, which are subject to the administrative control of about 75 Federal agencies. These include such far-flung activities as the disbursing accounts of Navy officers aboard ships, and Government officers drawing checks on the Treasurer of the United States in foreign countries.

A key problem in synchronizing check issuing procedures with the revamped procedures for processing checks after they have been disbursed relates to the procedures of those disbursing officers who have not been issuing checks in punched card form. For the past four years, representatives of the joint accounting improvement program of the three central fiscal agencies in consultation with representatives of major disbursing agencies where checks were still being issued in paper form—the Department of Defense, the Post Office Department, and certain others—have been working on this problem from two points of view: first, to convert all issuing operations where it was feasible from the standpoint of volume and other considerations to the issuance of checks in fully punched form; secondly, to develop procedures which would permit mechanization in the processing of paid checks for those disbursing officers where it was impracticable to issue the checks in the first instance in fully punched form.

Very substantial progress was made in the first area in bringing about conversion of paper checks to punched card checks. Between 1952 and 1955 an additional volume of about 33 million was converted from paper to fully punched card checks. In 1955 about 12.5% of the total number of checks issued were still in paper form. Incidentally, the cost for paying for this 12.5% of the total checks was approximately 63% of the total appropriation to the Treasurer for paying all checks.

It is, of course, obvious that the electronic data processing procedures for paying and reconciling checks required a solution to the problem of getting the remaining 12.5% of paper checks into punched card form so that they would be compatible with the remaining checks. The problem was solved with the close cooperation of the Accounting and Check Subcommittee of the Federal Reserve System. Under the plan which has been approved, all disbursing officers for whom it is impractical to install procedures for preparing checks in fully punched form will issue a new form of card check which will require no punching at the point of issue. From the point of view of the disbursing officer who issues the check, it will be inscribed as to payee, amount, etc., as if it were a paper check. These checks will, however, be prepunched at the time of manufacture to identify the serial number, disbursing office, and other constant information. The amounts will be punched by Federal Reserve Banks when they receive the checks through the banking system during the course of their check clearance operations. Thus, when the checks are received at the central facility in the Office of the Treasurer of the United States for electronic processing for payment and reconciliation, they will be completely compatible with all other punched card checks.

As one reviews the pattern of organizational relationships and the organizational changes required to make it possible for a system for centralized electronic processing of 350 million checks annually, it seems remarkable that it was accomplished. It could only have been accomplished by the fullest cooperative spirit of the personnel of many organizational units.

It is perhaps significant to make one further point in connection with the organizational impact of these new procedures. This deals with the question of centralization versus decentralization. For the past eight years, the predominant emphasis of the Joint Program to Improve Accounting in the Federal Government has been one of decentralization of accounting for management. The objective has been to establish the accounting systems at the points where management responsibility has been placed for the conduct of operations so as to make them responsive to day-to-day management needs. The basic idea is to establish effective internal controls within the many operational entities of the Government and take care of the needs at higher levels through reporting and review processes. This must continue to be the basic objective of the joint program if it is to accomplish its fundamental purpose of making accounting a dynamically useful management tool.

At first glance it might appear that the centralization of the check reconciliation operations is inconsistent with this general policy and trend. It might be, and has been, argued that reconciliation of disbursing accounts (which, of course, involves comparison of paid checks with issue records) is a basic element of internal control of the agency responsible for making the disbursements. Therefore, it could be contended that paid checks should be sent back by the Treasurer of the United States to the agencies responsible for making disbursements for reconciliation of their disbursing accounts as a part of their internal control over disbursing activities. Fundamental analysis of the problem, however, disclosed that the clerical work involved in handling the processing of paid checks at these diverse points would contribute nothing of substance to the real objectives for decentralizing accounting for management needs. On the contrary, by injecting necessity for the clerical effort involved, it would tend to becloud the real purpose of decentralization of accounting which should emphasize providing management, as a basis for decisions, with useful and reliable data with regard to the programmed and actual costs of the operations for which it is responsible and the effectiveness with which assigned responsibilities are being carried out.

Thus, the centralization of these vast clerical processes involved in the payment and reconciliation of Government checks cannot in any way be regarded as incompatible or inconsistent with the established policy and objective of decentralization of accounting for management. On the contrary, it has facilitated real decentralization in the light of its true purposes.

I foresee many of the applications of electronic data processing as achieving even greater progress toward the goal of integrated systems of programming, budgeting, accounting and reporting for management at its many diverse levels in the Federal Government. Use of electronic processes to eliminate from decentralized accounting systems clerical work and routine processes which can more effectively be performed at more centralized locations is one important element in achieving this goal. By removing the cloud of clerical work, such changes point up the real purposes in the development of management information. This will contribute substantially to the even broader goal of taking advantage of the potentialities of electronics for increasing the scope of useful information which it will be possible to develop for effective management and control of the many diverse and complex activities which comprise the Federal Government.

Realization of these goals, however, will require a high degree of interorganizational teamwork and a willingness to work objectively and open-mindedly on organizational changes in the light of the real ends to be achieved and the means which are available to achieve them.

EXECUTIVE PROBLEMS AND OPPORTUNITIES ARISING OUT OF AUTOMATIC SYSTEMS

LEO C. SIMMONS

Developments in Data Processing

Within the last few years we have witnessed a profound change in methods of data processing, a trend toward mechanization and mass production somewhat like the technological development which has produced our complex and highly-mechanized modern industries.

Few of us stop to realize that only about 100 years ago all accounting was carried on solely by hand-writing and mental computation. Mechanization began with the adding machine and desk calculator, which eliminated the necessity for human computation but still relied on human operators to enter the data and assemble the results. The various posting and special-purpose machines have speeded up the process, but have not affected its fundamental nature.

In the early part of this century the invention of punched card accounting made available a process by which the manual assembly and entry of data could be eliminated to a great extent in the processing of large volumes of data. When data had once been manually recorded on punched cards, an operator could use the cards in a sequence of data processing operations, carrying the cards from one operation to another and directing the processing.

Within the last few years, however, three new developments have made possible another great change in data processing, by which it is possible to eliminate much of the human effort remaining.

One of these developments was the Electronic Computer, a machine capable of performing a large number of operations at almost incredible speed, and also directing within itself a series of processes in a predetermined pattern, so that operator control and handling of data is reduced to a minimum.

Secondly, there are the automatic production recorders and similar machines, designed to create the original accounting data in mechanical form at the point of origin, without human effort.

The third development is the Integrated Data Processing concept, whereby an entire accounting process from raw data to finished result is carried out by machines, either the new types described or modified conventional machines, capable of accepting data in mechanical form such as punched cards, punched tapes or magnetic impulses, processing such data through operations which are largely prearranged and automatic, and delivering the result in a mechanical form which can be accepted and used by the next machine in the process.

These new developments have given us the means and the techniques by which the creation and processing of accounting data can be made substantially automatic and free from human effort. There are two areas, however, in which human effort is still essential and probably always will be. One of these is the planning, the other the use of accounting data. Individuals must determine the way in which data will be processed and prepare the instructions which the machine will follow, and someone must assemble the results for use in the decision making. Despite the claims that the "giant brain" can be a thinking machine, no techniques have yet appeared by which a machine can think and apply judgment. Thus, the procedure specialist and the management or analytical accountant remain as the human essentials in the mechanical accounting process, and completely automatic accounting has not been and probably never will be achieved.

The reduction of human effort through a high degree of mechanization greatly increases the importance of the human elements remaining. The methods of processing and the direction of the machines become of primary importance. As accounting becomes less a matter of quantities of human labor and more a matter of planning and control, a change occurs in the character of the accounting organization, and the executive becomes less the director of a working force and more the leader of a team of planners.

This shift in emphasis from the line accounting to the staff functions presents one of the problems of automatic accounting. Even in the short time since we undertook the use of these new techniques, we have begun to feel the change in our organization. Our general office procedure division, for example, which handles the planning and programming for the electronic computer, as well as for the Integrated Data Processing Program, has greatly increased in size within the last two years. Correspondingly, executive attention has had to be directed much more toward the planning functions.

The shift from manual to automatic methods of data processing, of course, brings problems of human relations. A machine which does the work of ten men seems at first glance to have displaced ten workers. Actually, this may not be so. The history of technological improvement in industry has repeatedly shown that machinery which reduces the amount of labor required to produce a commodity has resulted in decreased costs and subsequent increased demand. Our steel mills which formerly employed an army of unskilled laborers now employ an even larger force of skilled machine operators, mechanics and technicians. There is some indication that this same trend may be true in the accounting process. The demand of top executives for fast and accurate data on which to base their decisions has no perceivable saturation point; it has in the past been limited by the high cost and sometimes the physical impossibility of producing digested data at the time and in the form of its greatest utility. Moreover, the demands of business and government on the accounting function are constantly increasing and becoming more complex. It is entirely possible that the end result of the mechanization of accounting will not be decreased work, but more, better and cheaper accounting and statistical information.

Even if mechanization does not involve a displacement of workers, it may involve a radical change in skills required. Automatic accounting requires fewer key-pushers and more trained mechanics and planners. Workers will have to be trained in new skills, and the adjustment may in some cases be difficult. There is no doubt, however, that for those who make the change, the future will be considerably more rewarding, both in money and in job-satisfaction through the use of greater skills.

Experience with an Electronic Computer

An example of the way in which this process works is found in our own experience with the electronic computer in the National Tube Division of the United States Steel Corporation. Installation of this computer required trained operators and a large number of trained programmers. Programming, which is the preparing of instructions to which the computer will respond, requires a considerable knowledge of accounting procedures and techniques, and for this reason, our programmers were drawn chiefly from our procedures personnel. To replace them, other persons from our accounting organizations were promoted to procedures work. We have made an effort to draw our machine operators from the group which will be most directly affected by the computer's labor-saving speed; others in this group will be absorbed in the accounting organization in place of those upgraded as previously described. Of course, there is always some reduction in the number of persons in any group due to natural turnover; this will help to solve the problem of displaced manpower.

All of these persons affected by the changes must, of course, be trained in their new jobs. Our programmers, computer operators and procedures men working with the computers are given a course of about six weeks in computer logic and circuitry. The programmers then receive several more weeks of specific training in programming techniques, and the computer operators are gradually trained in actual operation, under the guidance of a skilled operator.

New jobs must also be learned by others in the Accounting Department who are assigned to new work as the result of the organization changes described. With us this has for the most part been "on-the-job" training by the supervisors; we have not yet found it necessary to introduce formal training programs.

What new training or development of new skills is required of the executive who undertakes a program of this sort? Certainly some changes will be required in his habits and thinking. With each forward step in the mechanization of accounting, his problems concerning the accuracy of performance become less and problems concerning the correctness of method will increase. At the same time, in the same way that he has already delegated responsibility for performance to line supervisors, he will now have to delegate more responsibility for methods and to rely heavily on the recommendations of his methods supervisors. Moreover, thinking in terms of mechanical handling of great volumes of data is quite different from thinking in terms of manual handling of data.

It is possible that for some executives these changes might be acute, especially in an organization moving directly from a largely manual operation to the high degree of mechanization represented by an electronic computer. In our organization we did not find it to be a severe problem. We have had for many years a highly mechanized accounting operation, using punched card equipment to a very great extent. As a result our executives and staff leaders were already "machine minded," and the changes wrought by our computer were no revolution but rather an intensification of a way of thinking to which they had become accustomed.

Actually, the degree of technical knowledge of computers and computer processes, required of a top executive undertaking a computer program, is not as great as one might suppose. It is essential that he be able to think in terms of the mass handling of data; it is essential that he be familiar to some extent with the technical language of computers; and it is essential that he have sufficient knowledge of the equipment and the operations so that he can understand the problems presented to him for decision. Beyond this, he will learn to rely on his subordinates, who have the real burden of acquiring technical skills. We believe that an executive who has a good background in punched card and other machine accounting methods and the ability to think in terms of machine processing, can acquire the additional background which he needs largely by self-education without formal training aids.

Another type of organization change which arises as a result of the adoption of large electronic systems, concerns the centralization of activities which usually accompanies the installation of such devices.

In recent years the trend has been toward decentralization of accounting functions. The difficulties of supervising the processing of ever-increasing quantities of data have led to an increasing tendency to permit each organizational unit to handle its own work and be responsible for its own results.

With the installation of a large scale computer, this trend is at once reversed. Due to the tremendous capacity, it is usually necessary to concentrate all the work of one kind in one location in order to justify the cost and effort and secure the maximum results from such a installation. The idea of such "data processing centers" appears to be gaining in acceptance as shown by the publicity being given to the computer installation at General Electric and the proposed installations at Sylvania Electric and the C&O Railroad.

This centralization raises several problems. The most obvious one arises from the situation where the plant executive is given, to incorporate in his own accounts, final figures concerning his own operations for which he must be responsible, but in the processing of which he has not had complete control. While it is true that plant management could be serviced by centralized computing centers in exactly the same way as they were originally under a local service set-up such as punched card machines, a great deal of the effectiveness of computer processing would be lost. This would necessitate the printing out of many intermediate results of no direct value to the computer process.

The answer to this problem appears to be in the realization and acceptance by top management of the relationship of a data processing center to the organization as a whole. The Comptroller has had to rely on subordinate executives for the correctness of their part of the company's accounting; he will now have the additional responsibility of assuring that his data processing group performs their function correctly, and the subordinate executives serviced by this group must rely on this assurance.

Another problem arising out of the centralization of accounting through the use of automatic systems is in the communication between central headquarters and the outlying locations. There is a great need for improved communication devices which will handle large volumes of data rapidly and at low cost. Some experience has already been had with telegraphic transmission of volumes of data. For example, the Coal Division of U. S. Steel Corporation receives time and production data by wire from several scattered mines, processes these data at one location into separate payrolls, and re-transmits the completed payroll data by wire to the originating locations. Such a system is practical with present equipment, however, only because the total volume of data is relatively low. To transmit with present equipment the data for a payroll of thousands of employees, for example, would be wholly impractical in the time available. Present communication systems are designed to handle relatively short messages at relatively slow speeds. Much has been done in recent years to simplify the problem of transmitting data in a form which is immediately reusable and in the conversion of transmitted data to a machine sensible form. The speed of transmission has also been somewhat improved, but it is still out of the question to think in terms of loading a large scale computer with input data transmitted solely by wire.

Opportunities for Computer Applications

Although the introduction of these new techniques of mechanized accounting does bring us many problems, the real challenge to the executive is in the opportunities which they present. The two goals of any executive are, of course, either cost reduction or a better product; to the accounting executive, "better product" means better service to management through more useful and more timely accounting information. The new accounting techniques I have described offer us opportunities for both, and our organization has undertaken or is planning several programs to take advantage of these opportunities.

Since these new developments are primarily techniques of data processing, our first programs are those involving large volumes of data. Our biggest effort has been the conversion of payrolls to a large scale electronic computer. We have centralized, in Pittsburgh, the wage payroll processing for our entire Division, including wage employees in six plants located from eastern Pennsylvania to Indiana. We are converting to the computer by stages. The Gross-to-Net payroll processing for the first plant started in February, 1955; by June this phase was being handled for all plants. At present, we are handling the entire payroll processing for three plants, including the compilation of gross earnings, gross-to-net computation, labor distribution and statistical reporting.

Some may question the selection of payroll as a first computer application. It is true that payroll has many more complexities than other routine accounting functions and requires a tremendous amount of programming effort. However, to us, it represented the most immediate application in an area where increased efficiency seemed possible. In addition, our payroll system was already almost completely mechanized on punched cards, which greatly facilitated the conversion to a computer operation.

In the field of Sales Accounting, we likewise expect to get both cost reduction and better accounting results through Integrated Data Processing. The Integrated Order-Invoice System now being made ready for installation in our Sales Offices and plants makes use of punched paper tapes as the means of communication between machines at various locations. Orders will be written at the Sales Offices with Flexowriters, which are electric typewriters capable of reading and punching paper tapes. Each Sales Office will be furnished with pre-punched, customer-consignee tapes for each customer in its district, and with product tapes containing the description of each item which such customers might buy. To write an order, the clerk selects from a file the proper customer and product tapes, and enters manually on the keyboard only the variable information such as quantity and shipping dates. As the machine writes the order, it also punches two tapes containing all the information on the order. One of the tapes is used at the plants to write the invoice and the other is used by the General Office for automatic entry of sales statistics information to be processed by the computer. Since all statistical coding for customer and product is in the pre-punched tapes, errors in coding are eliminated. Similarly, neither the Billing Bureau nor the Data Processing Bureau can make any error in transcribing information from the order. By eliminating a large amount of transcribing of data and all of the statistical coding process, we will effect cost savings, produce our invoices and sales statistics more promptly, and eliminate most of the possibility of errors in transcribing or in coding information. Moreover, we can in the future undertake transmission of the punched tapes by wire, speeding up the order processing and improving our customer service.

It is also possible through the proper use of the data obtained from this system to schedule plant operations. It is necessary, of course, to synchronize product requirements with production and equipment efficiency standards. However, the electronic computer through its tremendous speed and flexibility is capable of performing these operations on a daily basis, if necessary, so that management can schedule production with a minimum of clerical effort.

We have also embarked on a similar program by which all clerical operations in the Stores-Purchases-Accounts Payable cycle can be handled mechanically in accordance with the Integrated Data Processing principle. Our present plans call for inventories maintained on punched cards or magnetic tapes, which will be processed mechanically to give us the priced inventories, stock status reports (replacing item ledger cards), consumption and usage reports and stores materials cost distribution. During the inventory processing, re-order points will be detected and requisitions prepared mechanically. A punched card or tape produced with the requisition will be used to prepare the purchase order and receiving reports mechanically. Cards or tapes prepared from the vendor's bills can be mechanically associated with those for the purchase order and receiving reports, achieving mechanical checking of the vendor's invoices, including price and extensions. Finally, the cards or tapes for the checked invoices can be used in the mechanical preparation of Accounts Payable checks and the purchases cost distribution. Thus, the clerical portions of the entire inventory and purchasing cycle can be made virtually automatic, eliminating a great amount of transcribing of data, hand posting, comparing and checking.

In the application of automatic systems to the clerical process, one very promising field hitherto largely unexplored is the basic plant recording where we feel greatly increased efficiency can be secured. Until mechanization can be accomplished in this area, much of the possible effectiveness of integrated data processing is lost.

Our program calls for the design of equipment which will automatically record production information in a form, such as punched paper tape, which is usable in a mechanical accounting system. While our efforts in this regard are largely in the development stage, we have progressed on one project to the point where satisfactory results can be expected.

This project involves the installation of an electronic weighing, measuring and recording device at one of our seamless pipe mills. As each piece of pipe passes across the cooling table it is weighed and measured by the machine. The weight per foot of each piece is calculated automatically and flashed to an illuminated numeral board visible to the mill operator. The operator can thus control the wall thickness by rolling longer or shorter lengths as necessary. Since pipe is sold on a footage basis, it is important that heavy walls be avoided and that maximum footage be obtained from each piece of steel. In addition to the control of weight per foot provided by the electronic device, the data for each piece are recorded in punched paper tape, which includes totals taken at necessary points such as the end of an order or the end of a shift.

Although our emphasis so far has been on adapting these new data processing techniques to routine accounting functions, we are well aware of the opportunities which they offer in other fields. In the engineering field, for example, I have known of instances where engineers have spent months attempting to solve complex mathematical problems, which could be solved in minutes on modern electronic equipment. One example of this was the service we were able to give to our engineers in the designing of an improved eliptical gear controlling the shearing operation on tin plate lines. The usual shear design created mechanical unbalance at high speeds and made it impossible to attain the production rates for which the line was intended. This shear design had been a problem for some time and the engineers had the formula for calculating the required gear shape, but the calculations required were so complex that more than two man-years would be required to solve it on conventional calculators; and several attempts at solution had been abandoned because of the apparent impossibility of insuring against errors.

As a computer problem, one of our men spent a half-day with the engineers in charting the problem. Two men then took the problem to the manufacturer's service bureau in New York where with the assistance of expert programmers and mathematicians, the computer instructions were compiled in two days. The problem was then solved on our computer the next day in 2½ minutes, giving an answer which was absolutely accurate and in a form which could be turned over directly to a gear manufacturer.

A service of this sort should be thought of not only in terms of the cost savings, but also as a contribution to more effective use of skilled manpower. We know there is a critical shortage of engineers in this country; here is a way in which years of time of skilled technical men can be freed from routine tasks, so that their skill and training can be put to more effective use in planning and control.

Although the immediate result of this problem was a saving of two years in engineering time, the indirect benefit gained through improved productive efficiency can be tremendous. This increased efficiency could conceivably result in reduced facility requirements and consequent savings in capital expenditures.

Through even a single instance of this kind we are able to catch a glimpse of almost endless horizons. Beyond our present goal of better and cheaper accounting lies the over-all company goal of better and lower cost production. With our computer we can supply management with technical information, optimum plans and data on suggested production methods and cost, not practical with manual or punched card equipment because of the prohibitive cost.

The financial return from any possible technical improvements is almost without limit. For example, in a typical medium-size integrated steel mill, the total monthly cost of operation is about nine million dollars, of which about 55%, or five million dollars, is for goods and services directly consumed in production. This aggregate production cost is the field against which the technical attack is directed. If mechanical computation can aid in other ways, as in the tin-plate gear example described previously, the possibilities are almost endless.

Most certainly such opportunities do exist; some of them have already come to our attention. For instance, proper operation of a blast furnace depends upon the inter-action of an almost infinite number of variables, some related, some important, some probably negligible. Heretofore, any attempt to chart the theoretical effect of the factors on a scientific basis has been limited due to the infinite number of possible combinations of factors. With a 13-hour job on our computer, we furnished the engineers with mathematical correlations for 39 of these variables which they believe might be the most significant; with this as a basis for study, the problem no longer appears impossible of solution.

Conclusion

In my opinion, no one can visualize all of the opportunities presented to management through the automatic systems presently available or which will be available in the next few years. We believe, however, that the more spectacular uses of automatic equipment can come about only after adeptness and competence are acquired through background experience in the more familiar fields. For this reason, we have started our development with the standard accounting routines, keeping the wider concepts in the background as an ultimate goal.

Certainly some of the work we are doing is of an experimental nature at present. However, if we wait until all of these systems have been perfected by others, we will have needlessly delayed many of our opportunities for improvement and possibly endangered our competitive position. I am sure that if we do not take advantage of this new equipment as soon as we can do so, many of these opportunities will pass us by, at least for a substantial period and possibly for all time.

We like to think, however, that our interest in better ways of doing things is not wholly concerned with the welfare of our own business. Almost everything which we do in industry today to improve our operations and our products, or to reduce our product costs, eventually improves our standard of living. We are inclined too often to think of cost purely in relation to money values, without realizing that there are also human values involved. However, the value of a unit of production in money is determined by the amount of effort or time expended to produce it. In reducing the costs we produce more for less. The more we can produce in our working time, the greater the returns to each of us as individuals and the greater the time we will have for ourselves to enjoy the returns from our efforts.

A MANAGEMENT FORECAST

G. T. HUNTER

For the final presentation in this institute on electronics in management, I have been asked to give a forecast of changes which may come about in management activities.

Electronic data processing machines will be applied in three general areas. These areas are accounting and record-keeping, scientific and engineering computation, and management science. I shall discuss the first two areas briefly, and then concentrate on the third area which is of the most interest to the participants of this institute. The area of management science is the one we know the least, and the one from which we will get by far the greatest financial return and far-reaching effect on management.

The excellent speakers you have already heard have discussed the actual machines which are now available. In summary, these machines are useful because they have input and output facilities for handling data at high speed, they can do arithmetic at the rate of thousands of calculations a second, they have large storage facilities for holding many variables simultaneously, and they have the ability to make comparisons and logical choices at the rate of over one million per minute.

The area of accounting and record-keeping includes such topics as payroll, labor distribution, accounts receivable, inventory record-keeping, and others. These areas have been mechanized for years on both key-driven and punched card machines. They are now being handled in increasing numbers on electronic data processing machines. Machines are making appreciable reductions in time and cost in this area.

Payroll has been talked about more than any other application. This is partly due to the fact that it is generally one of the simplest and most mechanized processes in a business office. However, the application of large electronic machines to payroll cannot make large dollar savings because the whole process itself doesn't cost a large number of dollars. My comparison for this purpose is against the cost of materials, facilities, and inventories, which are far greater than the cost of payroll procedures in most business organizations.

In Poughkeepsie we use a large electronic data processing machine for our weekly payroll of eight thousand men. This requires approximately two hours a week for the calculations, and about two hours' use of an auxiliary machine to print the pay checks. The savings on this application cannot compare with those of the major application for which this machine is used—that of inventory record-keeping and analysis. The analysis is the part which will yield the real savings and, therefore, is the reason that this application should be classified as a management science application, and not as a simple record-keeping function.

The second area, that of scientific and engineering computation, is the one which has used electronic machines a great deal, and is the one which has shown the greatest development and the greatest results up to the present. Machines have been used for data reduction, design, and analysis in many fields of research and engineering. With the appropriate techniques it is possible to make a mathematical model of such things as an airplane, a petroleum refinery, or a factory assembly line. It is then possible to evaluate the model under a variety of operating conditions to find the best design, or operating situation. This will often be faster and cheaper than building and studying the actual item.

For example, in the past few months there has been a mention of a mistake in airplane or engine design, or both. The management decision to go ahead with this design was made in 1951, and today it is reported to have been in error, with a cost to the United States of more than one hundred and fifty million dollars. I would like to point out that that sum of money is more than the cost of all the electronic digital computing machines that have been built in the United States up to the present time. This mistake occurred at a time when there were only a few large machines in existence. I am not trying to use hindsight and criticize what was done. Rather, I want to point out that such a mistake should never happen again.

For example, the General Electric Company furnishes to its customers the characteristics of its jet engines in the form of a deck of 175 punched cards ready to go into a Type 701 computer. The customer can add to this deck the characteristics of any particular air frame design, and then simulate the flight of this combination inside the computer. In a couple of hours of computing, the machine can do the work that would take a year of hand calculation. It can be determined very quickly that a particular design is good or bad.

The reason that I say a mistake in design should not happen again is that in addition to the many machines already installed, every major airplane and engine manufacturer will have from one to five of the very latest IBM computers installed by the spring of 1957. Other machines and computing facilities are now, and will be increasingly, available to any company. Management can get quickly the complete information necessary to make a good decision—this situation has not been true in the past.

In another instance, engineering management reported that a certain compressor study would require 230 men for five years. The company had neither the men nor the time. Instead, they used a small computer and did the work with seven men in just four months. Here again, a computing machine enabled management to save both time and money.

The really exciting future application of computers to engineering problems seems to be that it will be possible to give the desired results and let the machine do the actual design of the system. At present, people generally do the design and use a computer to evaluate that design.

Machines are now being applied to data reduction for engineering test facilities. Several of our customers have told us that in the near future they will have a maximum delay of 30 minutes in giving the results of tests to engineers. The engineers can then make intelligent decisions based on adequate information. Here large savings may be realized since it often costs thousands of dollars an hour to operate a wind tunnel, engine test cell or other facility.

The cost of computing facilities sometimes is confused with the cost of doing computing. Management should realize that while the cost of more capable equipment is increasing, the cost per computation is decreasing. In 1955, for example, the cost of renting the most powerful computer in our New York data processing center was $300 an hour. However, this charge is less than nine cents a second for up to 15,000 steps of arithmetic, which is the biggest bargain in doing arithmetic that has ever been available. I believe that the cost per calculation will continue to decrease.

The third area of data processing is that of management science applications. I believe that this area offers the greatest potential savings to management and is, therefore, the most important one. It is also the one in which the least is known at this time and, therefore, offers the greatest challenge and opportunity for people in the future.

The big use of machines in this area will be to process data and furnish a condensed set of results for people to make an intelligent decision. The use of machines is making the thinking ability of people more important than ever before. People have to be able to state a problem, state a method of solution, and then make a final decision from the results. The machine only does a lot of arithmetic at high speed. If you doubt the importance of people, just remember that our latest computer, if given *wrong* instructions or data, produces 40,000 wrong answers a second! But you must place the blame for wrong answers on people, not on the machine.

Now let me give a few applications of machines to problems, with which I am familiar, in the management science area.

Probably one of the most complex production applications being done on an electronic computer occurs in the aircraft industry where the IBM Type 701 is used for production scheduling and control of shop orders. In this instance, after a contract is procured a master schedule is established stating the number of ships, rates of production and number of days a given rate is to be effective. The Type 701 prepares a Base Schedule which shows, by shop calendar date, the exact day each ship is due at a given station or line position on the production line. This schedule may be revised as manufacturing schedules accelerate or retard. Following the computation of the base schedules, ships of a given contract are grouped into lots for manufacturing. Thereafter, all fabrication and assembly parts are scheduled to the first ship of the lot.

All information pertaining to the schedule, engineering description, spares requirements, cost, etc. is written as one main tape file. A file is prepared weekly reflecting all changes in the main parts and schedule file. This file contains engineering and manufacturing changes, as well as inventory information.

This change file is processed with the main tape file and a completely new revised main tape file is written. Calculations are made during this processing. Engineering and manufacturing changes are entered in the main file. Part usage by assembly and plane is extended and summarized by lot and contracts. Net quantities are computed for each lot in each contract. Previous part orders are examined and if a need for a part is determined it will be scheduled and written on an output tape, to later prepare a shop order. A scheduling operation is performed and the need for part orders on succeeding lots is determined. The machine will continue to schedule quantities for each lot until a lot is reached which does not require the present initiation of shop orders. Finally, orders are written for those parts which require replacement.

Perhaps the most important concept illustrated by this use of the Type 701 lies in the consolidation of many files (all basically related to the part number) into one file. The weekly processing of this file against one change file representative of all types of change creates a variety of output data and automatically revises the main file to current status. Thus engineering, manufacturing, inventory and planning information are all treated simultaneously, for better management.

At IBM we have used the Type 701 for calculating the Machine Load and Raw Material Forecast for one of our manufacturing plants. Basic to this application is the fact that the inventory control system is based upon an ordering cycle. Thus, the inventory position of a part, as of a particular manufacturing day, is analyzed by the machine. Parts on order are added to the present stock, and from this sum the amount of back-order parts is subtracted. This quantity is divided by the average daily usage for the particular part to give the normal production time interval covered by the present inventory position. From this is subtracted a number of days equivalent to the protective stock or minimum stock level. This, then, is the actual production time interval before replenishment is required. This interval, expressed in days, is added to the current manufacturing calendar date to determine the first actual stock date, i.e., the date at which new parts should be available. The replenishment interval is then computed by dividing the economic lot size by the average usage.

The engineering part history, or "part routing," is now introduced. This is equivalent to operational estimates for machine tools or conversion processes, and labor and raw material. Typical routing operations for each part include setup and production rates, raw material per part, transit times, etc. The 701 examines the last operation used in the part routing. The hours required in this operation for the particular part are computed, e.g., multiplying economical lot size by hours per piece and adding setup time. These hours are rounded to the next highest day. The days spent in the operation are then subtracted from the first stock date for the part to determine the start date for the part in the operation. The replenishment interval is now added to this start date to determine each start date for the part in the given operation for the total scheduling period. Thus a series of start dates for a particular part through a particular operation is obtained. The 701 determines when a start date falls beyond the range of terminal day of the schedule period, terminating the computation.

Returning to the first operation start date, the 701 subtracts transit time for the part and examines the next preceding operation. Load computations are made, the replenishment interval added, and the process is repeated until the initial operation for the part is reached. Parallel with this operation, load totals for each operation are accumulated. Also raw material computations are made and summarized by time period.

In this particular application, the effect of various machine routings to accomplish a particular set of manufacturing properties can be arranged as part of the computer schedule. The effect of routing upon shop loading can be examined on the computer. Also, the effect of complete and partial ordering can be examined to the limit of time available upon the computer.

One of the ultimate objectives in using the computer as a production management tool will be the inclusion of the effect of chance upon schedules. To this end, an experimental application was programmed on a Type 701 to determine the feasibility of scheduling a precision manufacturing operation in a shop. Jobs in the shop were rated on a priority basis based on due date and the amount of work yet to be done. A group of jobs was chosen and these jobs scheduled, taking into account the chance variables of machine breakdown, operator performance, rejection rates, manpower availability and machine capacities. Each of these variables was brought into the solution by the use of density functions and random number generation techniques. Therefore, while the variables were random, their impact could be statistically predicted. For each permutation the schedule was computed several times with an average evaluated cost. Following this, other groups were scheduled in similar fashion, finally selecting that set of schedules which assured minimum cost. Accuracy of work measurement data is important in production scheduling. In performing production scheduling upon computers, it is basic that good operational estimates be available. The schedule can be no better than these estimates.

One company is currently using statistical methods to evaluate the work standards in a job-shop fabrication unit. In this application time data are gathered in the normal fashion and then subjected to statistical analysis to determine the importance of several production variables. Using the computer to perform the statistical calculations, final equations are developed for each hypothesis concerning the production variables. Prior to this, the data are examined by the computer for consistency about trend lines and in some cases the computer actually plots the distribution of the data. Having the equations relating the production variables, rate tables may be made which correspond to each particular hypothesis. The equations are evaluated for all ranges of production and the results compared with the actual data for closeness of fit. After the best standard is selected, it is possible to use the equations to determine the expected output of the workers in a particular plant. This can be done in the normal mathematical computation of expectation where past data are analyzed by class of production variables, with the associated probability of production falling within a particular class. The rates for each class are then applied to the probability distribution by class and summed, such a sum representing the expected production.

When the standards are so computed it is possible to use them in a variety of ways for improved management, for example, in incentive payrolls and the scheduling of labor forces.

The importance of using statistical methods in establishing productivity measurement lies principally in the better control the production engineer gains, as well as allowing for better prediction in scheduling labor and shop facilities. Generally, the production and industrial engineer has made little use of statistical and probability methods in his work. One of the reasons for this is the tediousness of the calculations necessary to establish statistical relationships. In this instance, the electronic computer adds a really new and powerful tool to production engineers' work.

An important application of mathematics on computers for production engineering has been reported by Dr. Melvin E. Salveson of General Electric Company. This is the problem of assembly line balancing, in which it is desired to establish work stations along the assembly line in such a way as to minimize idle time at each work station. In general, the component parts must be assembled in some specified sequence, obeying precedence relationships, with the elemental work tasks being defined by engineering standards. The problem is to group these tasks into work stations, consistent with the precedence relationships, in such a way that the sum of the idle time at each work station will be a minimum. Mathematically, this problem was solved through the use of linear graph theory, and a combinatorial approach to convex sets. This is an excellent example of a problem which is both discrete and combinatorial.

One of the basic tenets of management science is that the total view of the operation to be controlled must be employed in solving optimization problems. Thus, in production and inventory management it is necessary to consider dynamic interaction of these many elements. One company in the petro-chemical industries has investigated the use of game theoretic methods to solve the problem of optimizing production rates and inventories under variable seasonal requirements. In this application, various alternative actions (initial inventories and production rates) are specified for the producing unit. In opposition to the producing unit, the effect of seasonal demand by time period on a statistical probability basis is assumed. By matching expected seasonal requirements, taking into account mean and variability, against alternate actions at the producing unit, a series of strategies is evolved. On this basis, for each time period a production rate and inventory can be established which will maximize the expected profit of the operation.

Thus far, the notions of game theory have not been employed to solve management problems. Probably this is due in large measure to the psychological difficulties associated with attempts to quantify and predict the actions of a competitor. However, by idealizing nature as a competitor in the sense that it constitutes a set of variables over which we have no control, it is possible to use the methods of game theory in selecting courses of action which are essentially against, i.e., seek control over, nature. This method appears promising in many production engineering areas where sales and market forecasting must be used as the index upon which production is set.

As management attempts to refine control of its production and inventories, it must take into account the variability of the real world. Mathematical models have been constructed which involve the use of stochastic variables. An interesting example of these probability methods, commonly referred to as Monte Carlo techniques, has been studied by one of the large petro-chemical organizations. In this particular problem long and expensive shipping lines exist between the producing units and the market where the products are to be sold. Raw material is periodically shipped into the producing unit and inventories held at the unit in order to allow producing and inventory operations to meet market demand. In essence, the problem was to determine the amount of raw material needed at the producing unit to control inventory fluctuations, at the same time assuring a reasonably constant rate of shipment from the producing unit to market demand. A mathematical model was built paralleling the flow of material from the raw state (through processing, inventory and shipping) to the market. At each point, variability was introduced through the use of frequency distributions based upon past experience. For example, variation in shipping time was entered as part of the model. Also, the variation associated with the normal running time of the batch-type operation, as well as variations in the production set-up times, were included. Having built a mathematical logical model in which variability was treated, it is possible to study the expected operation under a wide variety of production conditions. In addition to this, various inventory control limits could be set and, as a result of these, expected production figures could be obtained. In addition to studying the relationship of inventory fluctuation and controls in production practices, this application is important in that it demonstrates that the variability inherent in all real operations can be included as part of the calculations of a production control operation. Particularly, a large scale electronic computer is an ideal instrument for this purpose since it can rapidly generate the random numbers required in Monte Carlo techniques as part of the procedure itself.

A particular mathematical method which is finding increasing use in production and inventory management is the transportation model. This is a specialization of the linear programming problem. The essence of this problem is the following: It is desired to transport an item from several dispersed sources, each with a given supply, to numerous dispersed destinations, each with a specified demand. Shipping costs from any one source to any one destination are known. It is desired to determine what amounts should be shipped from each source and to each destination in order to satisfy all market demands with minimum overall transportation costs. One company operating several plants, with a great number of warehouses dispersed throughout the United States for further distribution, had a capacity excess in the western part of the country and a demand excess in the east.

Because of this, considerable tonnages were shipped from western plants to eastern warehouses so that the cheapest distribution costs could not be achieved by simply shipping from each plant to the nearest warehouse. In this case, using the transportation model, a distribution was found which achieved a savings of many thousands of dollars.

A national food distributing company had a similar problem, but included in their study seasonal variations of supply and demand together with intra-seasonal costs. This problem was also solved by the transportation model of linear programming with a resultant saving of five hundred thousand dollars a year in transportation costs.

In the examples which have been described, you will find two common keys to their solution; the application of quite sophisticated mathematical methods, and the use of large electronic data processing machines to handle the tremendous number of calculations. Mathematics and machines will be the increasingly important tools of management in the future.

In conclusion, I predict a very bright future with management being assisted in many ways by electronic data processing machines.

The biggest problem for the future is that of education. All of us have a tremendous job ahead to convince industry and educational institutions that mathematics is the key to problem formulation and subsequent solution by machines. The need for persons today with a good background in the concepts of data processing is in the thousands. The need at present is increasing far more rapidly than the supply is being made available. As trained people and machines work on the problems of management science, we shall see tremendous accomplishments which will affect all of us for the better.

APPENDIX A

A LINEAR PROGRAMMING APPLICATION TO AIR FORCE LOGISTICS[1]

I. Procedure

1. The following description outlines a proposed computational technique for maintaining complete inventory control of high volume items. This control will permit the directing of transshipment of assets between bases or between bases and warehouses, the initiation of procurement action, and the construction of master repair schedules. The controlling factor in such a computation is the minimization of over-all cost.

2. Assumptions—general.
   a. A computation of consumption requirements and reparable generation for item k at each using location has been made.
   b. Availabilities of item k, by condition, at each location are known.
      Condition
      (1) Serviceable.
      (2) Base reparable, i.e., able to be repaired at base level.
      (3) Depot reparable at base, i.e., able to be repaired only at depot level, but located at base, the point of generation.
      (4) Depot reparable at depot.
   c. Only four types of cost are considered—transportation costs, average cost of base repair, average cost of depot repair, and unit cost of the item if procured.
   d. Base reparable items will always be repaired at the base where they are generated prior to shipment to another base.

3. *Assumptions for the purpose of this exposition.* The following can be modified substantially without disturbing the basic structure of the computation.
   a. Serviceables at any location can be shipped to any other location world-wide, in one (1) month.

[1]This model was formulated by Saul Hoch and Jules Silver, Headquarters, Air Material Command, USAF, March 1955.

b. Any one item in reparable condition can be repaired in one (1) month.
c. Each item in depot reparable condition will be repaired in one of two specified depots.
d. Transportation cost varies proportionately with the number of items shipped. Shipments will be restricted to minimum shipping packs.
e. Serviceables and due-ins from manufacturer will be used to satisfy requirements before reparables are to be used for such purpose providing the minimum cost requirement is satisfied.
f. It is desired to effect re-distribution of availabilities of item k for four (4) consecutive months, starting with month 1 and running through month 4. An availability at month 1 is considered to be available on the last day of that month. A requirement in month 1 is considered to be necessary for satisfaction during that month.
g. A procurement lead time of three (3) months is in effect (includes one (1) month transportation time).

4. Procedure
a. Monthly gross requirements for each of m using activities (r bases, m-r depots and repair centers) are computed starting with month 1 and running through month 6. (Gij; i=1, 2....6; j=1, 2....m). These requirements represent the row totals.
b. Column totals are computed as follows:
(1) The number of serviceables of item k available at each location at month 0 are determined. (m cols).
(2) The number of base reparables available at month 0 at each base are determined. Also determined are the number of *additional* base reparables that will be generated monthly through month 4 by each base (5.r cols).
(3) Similarly, the number of depot reparables available at each base are determined for months 0 through 2 (3 5 cols).
(4) The number of reparables at each depot at month 0 are determined. (2 cols).
(5) From the current procurement schedules the number of due-ins from each of h manufacturers of item k are determined for months 0 through month 4 (5 h cols).

(6) One (1) column is provided for availabilities from new procurement. This column total is arbitrarily set to be the total of the row sums (total requirements).

c. Costs are now entered in each cell of the cost matrix as follows:

(1) If a cell represents an impossible situation (e.g., shipment of a reparable in month 4 to satisfy a requirement in month 5) enter a number F which is greater than the cost for any possible situation. Exception: in the first 3 rows of the column for "availability from new procurement" enter F′ which is greater than the cost for any possible situation and less than F.

(2) All other cells under "Serviceable" column headings.

(a) Available at location j for location j. Enter 0.

(b) Available at location j for location p (not equal to j). Enter the transportation cost of shipping one (1) unit pack of item k from j to p.

(3) All other cells under "Base reparables" column headings.

(a) Available at location j for location j. Enter average cost of base repair.

(b) Available at location j for location p. Enter average cost of base repair plus transportation cost (j to p).

(4) All other cells under "Depot reparables at base" column heading.

(a) Available at location j for location j or p. Enter the average cost of depot repair plus transportation cost (j to depot) plus transportation cost (depot to j or p).

(5) All other cells under "Depot reparables at depot" column headings. Enter average cost of depot repair plus transportation cost from depot to requiring location.

(6) All other cells under "due-ins from manufacturers" column heading. Enter the cost of transportation from manufacturer to location j.

(7) All other cells under "Available from new procurement" column heading. Enter the average unit cost

of item k (including estimate for procurement administration) plus transportation to location j.

d. A very small cost e is selected arbitrarily (e.g., 0.01) and multiples of e (e, 2e, 3e. . . .ne) are added to the cells of the cost matrix as follows:

(1) Serviceables: Consider the partial column of costs under a single column heading opposite the rows pertaining to consecutive time periods for a single location j as a "set" of homogeneous costs. (Normally, the costs will be all equal for real situations and F for all impossible situations). Add e to the first cell of each set (earliest-time period of set) which has a cost other than F. Similarly, add 2e to the next earliest-time period of each set, etc. until ascending multiples of 4 have been added to all non-F cells of each set. (See 5b, below).

(2) Base reparables: Consider separately each sub-matrix of costs formed by s rows representing requirements of a single installation (j) for s time periods and t columns representing availabilities for t time periods from a single installation (j or p). Add e to cell A s t of the sub-matrix. Add multiples of e to every other non-F cell of the sub-matrix so that every non-F cell will have a higher multiple of e than the next non-F cell to the right or the next non-F cell below it.

(3) Columns and rows for depot reparables at base are handled as in (2) above.

(4) Reparables at depot are handled as in (2) above.

(5) Due-ins from procurement are handled as in (1) above.

(6) Nothing is added to the cells of the column for availability from new procurement.

e. An optimization computation is then made allocating the time-phased availabilities to the time-phased requirements while minimizing total cost.

5. Results

a. If real availabilities (excluding new procurement) are less than requirements during the first three (3) months (1, 2, 3) the computation will show the excess requirements being satisfied from new procurement even though this is impossible (3 month lead time). A determination must be made as to whether such requirements will merely not be met or whether additional requirements must be added to later time-periods. If the latter is determined to be required, the requirements are adjusted and re-computation is made.

b. The addition of multiples of e to the cost cells accomplished the following:
   (1) Serviceables and due-ins will be used to satisfy requirements for time period i before satisfying i+1 since i has a slightly lower cost than i+1.
   (2) Reparables will not be used to satisfy requirements in time period i if they can be postponed to i+1 since the latter time period has a slightly lower cost. This means than serviceables and due-ins will be used first.

c. For the purpose of this exposition, it has been assumed than an average unit cost of item k will be used for new procurement. Obviously, if more detailed data are available, additional columns for different sources of new procurement, each with a separate unit cost, can be added.

6. Attached is a sample matrix for 4 time periods showing requirements at 3 bases, availabilities at 3 bases, 2 depots, and 1 manufacturer.

INTEGRATED LOGISTIC MANAGEMENT OF AN AF ITEM

COST MATRIX

INSTALLATION	PERIOD	SERVICEABLES at BASE 1 JAN	SERVICEABLES at BASE 2 JAN	SERVICEABLES at BASE 3 JAN	BASE REPARABLES at BASE 1 JAN	BASE REPARABLES at BASE 1 FEB	BASE REPARABLES at BASE 1 MAR	BASE REPARABLES at BASE 2 JAN	BASE REPARABLES at BASE 2 FEB	BASE REPARABLES at BASE 2 MAR	BASE REPARABLES at BASE 3 JAN	BASE REPARABLES at BASE 3 FEB	BASE REPARABLES at BASE 3 MAR	DEPOT REPARABLES at BASE 1 JAN	DEPOT REPARABLES at BASE 2 JAN	DEPOT REPARABLES at BASE 3 JAN	SERV at DEPOT 1 JAN	SERV at DEPOT 2 JAN	REP at DEPOT 1 JAN	REP at DEPOT 2 JAN	ON CONTRACT WITH MANUFACTURER JAN	ON CONTRACT WITH MANUFACTURER FEB	ON CONTRACT WITH MANUFACTURER MAR	ON CONTRACT WITH MANUFACTURER APR	NEW PROC
BASE 1	JAN	0.1	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F'
	FEB	0.2	T+2	T+2	R+5	F	F	F	F	F	F	F	F	F	F	F	$T'+1$	$T'+1$	F	F	$T''+1$	F	F	F	F'
	MAR	0.3	T+3	T+3	R+4	R+3	F	T+ R+4	F	F	T+ R+4	F	F	F	F	F	$T'+2$	$T'+2$	$R'+T'+3$	$R'+T'+3$	$T''+2$	$T''+2$	F	F	F'
	APR	0.4	T+4	T+4	R+3	R+2	R+1	T+ R+3	T+ R+2	F	T+ R+3	T+ R+2	F	$T'+T'+R'+1$	$T'+T'+R'+1$	$T'+T'+R'+1$	$T'+3$	$T'+3$	$R'+T'+2$	$R'+T'+2$	$T''+3$	$T''+3$	$T''+3$	F	$U+T''$
BASE 2	JAN	F	0.1	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F'
	FEB	T+2	0.2	T+2	F	F	F	R+5	F	F	F	F	F	F	F	F	$T'+1$	$T'+1$	F	F	$T''+1$	F	F	F	F'
	MAR	T+3	0.3	T+3	T+ R+4	F	F	R+4	R+3	F	T+ R+4	F	F	F	F	F	$T'+2$	$T'+2$	$R'+T'+3$	$R'+T'+3$	$T''+2$	$T''+2$	F	F	F'
	APR	T+4	0.4	T+4	T+ R+3	T+ R+2	F	R+3	R+2	R+1	T+ R+3	T+ R+2	F	$T'+T'+R'+1$	$T'+T'+R'+1$	$T'+T'+R'+1$	$T'+3$	$T'+3$	$R'+T'+2$	$R'+T'+2$	$T''+3$	$T''+3$	$T''+3$	F	$U+T''$

BASE 3

JAN	F	F	0.1	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F'
FEB	T+2	T+2	0.2	F	F	F	F	F	F	R+5	F	F	F	F	F	T'+1	T'+1	F	F	T''+1	F	F	F	F'
MAR	T+3	T+3	0.3	T+ R+4	F	F	T+ R+4	F	F	R+4	R+3	F	F	F	F	T'+2	T'+2	R+T' +3	R+T' +3	T''+2	T''+2	F	F	F'
APR	T+4	T+4	0.4	T+ R+3	T+ R+2	F	T+ R+3	T+ R+2	F	R+3	R+2	R+1	T+T' +R' +1	T+T' +R' +1	T+T' +R' +1	T'+3	T'+3	R+T' +2	R+T' +2	T''+3	T''+3	T''+3	F	U+T''

T   Unit cost of transportation between bases
T'   Unit cost of transportation between bases and depots
T''   Unit cost of transportation between bases and manufacturers
R   Average unit cost of base repair
R'   Average unit cost of depot repair
U   New procurement unit cost
F   Inordinately high cost
F'   Inordinately high cost, but less than F

Repair cycle 1 month
Transportation time 1 month
Procurement lead time 1 month

APPENDIX B

THE NATIONAL BUREAU OF STANDARDS' PROGRAM: AN EXTRACT FROM THE HEARINGS ON AUTOMATION AND TECHNOLOGICAL CHANGE[1]

The Joint Committee on the Economic Report, created pursuant to Public Law 304, 79th Congress, of which Senator Paul H. Douglass was chairman and Representative Wright Patman was vice-chairman, held hearings on various aspects of automation, some of the testimony having a bearing upon electronic computers and their applications to data processing. The editors deem it in the public interest to quote parts of the testimony by Dr. V. A. Astin, Director, National Bureau of Standards, for wider circulation.

"The Bureau's work on automatic electronic computing machines began as a part of the organization's technical assistance program. In 1946 requests for such assistance came from three different sources: The Bureau of the Census, the Office of the Air Comptroller, and the Office of the Chief of Ordnance. The Bureau of the Census was exploring the possibilities of applying recent advances in electronics to their large data-processing problems. A preliminary survey showed that the prospects were very good. This was followed by a contract placed by NBS with the former Eckert-Mauchley Corp. to prepare detailed performance specifications for a machine suitable for the needs of the Bureau of the Census. The completion of this contract was followed, in turn, by a purchase order placed by NBS for three large electronic data-processing machines; one for the Bureau of the Census, one for the Office of the Air Comptroller, and one for the Army Map Service. This order was filled by the delivery of the first three Univacs.

The problem brought to the Bureau in 1946 by the Office of the Air Comptroller required the services of both electronics and mathematical experts from the Bureau's staff in connection with logistics planning problems of the Air Force. A preliminary analysis of these requirements pointed to the desirability of hav-

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[1]U. S. Congress, Joint Committee on the Economic Report, Subcommittee on Economic Stabilization. *Hearings, Automation and Technological Change*, October 14-28, 1955. Washington: Government Printing Office, 1955, pp. 572-573, 576-581.

ing available at an earlier date a somewhat more modest computing machine than the expected Univac. This led to the design and development and construction by the Bureau of its Standards electronic automatic computer, commonly known as the SEAC. The SEAC was placed in productive operation almost a full year before the first Univac was delivered, and it has now been operating on an around-the-clock basis for more than 5 years.

Also in 1946, the Office of the Chief of Ordnance asked the Bureau to study critical components and subassemblies for a data-processing machine which the Army was procuring for its Ballistics Research Laboratory at Aberdeen, Md. This led to an active program at the Bureau on the development of materials and components for use in the computing machine field and to the development of reliable evaluation techniques for such components.

A little later the Bureau designed and built for the Department of Defense a mobile and more advanced machine, the DYSEAC. The DYSEAC was turned over to the Department of Defense in the spring of 1954, and is now in operation at the White Sands, N. Mex., Proving Grounds. The availability of the SEAC coupled with the Bureau's considerable experience in this rapidly growing field has resulted in numerous requests for technical advice and assistance in connection with the design and possible utilization of modern, high-speed, electronic computing devices. Before discussing more specifically the nature and importance of some of these requests, I should like to outline some of my own views concerning the importance of these new technological developments to our national economy and to our general welfare. The relationship of these developments to our economy is, I believe, closely associated with the interest of this subcommittee in the field of automation.

Automation is a relatively new word. It has been defined in many ways by various people. It probably means, the process of rendering automatic. From this point of view, the newest thing about automation is the word itself. The development of devices to perform functions automatically is a very old activity. For example, the ancient Romans invented a hydraulic float valve to control automatically the level of water in storage tanks. I would prefer to consider the subject of mechanization which is a broader area of technology, with automation as one of its important subdivisions. The general goal of mechanization is increased productivity; to use machines to aid man in producing more goods and services. Increased mechanization and increased productivity have expanded together. This has been especially noteworthy over the past 150 years, and particularly in the past 50 years.

* * * * * *

Our Federal Government has the largest business office operations in the world. Hence, it seems logical that if modern data-processing machines have a place in improving the efficiency of large-scale office operations, there should be numerous possible applications within the Federal Government. Our experience has shown that this prospect is indeed very good.

The advisory and consulting services of the National Bureau of Standards have led to a need for keeping abreast of all major developments involving data-processing systems. This experience has enabled me to provide a brief summary of the "state of the art" for its possible interest to the members of this subcommittee. It is included as an appendix to my prepared statement.

Census Bureau

I mentioned earlier that our first activity with modern computing machines was in assisting the Bureau of the Cenus. Census Director Robert W. Burgess has already told you of their experience with computing machines so there is no need for me to discuss that phase of our work. There was, however, a related development of the Census Bureau that should be mentioned briefly. This development involved automatic means for translating the data on the record sheets of census enumerators into a form that could be fed directly into their computing machines.

The machine we developed has been named FOSDIC (film optical sensing device for input to computers). The machine reads marks on microfilmed copies of documents that have been marked with an ordinary pencil or pen, and then processes the information into electrical pulses which are recorded on magnetic tape for direct input to an electronic computer such as the census Univac. FOSDIC is designed to reduce the work that is now involved in converting written records into a medium acceptable as input by data-processing machines. This is particularly true since FOSDIC allows considerable freedom in design of the documents and does not require the use of any special writing equipment.

It is anticipated that ultimately the use of this machine will reduce appreciably the massive amount of paperwork entailed in summarizing census information on the entire population. Although designed for census operations, FOSDIC may be generally applied to the processing of other types of information that must be handled in large quantities.

With the development of many large-scale electronic computers in the past few years, there has been an increasing need for equipment to bridge the gap between the machines and their sources of information. This is especially true for computing systems which perform relatively little computation on a large mass of data obtained from many sources. Considerable attention has been given to computers and their input-output equipment but relatively little to "pre-input" apparatus or instrumentation permitting the computer to have direct contact with sources of information. When human beings are considered as sources of information, only two partially automatic means of communication are in general use. These are (1) typewriters of various forms and (2) special marking instruments such as punches or conductive pencils. An alternate method is through the manual preparation of punched cards. To these methods has now been added FOSDIC, a completely automatic machine which processes marks made by an ordinary pencil or pen into a form directly usable by the computer.

Patent Office

Another unit of the Department of Commerce, the Patent Office, has a particularly challenging problem in the area of possible mechanization of patent search. Our patent system is closely related to the industrial growth and prosperity of the United States. It plays a major role in the creation of new products and processes, yet our patent system is at a crossroads because of the very increasing complexity in the continued program of inventiveness. The present patent examiners are as dedicated and competent as their predecessors, but they face a task that is infinitely more complex than that of even a few decades back. The unprecedented pace of science and technology is producing new facts and inventions at a rate beyond the capacity for patent claim handling procedures which have been developed over the years so that the present staff is unable to keep the size of the backlog of patent applications from steadily increasing. In awareness of this problem, the Senate Appropriations Committee specifically directed the Department of Commerce to make an aggressive investigation of the possibility of mechanizing patent search operations. In accordance with this mandate, a committee, headed by Dr. Vannevar Bush, was appointed. This committee concluded that if the patent system is to continue to make its contribution to our expanding economy, mechanization of the routine aspects of the patent search process is essential, and that the automatic data processing art has reached a stage of development which makes feasible its application to this complex problem.

Accordingly, the Patent Office and the National Bureau of Standards are cooperating in a joint program of research and development to adapt machine techniques to these Patent Office operations.

Army Quartermaster

Our work for the Army Quartermaster Corps gave us experience in coping with the problems of Government purchase and procurement.

In carrying out provisions of the Armed Services Procurement Act of 1947, a number of complications arise in determining the bidder or combination of bidders who will charge the true lowest cost to the Government. True costs require consideration of different freight rates from factories to depots. The bidder himself may state restrictive provisions such as minimum and maximum quantities, or "block" or "hinge" bids whereby he may quote different prices on different quantities.

The attempted resolution of lowest cost for bids on contracts involving a variety of complicating factors, when carried out by manual methods, results in high cost both in time and manpower. On 1 typical operation, 700 man-hours were expended without trying all the possible combinations, and it was estimated that 4,000 man-hours would have been required to calculate all combinations.

A second shortcoming of manual computation is that in some cases it is not possible to solve the problem at all in the time available. For example, a proposed contract for 860,000 woolen jackets to be fabricated for 13 different destinations, estimated to involve 223,000 different combinations, had to be canceled because bids could not be evaluated by manual computations.

Accordingly, a program was established in the Applied Mathematics Division of NBS to explore the use of new mathematical techniques (called linear programming) in conjunction with the use of high-speed electronic computing equipment.

The linear programming computation procedure, as coded for SEAC, is then used with data on the various bids received for each specific problem, and the machine operates on the specific problem by first assuming that an award satisfying the various restrictions will be chosen regardless of its cost. A cheaper allocation is then sought, and it is substituted for the first. The search for still cheaper allocations continues until no cheaper award can be found. For the typical problem, about 2 hours of SEAC computation are required before the minimum cost answer is found.

The direct savings achieved through the speed of electronic computation can be illustrated by the fact that, for a problem that would have required 1,000 man-hours of labor at a cost for manual computation of approximately $2,500, the machine could have tried all combinations in about 40 minutes at a cost of $80 or less. Direct savings are also achieved through the saving of time since bidders may limit the effective period of their bids to option periods of 20 days or less from the date of opening bids.

In summary, then, the linear programming technique makes possible the development of solutions to bid evaluation problems in less time, at less cost, and with absolute accuracy.

Veterans' Administration

The Bureau has also been called upon by the Veterans' Administration for work in relation to actuarial tables. In this case, the Univac system was used to provide the actuarial tables necessary for the new uniformed services survivors' benefit program. Using conventional methods by desk calculation, this would have required an estimated 25,000 man-hours. The job actually took 1,443 man-hours. The cost by conventional means would have been in the neighborhood of $200,000; it was actually completed for about $15,000 with the Univac.

In the course of the entire job, the Univac computed 357,012 numbers to 8 significant figures. The 1,443 man-hours used on the problem included time spent in analysis and process charting, flow charting, coding, preparing desk-calculated samples for checking, preparation for and operation of the machine, report writing, hand editing and checking tables, and maintenance.

The actual time spent by the Univac in generating the numbers (not including checking of programs) was 41.4 hours. The total time used by the computer system was 104 hours. As a comparative figure, a few sample values computed by hand for checking purposes required 55 man-hours.

More significantly, however, the Congress directed that this veterans' insurance program should go into effect within 60 days from the time that the act was signed. The use of the computer made it possible to provide the necessary tables so that the program did go into effect on schedule with maximum benefit to all concerned, something that would have been impossible without the use of these new general-purpose, high-speed tools.

Navy Aviation Supply Office

The Bureau has also assisted the Navy in applying automatic techniques to its inventory-control and supply problems. The data-processing application that is now in operation at the Navy's Aviation Supply Office is a good example of better use of present resources. In the Navy supply system, there are some 13 materiel control centers, called supply demand control points. These control points have cognizance over certain broad categories of material. In the case of the Aviation Supply Office, the responsibility is for aircraft, aircraft engines, and supporting spare parts and accessories.

The supply replenishment actions used to be based on quarterly distribution and procurement in accordance with predicted demand determined by existing inventories and demand for a previous quarter. Under this control system, the regular quarterly actions had frequently to be supplemented by special actions prior to the next scheduled distribution in order to take care of fluctuations in actual demands. In some cases, as many as 40 percent or more of the stock transactions were interim transactions reflecting such unanticipated demands.

In an attempt to improve the control system, the program usage replenishment system (PURS) technique was developed in the hope of attaining a more realistic balance between inventory levels and projected requirements based upon program plans. However, the introduction of this system materially added to the computational workload at ASO. To extend the PURS procedure to additional classes of material required an even greater workload. It was therefore reasonable to look toward the adoption of electronic data-processing techniques as a way of accomplishing this mission more expeditiously and more economically.

The electronic computing equipment that has been installed is now at work on this job, so that management may more effectively control the procurement and distribution of supplies to meet requirements.

Air Materiel Command

The Air Materiel Command of the Air Force had a problem of logistics control similar to that of the Navy's ASO. They are now using and actively exploring the further use of computers for logistics management. One of the problems they face is the development of a system which can be expanded during an emergency without requiring a greatly increased staff.

The Bureau has assisted them in this program. In the first instance, the Bureau assisted in the procurement of their automatic device. In the second instance, we are helping to assist the Air Materiel Command in training their supply and logistics personnel at various bases. The interesting aspect about this program is that we have been successful in training GS-4 and GS-5 stock clerks to carry out some of the programming operations for the computer.

I have reports that they are doing quite well. What this means is that for some of the automatic programming, relatively untrained people can be taught to do the work, thereby releasing the more highly trained for more complex work. I might mention here that the Bureau has now had considerable experience in training personnel to operate automatic electronic devices of this sort. I think it is one of the important values of our central computational and data-processing staff.

Federal Housing Administration

The experience of the Federal Housing Administration provides an example of how more effective work can be done with the use of data-processing machines. In the low rent housing program administered by the FHA it is necessary to audit income and other statistical data concerning the tenants. With their present staff this can be done only on a sampling basis. Carrying out this operation on the SEAC it was shown that a 100 percent audit would be possible with the same staff. In addition, their staff would be able to give more attention to borderline cases where careful, human judgment is required.

This list is by no means complete. But I hope it has served to demonstrate some of the advantages to be derived from applying modern data-processing techniques to Government operations. There are, in fact, a host of applications which are now in the planning stage or, in an even greater number of cases, still uncontemplated.

In recognition of the demand for Bureau services in this field and of the increasing use of automatic devices for Government operations, the National Bureau of Standards has requested and received initial appropriations from the Congress for the construction of a pilot data-processing machine. This machine is now in the planning stage and will take about 2 more years to get into operation. It will provide Government with a central facility for studying the feasibility of various automatic systems and components for use in machines to serve the particular needs of Government agencies. This pilot facility, which will be highly flexible in character, will be used to study the large variety of problems encountered in numerous Government operations, and will be adaptable for actual sample trial runs of contemplated systems.

The facility will also provide our staff with increased research and engineering experience in order that we may stay at the forefront of new technological advances in this field."

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