PROCEEDINGS: AUTOMATIC DATA PROCESSING CONFERENCE

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HARVARD UNIVERSITY

September 8 and 9 — 1955

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Edited by ROBERT N. ANTHONY

DIVISION OF RESEARCH

GRADUATE SCHOOL OF BUSINESS ADMINISTRATION

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Foreword

THE problem of establishing a basis of communication and understanding between technical people – scientists and engineers – on the one hand, and businessmen, on the other, is not new. The picture of the "up-in-the-clouds" scientist who cannot get through to the "down-to-earth" production or sales executive, and vice versa, is well known, and for years management has sought ways in which the language barriers separating these groups could be overcome and their differences in viewpoint reconciled. In the accounting-control area, however, this communication problem did not arise until very recently. It was created, of course, by the recognition that the scientific method and certain mathematical techniques were of practical value in the solution of management problems and by the development of new and extremely powerful tools for processing numerical information.

With reference to data processing, the essence of this new communication problem is that businessmen must find ways of telling the technical people what their requirements for data are, so that equipment can be designed to furnish these data as efficiently as possible; and the technical people must find ways of telling businessmen about the potential uses and the limitations of the new equipment. Unless this information can be communicated, it is unlikely either that equipment will be designed to meet the real requirements needs of business for data (as distinguished from what technical people *imagine* are these requirements) or that businessmen will recognize and take advantage of the potentialities of the new developments.

The conference reported in this book is one of many attempts being made throughout the country to provide such a basis of communication. Publication of these proceedings is another step toward the same objective.

The Harvard Business School Conference on Automatic Data Processing was held on September 8 and 9, 1955, concurrently with a conference on Automation. These conferences were held as a service to The Associates of the Harvard Business School, a group of companies and individuals who, among other things, are interested in and support the research activities of the School. Invitations were extended to individual Associates and to controllers, financial executives, and top management of member firms, and the program was designed entirely to meet the interests of these persons. More than 300 attended.

The Conference started with two concurrent sessions. The first, reported in Part 1 of these proceedings, was designed as an introduction to automatic data processing for those who had no previous background in the field. The second, reported in Part 2, was for participants who already were acquainted with the subject and focused on an issue of considerable current interest to management: the extent to which data processing functions should be centralized in one geographic location in multiplant companies.

The balance of the Conference consisted of three sessions for the whole group which are reported in Parts 3–5. In Part 3, recent developments in equipment are described, and problems of selecting likely applications for automatic data processing are discussed. The talks reported in Part 4 are descriptions of applications of automatic data processing equipment in two areas: (1) order processing and production planning and (2) payroll. Part 5 deals with developments in operations research and the relationship of operations research to automatic data processing.

Most of the talks and discussion reported here are edited transcripts of recordings made at the Conference. We regret that the excellent talk by Mr. Trevor Sainsbury of Westinghouse Electric Company on developments in inventory control in his company was not recorded, and consequently is not included, and that a record was not made of the discussion at the end of Part 4.

Planning a conference of this type is a considerable undertaking extending over many months. Professor James R. Bright was general chairman of the Automatic Data Processing and Automation conferences. Professor Edward L. Wallace, operating head of the School's research project on data processing, was responsible for the program of the Automatic Data Processing Conference, and made all arrangements with the speakers. He was assisted by

Messrs. Peter Laubach, Peter McNerney, and Carl Dudley of the research project staff. Mr. Vernon Alden, director of the Associates, handled invitations, housing, and other physical arrangements.

Mrs. Elizabeth L. Dalton edited the transcripts, with the advice of Mr. Laubach on many technical points. Since many of the talks and all the discussion were informal, the transformation of the spoken words into a readable presentation was an exacting job. Miss Yvette T. St. Jean designed this book and handled the job of getting it published. As always, my secretary, Miss Helen F. Vinal, helped the team working on this venture in such a variety of ways that I shall not even attempt to list them.

Although the work of these people behind the scenes was important and is sincerely appreciated, the success of a conference depends, of course, on the speakers. With two exceptions, our speakers were not members of the Harvard Business School Faculty. In selecting outside men, our objective was to obtain the best qualified man in the country for each of the topics we thought should be discussed, and the talks reproduced herein are the best possible evidence of our success in doing so. The School deeply appreciates their participation in this educational effort.

ROBERT N. ANTHONY

Associate Professor of
Business Administration

Soldiers Field
Boston, Massachusetts
April 1956

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PART ONE

Basic Principles and Techniques

CHAPTER 1

Automatic Data Processing Methods

T. F. BRADSHAW

Partner, Cresap, McCormick and Paget

WHEN I was on the staff of the Business School, I had the good fortune to be associated with Ross Walker, Bob Anthony, Russ Hassler, Charlie Bliss, and others like them. From them I learned about a large and basic change taking place in the way management was managing, a change characterized by Professor Ross Walker as the substitution of "instrument flying" for "seat of the pants flying." This concept of management led, among other things, to the development of the Control Course here at the Business School, a course which has been a pioneer in education for business administration. This changed concept of management also led to the adoption of a useful attitude of mind, combined with effective action in many business enterprises. I think this concept of management has provided a remarkable example of the cross-fertilization of Business School thinking and management action.

I want to talk about this change in management concept. It is still, in my opinion, the most important change going on in the business world. I think this new concept of management consists of three parts. The first is setting up company and departmental goals and the necessary controls to insure flexibility in planning and in the attaining of those goals. The second is organizing so as to spread the proper motive throughout the company organization. And the third is building an organization that can help the chief executive carry out his job of coordinating the parts and that also can supply him with the tools of planning and control.

One thing has been added in recent years. A mechanical revolution in data processing has occurred which will, I believe, alter substantially the rate at which this new concept of management will evolve. It will do so by providing the tools of forward planning and controlling operations with an economy and completeness that none of us thought possible only a few years ago. It will do so and – this is far more important – it will do so by forcing the change. I am convinced that the only way in which the enormous potential savings inherent in the use of electronic data processing equipment can be realized is by applying these machines within the framework of this new concept of management. In short, effective utilization of electronic equipment demands a new concept of procedures, which will in turn supply the tools by which management plans and controls operations. In what way do these large technical advances in electronic data processing equipment require a rethinking of our basic procedures? What impact will they have on the way management organizes to accomplish its job? I should like to place before you some thinking about each of these questions.

But before examining these questions I should like to explore with you some of the changes that have taken place in data processing equipment. These are just a preamble to the main event; the main event is always management, not the available techniques. It is important, of course, for us to relate our own past experience in data processing techniques to today's electronic equipment. I take it that most of you are no better versed in electronic delay lines, vacuum tubes, and mercury tanks than I am. Understanding what goes on beneath the hood of your car will not help you become a better driver. The important things to know are: how to run your car; how to take care of it; what expert to take it to when something goes wrong; and what new developments are likely to alter your mode of transportation. There are always those whose curiosity leads them to poke about under the hood. The results are sometimes good, but generally bad. In any event, the results are not relevant to the problem of "getting from here to there."

Electronic equipment is truly awe-inspiring, but it deals with very familiar things. We have prepared a series of slides to show the evolution of data processing from pencil to electronic equipment. Although much of what is shown on these slides is familiar to you, I think it is important for us all to realize that we are dealing with what we have always dealt with, namely, the problem of handling masses of data in such a way that effective business decisions can be made.

Data processing is the inevitable paper work necessary to the production and distribution of goods and services. It includes the clerical work of production and sales personnel. It is not restricted to accounting by any manner of means. It is the entire flow of paper work throughout the business, whether it be production or sales or costing or what have you. It is certainly increasing in volume and cost, and it is susceptible to industrial engineering techniques.

Here I should like to introduce the concept of the building blocks of data processing (see Exhibit 1.) These five building blocks, classifying, sorting, calculating, summarizing, and recording, are the basic elements into which all data processing problems subdivide. These are the functions which have to be performed whether they are done manually or by the most advanced type of electronic equipment. By studying the building-block components of different types of equipment, I think we shall see that electronic computers are no more than a significant advance in solving the problem that has seen many significant advances over a period of years.

Now what do we mean by these building blocks?

Classifying: Before we can handle any data such as invoices, orders, or other source material, we must know how we want to classify these data. This is quite commonly done by developing codes.

Sorting: Sorting falls generally into two types. First, sorting to sequence for transcription to other records or for filing purposes. Second, sorting to obtain a distribution, such as by product, by territory, or by types of expense.

Calculating: Multiplication and division problems involved in data processing vary from very simple calculations up to extremely complicated ones. Generally speaking, of course, the calculations found in business are of a much lesser order than those found in the scientific and engineering studies.

Summarizing: There are several types of summarizations that are commonly required in data processing. Those that are most familiar are totals of sales invoices, sales orders, production and sales statistics, or total expenses such as would be required for accounting records. Another use or purpose of summarization is for control to determine that subsequent work is done accurately.

Recording: Recording includes transcription, reproduction, and filing of source documents as a matter of record. It might be argued that these subfunctions be treated separately, but we feel it is more useful to an understanding of data processing problems to consider them collectively.

Looking back over the years, there appear to have been five significant stages of advancement from manual routines to the electronic computers (see Exhibit 2). The first stage was a simplification of the individual functions through the application of work-simplification devices. The second stage was mechanization, and with mechanization came combinations of two or more functions. The third stage, that of punched-card tabulating equipment, introduced compatibility of machines. For the first time we had a way of moving from machines that would perform one or more of the functions to other machines that would perform additional functions through the medium of the punched card. In the fourth stage, the punched tape introduced compatibility to a wide range of equipment; accounting machines, typewriters, addressing equipment, calculators could now be used in combination with each other and with punched-card equipment. And the fifth stage is that of electronic computers. The important principles introduced are intercommunication and rapid processing. For the first time one piece of equipment, capable of storing raw data and processing instructions, will perform all the building-block functions at the speed of light.

Let us examine the first stage very briefly. Examples of purely work-simplification devices are, of course, familiar to you all. Charge plates applied to source data will facilitate sorting at later stages of processing. Key Sort cards are a familiar device for rapid sorting of data. Typewriters and adding machines represent the application of work-simplification devices to the building blocks.

Let us look at the second stage very briefly – mechanization plus the combination of two or more functions. The machines shown in Exhibit 3 combine two of the building blocks, for example, the adding machine, the printing calculator, the adding check writer, the cash register. Just to round out our picture,

Exhibit 4 shows some of the equipment that combines four of the building blocks. These are the most advanced types in this second stage: the computing-billing machine, the window posting-billing machine, and the proof machine. All are commonly known as accounting machines. Accounting machines represent the farthest that we have pushed the stage of mechanization plus the combination of functions.

Now let us take a look at what this second stage has meant in terms of effectiveness. Accounting machines are most effective in recording, sorting to distribution, and in summarizing. They are useful in special situations for calculating. They are limited in initial classifying. They are not compatible with many other forms of data processing equipment. You cannot move readily from one machine to another without having a clerk pull the papers out to go into another machine. There is a lack of intercommunication between the functions, that is, between the building blocks.

The third stage is the punched-card stage which introduces compatibility of equipment. The basic punched-card equipment — the key punch, the sorter, the reproducer, the accounting machine — all the conventional punched-card machines have single characteristics or combinations of building-block characteristics, but they are compatible with each other by virtue of the punched card. Some punched-card machines that combine several of the building blocks are shown in Exhibit 5.

Let us take a look at what this third stage has meant. The punched-card equipment meets the need for compatibility among machines of the same manufacturer. This equipment is effective in recording, calculating, sorting to distributions, and summarizing. Again, like the accounting machines, the equipment is limited in its capability for classifying, that is, initial coding. It offers possibilities for combining functions into relatively continuous processes. It has a limited intercommunication between functions. It must rely on operators to move blocks of cards from one machine to another. One of the greatest contributions of punched-card equipment has been that it requires discipline of procedures and written manuals to be truly effective. For the first time we now have something in the office that is comparable to a factory operation. Punched-card equipment will not, of course, be replaced by electronic equipment for many years to come, and I

EXHIBIT 1. BUILDING BLOCKS OF DATA PROCESSING

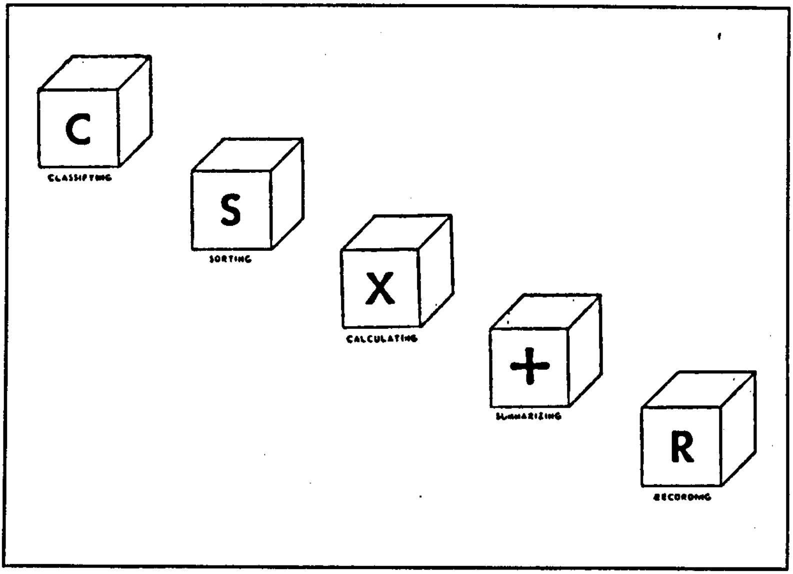


EXHIBIT 2. SIGNIFICANT STAGES OF DEVELOPMENT IN DATA PROCESSING

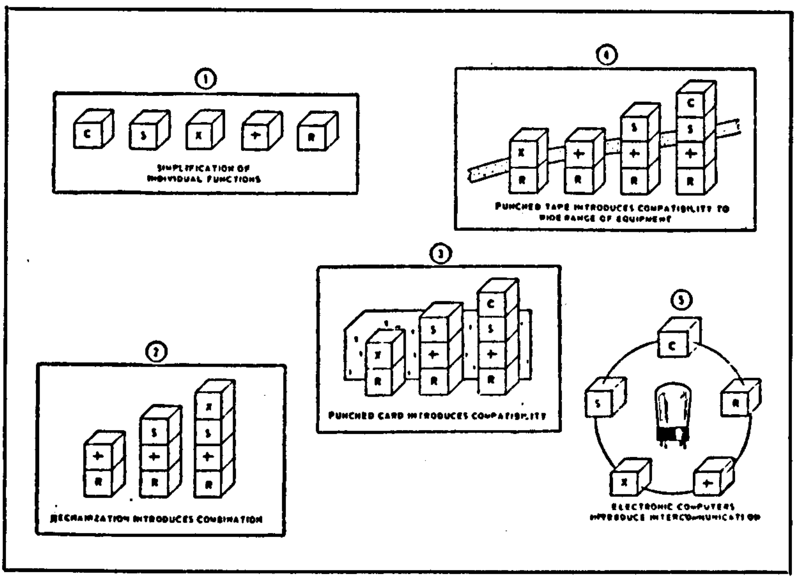
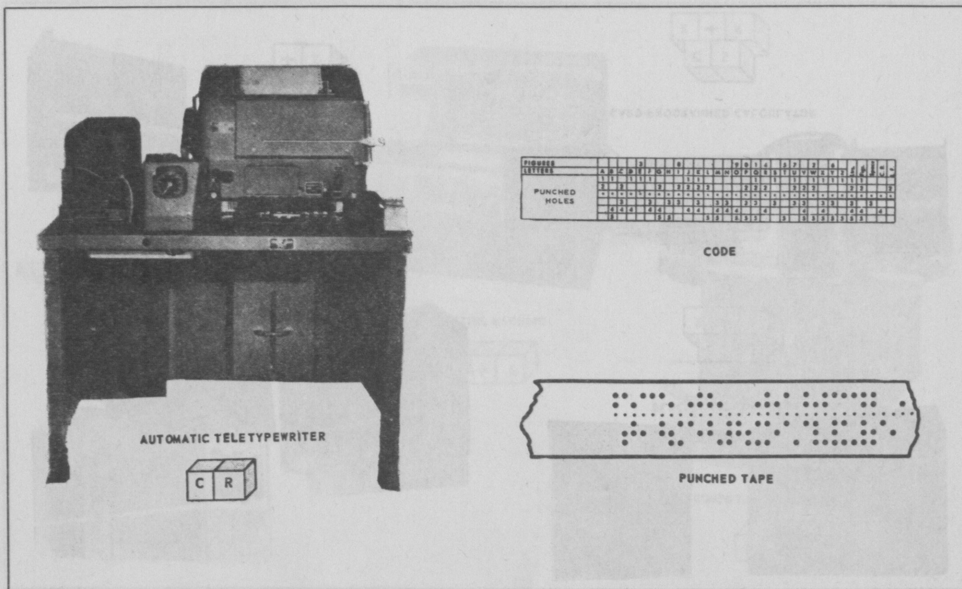


EXHIBIT 3. MECHANIZATION – COMBINATION OF TWO FUNCTIONS

Exhibit 4. Mechanization – Combination of Four Functions

EXHIBIT 5. INTEGRATED PUNCHED-CARD EQUIPMENT

Exhibit 6. Compatibility of Different Equipment Through Punched Tape



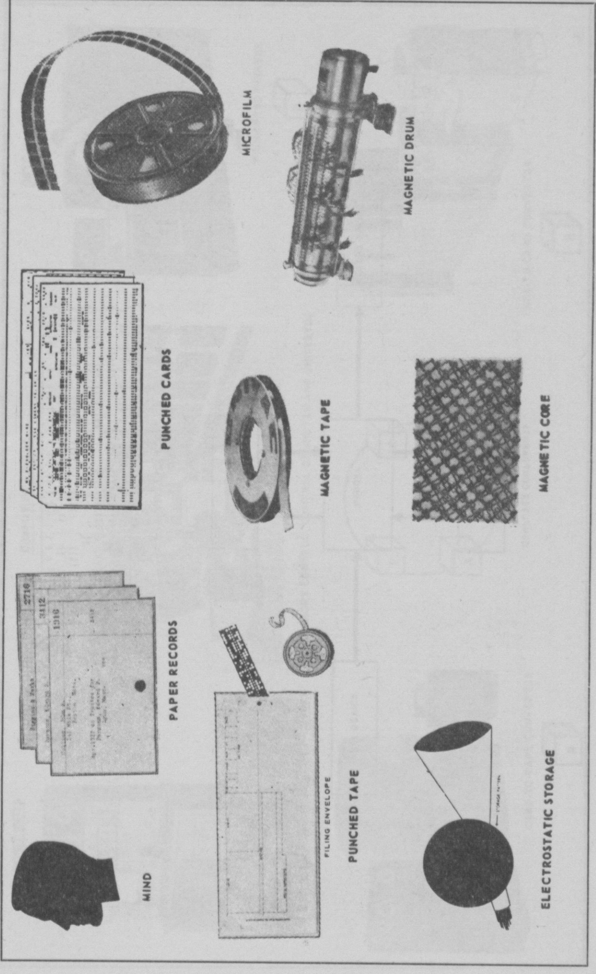
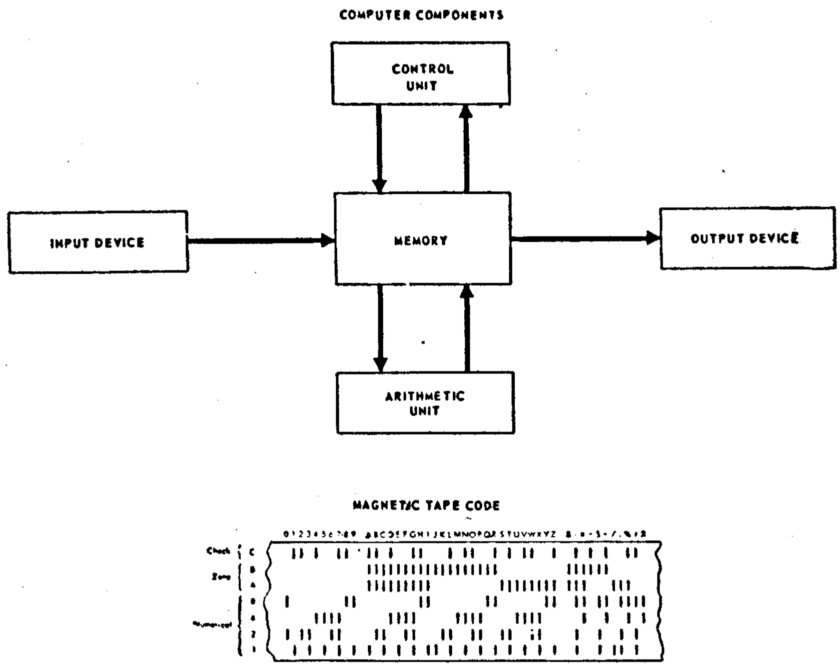


EXHIBIT 7. TYPES OF MEMORY

EXHIBIT 8. BASIC COMPUTER COMPONENTS AND MAGNETIC TAPE CODE



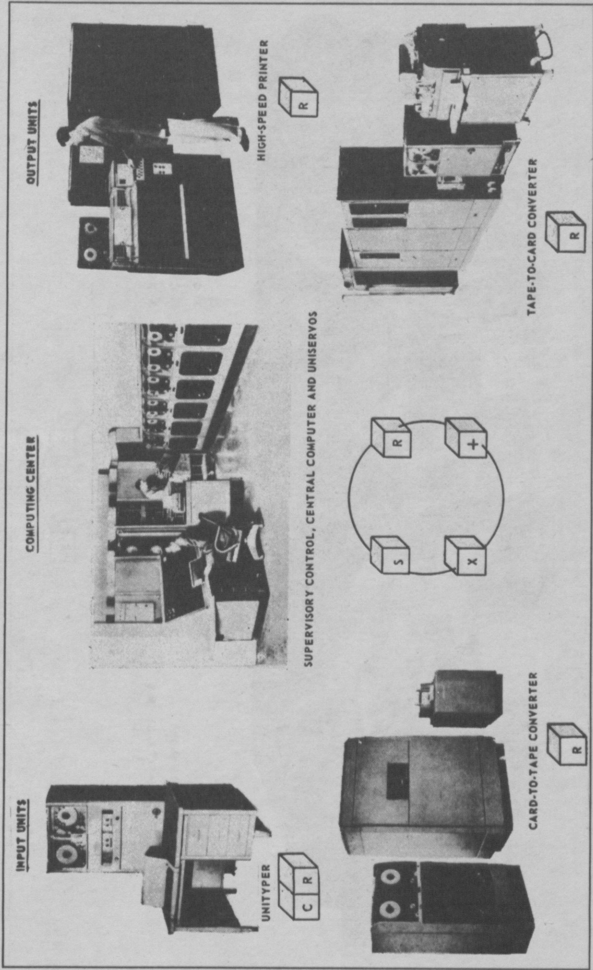
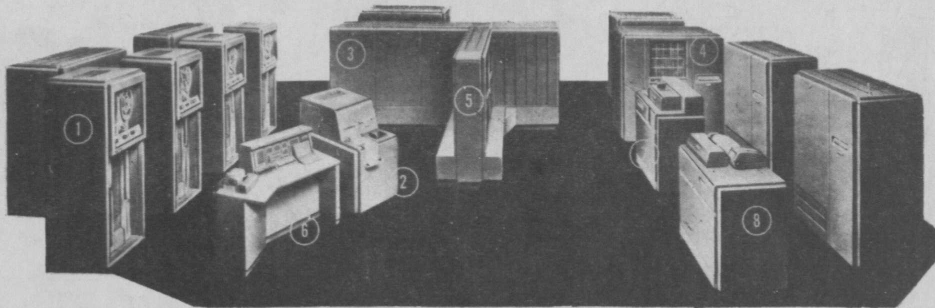
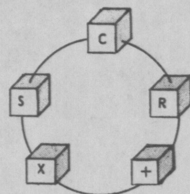


EXHIBIT 9. REMINGTON RAND UNIVERSAL AUTOMATIC COMPUTER

EXHIBIT 10. IBM 705 ELECTRONIC DATA PROCESSING MACHINE



1. MAGNETIC TAPE UNITS
2. CARD READER
3. MAGNETIC CORE MEMORY
4. MAGNETIC DRUM STORAGE UNIT



5. ARITHMETICAL AND LOGICAL UNIT
6. OPERATOR'S CONSOLE
7. CARD PUNCH
8. PRINTER

think we shall all see much more complex punched-card installations and more completely automatic operations than are now in existence.

The fourth stage, that of the punched tape, introduces compatibility to a wider range of equipment. The punched card produced compatibility for equipment that could be activated by a punched card and therefore necessarily was rather limited. Exhibit 6 shows a punched tape that can be applied to many different kinds of equipment. Most of us are familiar with the teletypewriter with the five-channeled punched tape, which can be produced by the teletypewriter for automatic transmission of messages from a central receiving point. In recent years this five-channeled punched tape has been developed as a "common language" between different types of office equipment so that the compatibility, which has existed between units of punched-card equipment, can be extended to other equipment.

There are a number of fairly common types of office equipment that can produce tape. Using the card-to-tape converter, a block of cards can be converted into a tape, and the tape may be used at the same location or teletyped or mailed to a different location. A cash register with a tape offers point-of-sale recording for later processing on machines. The typewriter tape punch will prepare typewritten copy and punch information into a tape at the same time. Other tape equipment includes the nondescriptive accounting machine and the window-posting machine equipped with tape punches. The Computyper, a marriage of the Flexowriter (which is an input-output typewriter), and the Friden rotary calculator, also produces a tape. The 10-key adding machine can summarize and produce a tape. The Flexowriter is an output and an input machine; it will produce a tape and will read a tape.

What has the fourth stage meant? Punched-tape equipment extends compatibility to a wide range of data processing equipment. It improves the classification of original records for subsequent mechanical processes. For the first time we have machines that can typewrite sales orders in the usual manner and at the same time produce punched cards through the medium of a punched tape. We are thus able to guarantee consistency with the original records. Punched tape improves communication between functions, although it still requires manual attention to transfer the tapes from one machine to another. It also permits communication between operations at great distance through the use of teletype networks, or by mailing the punched tape. Perhaps the most significant opportunities here are that complete data processing systems can be built without too much change in existing methods of operation and organization. Once these systems built around tapes are developed to the point where they are completely integrated operations and the procedures are written down, then we believe it can be a relatively simple matter to transfer these procedures to electronic equipment.

Before proceeding any further, let us take a look at the concept of memory, which has been developing through all these stages (Exhibit 7). In the beginning we had the human mind and nothing else to memorize such information as was required. In many cases today, of course, this is the sole source of information for data processing. The next "higher" order of memory would be various types of paper records, which, as you know, are maintained in significant quantities. To some extent these files have been supplemented by punched-card files, and master card files. In the last decade we have seen a large amount of information transferred to microfilm for permanent storage to reduce the size of the files. With the advent of the various tape-producing and tape-actuating equipment, we now have the possibility of master files of punched tapes, which may be stored in envelopes. Magnetic tape has been used for some time as a recording medium and is now beginning to come into its own use for maintaining business files. The bottom row of the exhibit shows some of the devices used for storing information within a computer. The important thing here is not the technical aspects of these, but the fact that they are the same as the other devices shown here. They provide the same kind of service as far as data processing is concerned. They provide it with much more rapidity and with much greater depth, but it is still the same service. These advanced kinds of memory devices enable us to store both raw data for a problem and the instructions on how to handle those raw data.

With the concept of memory and of the development of these building blocks in mind, let us then turn to the fifth stage, that of electronic computers, which introduce complete intercommunication and complete compatibility for all the building blocks. Exhibit 8 shows the components of an electronic computer in very simplified form. These are the features of all computers whether they are general-purpose or single-purpose. The main difference between the general-purpose computer and the single-purpose computer is that the general-purpose computer is flexible in nature whereas the special-purpose computer has built-in programs and can perform only the functions for which it was constructed.

The principal component of a computer is the memory, which can be magnetic drum, cathode ray tube, acoustic delay lines, or magnetic core. Usually contained in the same framework as the memory is the arithmetic, or logical, unit which can perform addition, subtraction, division, multiplication, comparison, transfer, or of course any combination of these functions. As indicated by arrows, information can be transferred from the arithmetic unit to memory, or vice versa, as many times as is necessary. The control unit is necessary to set the computer in motion, to see that it performs the tasks that it is supposed to perform, and to attend to the equipment when breakdowns occur or when the machine stops through faulty programming. The control unit has communication with the memory, and the memory has communication with the control unit. Whenever something goes wrong with the operation of the computer, it will automatically type out this information on a typewriter attached to the control unit. In addition to these three basic units it is necessary to have both input and output. And, of course, the great difference between computers used for scientific work and those used for data processing is the difference in the volume of input and output. Business requires enormous input and output and relatively little grinding of the gears once the data get into the machine.

By way of illustration, Exhibit 9 shows the Remington-Rand Universal Automatic Computer, generally known as the Univac. Quite a substantial number of Univacs are in actual operation now. Many more are on order. The Unityper and the card-to-tape converter here on the left are used to produce magnetic tapes, which are placed in the Uniservos for introduction into the central computer as the input device. In other words, you get the information in either by tapes or by direct typing. Both have to be translated into a magnetic tape. Information from the computer is again produced on magnetic tapes, which are used to actuate either the high-speed printer or the tape-to-card converter.

The high-speed printer is a relatively new machine that prints at the rate of 300 to 600 lines a minute depending upon the number of carbon copies required. This output speed is greatly in excess of punched-card equipment, but not fast enough for the computing speed of the machine.

Just so we do not play favorites, Exhibit 10 shows the IBM 705 electronic data processing machine on which many orders have been taken. I hesitate to say that none have been delivered, because keeping up with this field is extremely difficult. Some perhaps have been delivered, but the last time I investigated they had not.

The card reader and the card punch are additional input and output units which may have some advantage, particularly during the period of conversion from punched-card equipment to electronic computers. The memory is of the magnetic core type and is supplemented by a magnetic drum of considerably higher capacity.

Let us now see what this fifth stage may mean. Computers stand at the end of a long line of improvements in the manual methods of classifying, sorting, calculating, summarizing, and recording. Basically, they provide intercommunication without manual interference and integrate all sorting, calculating, summarizing, and recording. They reduce the importance of sorting since distributions are made in random sequence. It is not necessary to sort original information into piles in order to obtain sequence in distributions. They have limited capability for classifying. For instance, they are not able to read electric utility meters directly into the computer or directly onto magnetic tape. Such an ability, of course, would eliminate the long process of getting the information into the equipment by key punching of cards and card-to-tape conversion.

More so than with any other type of equipment, these computers accentuate the need for logical procedures. Standardization and more advanced thinking-out of business problems will be required before computers can be used successfully. If they are used for illogical procedures, it is doubtful that they will ever achieve their full capabilities. Computers have an unlimited potential for development, but a vast amount of work must be done in development of organization and procedures to the point where they can take full advantage of these new techniques.

If I may return to the major questions raised at the beginning of this talk, let us look at some of the changing concepts of organization and responsibility that will be required before we can put electronic equipment to work. Accounting and statistical data can be processed on electronic equipment at incredible speed for three reasons.

The first reason is that the equipment can handle the building blocks very fast. That, of course, is understated. The Univac can handle eleven-digit numbers in this way: add at the rate of 1,900 a second, subtract at the rate of 1,900 a second, multiply at the rate of 564 a second, divide at the rate of 257 a second, and compare at the rate of 2,760 a second.

The second reason that data processing can be handled so speedily is because of automatically sequenced operations. In all preceding stages of data processing, it was necessary for the operator to take a batch of papers or a batch of cards or a tape from one machine to another in order to perform successive data processing steps. Once the instructions are given to the computer, there is no need to stop for manual handling as the machine goes from one step in the process to another.

The final element of speed is that all exceptions can be made routine. In all the preceding stages of data processing that we have looked at here, all exceptions to the regular procedure had to be handled as exceptions; that is, they had to be handled outside the flow of regular procedures. If we can think of all possible exceptions and if we can write instructions to the electronic equipment for handling those exceptions, the machine will then handle the exceptions in a routine way without stopping. For these three reasons, then, data can be processed at incredible speed on electronic computers.

As you know, a number of installations of electronic computers have been made. I do not want to be misinterpreted, but we feel that the results of most of the installations have been poor to fair. We think they have been poor to fair for a number of reasons. The first reason is, of course, the experimental nature of the installations. Those companies which are already involved in installations are obviously trail blazers. Therefore they must run into all the problems of applying it, all the problems of a trail blazer. There is a lack of competent personnel. There is certainly a lack of competent programmers. A programmer is a highly trained man who starts off with a fine logical mind – a very difficult combination.

The second reason that we think these results have been fair is the failure to realize the enormous preparatory time and thought. I think today's businessmen in planning for their needs in this field are making fairly adequate appraisals of the time involved. But in the earlier days I don't think they did. And there are two tremendous preparatory steps that need to be taken. One, I think, will become obvious as we continue, and it is that your whole procedural structure has to be looked at. You have to rewrite your procedures: think through your procedures and rewrite them for the equipment. And then the second phase is that you have to interpret those procedures. You have to translate those procedures into computer language.

In regard to the program phase itself, the first step is the actual procedures phase, and the second is the programming phase. In a simple procedure, that is, the writing of the program steps, the actual number of program steps can run into the thousands. And in a fairly complex situation, the program steps can run into the hundreds of thousands. Each program step has to be thought out in terms of its effect on succeeding and preceding program steps; and, if you are involved in the process of writing out thousands or even hundreds of thousands of these program steps, you have a very hard job on your hands.

The final reason is the failure to recognize that the machines may possibly and very likely require a new concept of data processing. There is a need, we feel, to reorient our thinking away from functional areas such as payroll, inventories, production planning, and so forth, and toward thinking in terms of the impact of a single transaction on all functions. We think that Mr. George Troost, Vice President of Chrysler, has summed this up very neatly when he said, "We believe it necessary to develop an integrated approach wherein the requirements of sales, production planning, material control, production, statistical accounting, and treasury functions are viewed together so that a consolidated, coordinated system of data processing can be thoroughly developed."

Why must this be so? Why can we not transfer present procedures to electronic equipment and expect maximum results in terms of cost savings and increased service to management? The reason is, I believe, that both our present procedures and our present organizational approach to handling procedures are the product of the kinds of equipment with which we have been working. In other words, our present concept of cost accounting, accounting, budget analysis, statistical analysis are all compromises between what management needs to do its job and the technical means of handling data that have been at our disposal. In the same way the manner in which we have organized for processing data has been the result of the kind of equipment available and the data processing methods required by that equipment.

To illustrate this, consider a typical functional procedure, the sales paper work process. What does the sales paper work process consist of? It consists of acknowledging sales orders, initiating or planning production, shipping the goods, invoicing customers, maintaining accounts receivable, and preparing sales statistics. How have companies organized to carry out the sales paper work process? In a reasonably typical company, the sales department has organized sections to handle the preparation of sales order processing. The accounting department has organized sections to handle the preparation of invoices, the maintenance of inventories, and the maintenance of accounts receivable. The production department has organized sections to handle shipping and production planning and control. In spite of the fact that all these processes within the sales paper work process are interrelated, that one is really a part of another, these processes are broken up and each part is performed by an independent organizational unit. The net result of performing related data processing piecemeal in a number of organizational locations is that data processed in one department must be provided to other departments where it must be reprocessed to meet that department's needs. This reprocessing of data is the largest single factor causing high clerical expense and limited report data for management. Such reprocessing, we feel, is the basic data processing problem that electronic equipment can help solve. Only by solving this problem can electronic equipment realize its full potential.

There can be, we believe, a three-stage approach to solving this basic data processing problem: first, reorganization of data processing units; second, integrated data processing through the utilization of nonelectronic equipment; third, complete reorganization and the use of electronic data processing equipment. I should like to discuss each one of these stages briefly.

The first approach, that of reorganization of data processing units, can be illustrated by reference to an actual case. A manufacturing company operated six mills. Each mill had its own cost, production planning, and inventory departments. The purpose of these staff groups was to process all data at the mill level and provide mill management and the vice president in charge with various reports. The vice president of manufacturing, in turn, had a number of staff groups reporting to him, — inventory control, payroll, industrial engineering, cost estimating, cost variance analysis, production planning, and general accounting. The purpose of these staff groups was to reprocess the informational reports supplied by mill management in order to provide control information to the vice president and other members of top management.

A reorganization was undertaken which comprised, in simplified terms, two parts. First, the vice president's staff groups were consolidated into two groups: one devoted to data processing and the other to provide analytical and interpretive services to management. Second, at each mill all the staff groups were dissolved and replaced by an administrative assistant with a small clerical force.

Of course, more than a reshuffling of boxes on an organization chart has taken place. Each mill now supplies original data to the central data processing group. The data are processed centrally and reports are prepared for the vice president and the mill managers. The administrative assistant interprets results for his respective mill managers, provides original data to the central data processing group, and makes sure that his mill is getting whatever information it needs.

Note that this first approach to solving the data processing problem involves no mechnical or electronic equipment. Even without the introduction of mechanical equipment impressive results can be obtained. In the particular instance the clerical force was reduced from 142 to 92, and more accurate and timely reports resulted. That then, is the first approach — a purely organizational approach.

The second approach is integrated data processing through the utilization of nonelectronic equipment. The second stage consists of making use of a common language device to provide the links that tie together a number of business machines in common use, such as typewriters, bookkeeping machines, punched-card equipment, and so forth.

The five-channel tape becomes the common language link between the original recording and all subsequent recordings. In concrete terms, this means that the sales-clerical process could be accomplished by an initial recording of a customer order on an electric typewriter equipped with a tape punch and that all subsequent processes from this point on could be accomplished on machines activated by that tape. This equipment might include punched-card equipment for production planning, graphotype machines for the preparation of shipping tags and labels, electric typewriters for the preparation of invoices, and bookkeeping machines for accounts receivable recording.

This is integrated data processing and can be accomplished with a minimum of organizational arrangement and a minimum of training in new skills; and it can be accomplished, of course, without the introduction of electronic equipment. It can result in lower clerical expense, faster delivery of reports, and a minimum of errors; and, as I pointed out before, it can be a very essential preamble to thinking in electronic computer terms. It can set the stage for electronic computers.

The third stage is complete reorganization and the use of electronic data processing equipment. We feel that this stage can develop from either one or both of the preceding stages. For full realization of the potential of electronic equipment, there must be a merger of the central data processing concept of organization and the integrated data processing concept. This merger will mean that a new concept of procedures has been implemented. It will mean that data processing has been centralized and that there is no human processing or reprocessing once the original data are prepared for the machine. Finally, it will mean that the basic interdependence of procedures is recognized.

In this third stage we can conceive of feeding original data into the equipment, data such as raw material requirements, standard product costs, available inventories, manufacturing orders, assigned capacity and allowed costs, payroll data, sales orders for immediate delivery, sales orders for subsequent delivery. From the machine would be drawn the reports and documents needed for the day-to-day operation of the business: available inventory reports, purchase orders, plant schedules, cost variance analysis, production reports, material usage reports, performance reports, available stock reports, planned shipment reports, invoices, bills of lading, and so forth.

The clerical savings in this third phase will be impressive indeed, but of far more importance will be the kinds of reports and information available to management. The use of such an electronic integrated data processing system will make available, we feel, three kinds of information:

1. Information with which to plan. This information will consist of appraisals of the future, analyses of past data to provide forecasts, and the rapid preparation of detailed schedules for manufacturing, purchasing, shipping, and so forth.
2. Information with which to test plans. Once a budget plan is set, is it the best plan? One way to find out is to test a number of plans to see which provides the best balance and maximum profit results. This kind of testing has never been possible. The company of today is fortunate to get through its budget cycle once a year.
3. Information with which to control plant operations and change plans when necessary. This information will consist of daily reports when needed and weekly and monthly reports prepared on time and in sufficient detail so that control can become effective.

These three kinds of information — information with which to plan, information with which to test plans, and information with which to control plant operations — add up to the tools of management planning and control. As such, they merely add impetus to a management movement long under way and firmly established in some companies.

In summary, first, there is a basic underlying change taking place in the ways that management manages. This change was under way long before the advent of electronic data processing equipment. Second, in order to realize the potential economies inherent in electronic data processing, a new concept of procedures must be developed. Third, very likely such a new concept of procedures will consist of a merger of central data processing and integrated data processing. Fourth, not only will large clerical economies result from the application of electronics processing equipment within the framework of such a procedural system, but also management will be provided with the information of a kind never before available with which to plan and control operations. Finally, this means that the basic change in management under way will not suffer any change in direction, merely a change in rate of change.

There is a large revolution in concepts of management now under way. The advent of electronic equipment has added impetus and force to this revolution. It has not changed its direction. A large and important structure is being built on the foundation laid here at the Business School a number of years ago.

CHAPTER 2

Principles of Electronic Data Processing

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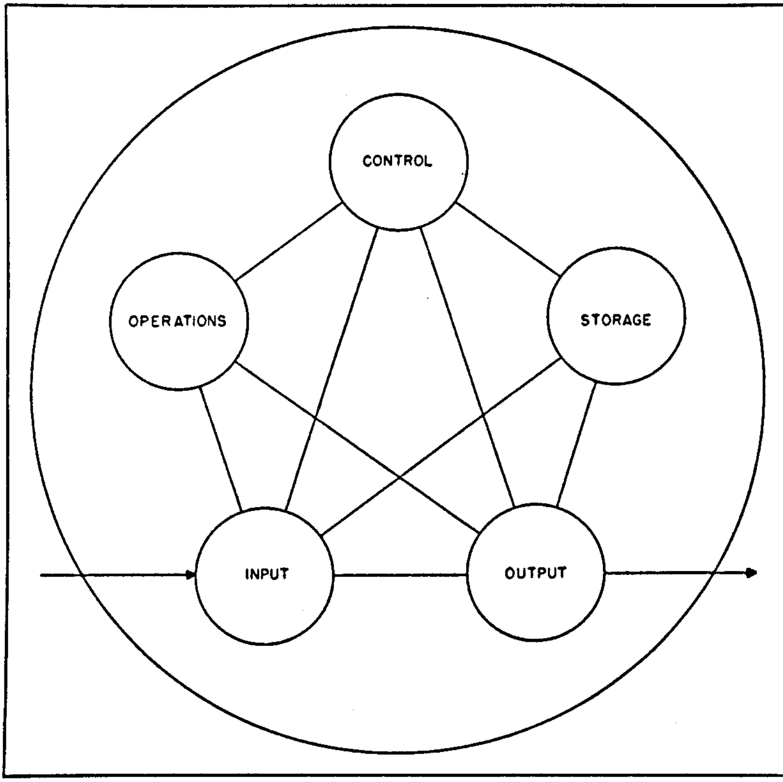
THE details of the internal construction and the mode of operations of our electronic data processing machines are very intricate, and it isn't the purpose this morning to go into all the horrible details of what wire connects what wire inside these machines. There are very few people, even those operating the machines, who really remember what wire goes where. However, those general traits of machines that are likely to be useful to one who is interested only in using the machines, rather than in building them, are of great simplicity. I should like to sketch some of these traits for you this morning.

I think first I shall go over some of the basic characteristics that are common to every machine. This five-block diagram (see Exhibit 1) seems to be a great favorite this morning. The big circle represents our electronic data processing system. The system is inside. We are shown an arrow here at the left to indicate data going into the machine. These are raw data which are to be processed. Something miraculous happens to the data inside the machine, and, lo and behold, at the output we get reports, predictions, sales figures; all our accounting is done for us; and all it has taken is to push a button. Of course, it isn't really that simple.

What I should like to do is not only to say a little bit more about what really goes on inside the black box and to point out why it is a very useful black box, but also to point out why it is very far from being a miracle and very far from being capable of producing miraculous results. These five major components of the machine — input, output, operations, control, and storage — do not

EXHIBIT 1. AN ELECTRONIC DATA PROCESSING SYSTEM: GENERAL ORGANIZATION



necessarily represent actual physical units. You may have one physical unit performing both input and output functions. Each one of these has some measure of control inherent in it, and so forth, but it is very useful when one is talking about computing machines from the applications point of view, rather than from the engineering point of view, to think of the machine in terms of what one might call its logical design, rather than its engineering design. As users of machines, you do not especially care what particular type of screw or type of wire is used inside the machine. The essential features are inherent in its logical organization. I should like to say something about the functions of each one of these units.

The input circle provides the link between the machine and its operators, or between the machine and other machines. As you probably know, data are represented inside a machine not by ink or paper, but by such devices as electric impulses, magnetized spots, and so forth. It is a peculiarity of electric impulses and magnetized spots as used in computers that they have what we call a binary character. A magnetic spot either is there or is not. The electric impulse either is there or is not. You can only distinguish these two states. This makes it necessary to adapt our ways of representing information in a way that is fitted to this peculiarity of the technology of the machines. It means that, instead of being able to scribble in our own handwriting, or in any arbitrary type on a piece of paper, we are very much restricted in the type of symbols that we can use to represent information inside the machine.

There are several solutions to this problem. One is to require everyone to write in binary form. I think that this proposal, if anyone would make it seriously, would rank with the recurrent proposals to change the number system from base ten to base twelve or to teach everybody Esperanto. The other alternative is to let people continue to use the language they are accustomed to and then to provide input devices to change this human language into machine language, or, in technical words, into the machine coding system. This is very simple in principle, but in practice, especially in business data processing application where input volume is large and arrives from many sources, the translation from human language into machine language can often be a very, very important cost factor.

The problem arises not only from the conversion of human language into machine language, but also from a conversion of the language of one machine to the language of another machine. Those of you who have tried to use punched cards of various manufacturers on a single type of machine will know how nasty this problem can be. In principle it is possible to transcribe information from media used by one machine to media used by another; but, unless very careful planning has been done or unless we achieve a Utopia which does not exist at present, this conversion usually requires the use of equipment which in itself may match the cost of the central computing equipment. Quotations for such things as magnetic tape-to-card converters and vice versa rate in the hundred thousand dollar bracket.

This input operation is a very simple one, but in business data processing applications it can loom very large. One analysis with which I was connected during the summer involved the study of putting certain types of bank transactions on a machine. It was found that the cost of the transcription of original documents into a medium suitable for machine input was perhaps the single largest cost factor in that particular application. I shall say no more about this except to point out that, while the input is down here in the left-hand corner where it is not a very impressive-looking circle, it is a very, very important one. So we get data into the machine.

Once we have the data inside the machine, what do we do with them? We are going to come to that in a moment. Let us first assume that we have operated upon these data and are ready to bring them out. And we now require output devices which perform the same functions as the input devices, but in reverse. Here the job is to convert machine language into human language. A typical output device might be an electric typewriter activated by the electric impulses supplied by the machine, which cause the type keys to strike the ribbon and paper, the carriage to return, and so forth. Very much of the same sort of problem applies to the output section that applies to the input section, in that again we are faced with a translation. In addition, and this is something I should have mentioned in connection with the input problem also, we have the whole problem of speed-matching, of matching the speed of the internal operation of the machine to the speed of operation of the input and output devices and also to the speed of the remainder of the business organization of which this data processing system is only a minor part. I shall say more about this speed-matching problem later.

The operations unit, which is represented by the circle on the left, does just what its name implies. Typically, it may have facilities for adding or for subtracting one quantity from another, such as, for example, a debit from an old accounts payable balance to create a new balance. In a scientific computer the main job of the operations unit is to do arithmetic. I think it is true that in most of the data processing systems of large scale now on the market the emphasis on arithmetic has been retained in the design of the operations unit. I think you will probably agree that, in most business applications, addition and some subtraction, for example to post debits and credits, are perhaps the major arithmetic operations so far as the routine data processing goes. In the preparation of statistical reports and so forth, there may be a greater need for arithmetic facilities, but I should like to suggest that the preparation of statistical data and random reports might often be regarded as a kind of scientific problem or an investigation problem, rather than as a routine problem of the type of day-to-day management of, say, accounts receivable or stock inventory.

In these routine operations arithmetic plays a very minor role. The major operations are usually logical operations such as sorting and selecting. But the contemporary automatically sequenced computer has some great disadvantages insofar as the performance of such operations as sorting is concerned. In particular, while these machines appear capable of sorting at high speed, I think that one has to make a very careful comparison of the cost of sorting inside one of these machines with the cost of doing the same job by hand or by using punched cards, or some other type of unit record and ordinary mechanical sorters. The reason for this should be more apparent when I come to a discussion of programming where you will see that, while these machines are capable of very high nominal operating speeds, amazingly high speeds, there are some very good reasons why these speeds are not sustained in practice. As an illustration, the speed of card sorters is often stated to be 200 or 500 cards per minute, but when you have to sort a stack of cards on ten columns, the effective speed is really only twenty cards per minute or fifty cards per minute. The practice that is universal in the computer and in the accounting machine business of quoting speeds on the basis of such elementary operations as a one-column pass at a card sort, or one arithmetic operation, gives a very serious distortion of the picture, as you shall see when we come to the question of programming.

In addition to arithmetic, the operations unit of a data processing machine should be capable of performing sorting operations and of doing a certain number of logical operations such as comparing different quantities, classifying transactions, selecting accounts belonging to specified categories, or deciding whether special attention should be called to a particular account, and so forth.

The control unit, which I have represented at the top here, is really the central executive of the machine. It controls the operation of all the other units of the machine, but it does so purely on the basis of instructions that have had to be supplied to the machine by either its builder or its user. As Mr. Bradshaw pointed out in his talk, the distinction between general purpose machines and special machines, although not a black and white one, lies somewhere in this area and depends upon how much the machine's mode of operation has been specified by its designer and built into the machine, and how much is left to the user of the machine to determine. There are advantages and disadvantages to both types of operations, and a broad spectrum of more or less special, or more or less general, machines. But this is a problem far beyond the scope of what I am to discuss here.

Finally, the storage unit, shown on the far right, is the main memory organ of the machine. Such units consist, as you have seen before, of magnetic drums, tapes, cores, and so forth. They serve the machine as a rule book, as a reference book; and in most business data processing applications this is where the account ledgers, or other business records, are kept. Here again, in the storage unit there arise problems that are not quite apparent on the surface. Surely we can now store large volumes of information on such media as magnetic tape or magnetic drums, and these are accessible to machines at very high, theoretical speeds. But in view of the way present technology operates, it is almost axiomatic that the higher the speed at which you can get that information from one of these storage devices, the greater its cost. There is a very definite upper limit to the amount of storage capacity of rapid access that you can economically provide in such a machine. There comes a point where it is no longer reasonable to provide high speed, rapid access memory, and then one looks to some other types, such as magnetic tapes, where access may be not so rapid under certain circumstances but may be as rapid under other circumstances, if you are willing to do sorting.

The whole storage problem is one of great difficulty because of these cost limitations. So far as our particular discussion is concerned, the extent of this problem will become even more apparent in connection with our discussion of programming because among the things that the storage unit is required to hold are the instructions for the machine. The more instructions it holds, the less information it holds. Also, the more exceptions you want to provide for, the more instructions you need. The more instructions you need, the more space you need, and again there comes a point where economics may dictate that you leave an exception out of your automatic process and process it manually. In which case you may ask, where is one to draw the line? How far does this slow down the machine? What happens now? These, again, are problems which I am not going to discuss at length here but shall leave them to you to think about.

In this discussion I have shown every one of these five units connected to every other one by a line. It is in this fact that the great advantages of electronic data processing systems arise, mainly, that the whole system is one unit. As far as the operator is concerned, there are an input and an output and some control buttons. Everything else, once the instructions have been provided, happens inside. The control unit communicates directly with the operations unit, tells it what operations to perform. The input unit receives data from the outside, may put it into storage, or may put it into the operations unit to have something done to it; or information coming in as input may influence the control unit, which will influence the further course of operations of the machine. Information held in storage may be released to the output. It may influence what happens at the input. The storage information may be used as instructions for the control unit of the machine. In other words, everything is interconnected and interrelated. And once the machine has been designed and built, once the machine has been programmed, once all the bugs have been ironed out, then it is sufficient to push a button and let the machine proceed. It takes care of itself inside.

I have said three "once's" in qualifying this statement. I should like to qualify it further. The machine will keep going usefully only so long as there are no errors. A great deal of work has been done, some of it very successful, on making the internal operation of these machines reliable – error-detecting codes, duplication of equipment, et cetera. In general, it is quite true that the machines are extremely reliable. In particular, they are not prone to the type of errors that we make when we start to doze or fall asleep. The machine tends either to be completely alert and do its job correctly or else break down completely. It will not just start dozing. You know when something happens. When a mistake does happen in one of these systems, it tends to be a lot more serious than in a manual system. One girl working at her own sluggish rate will have a certain production rate and a corresponding error rate. This error rate is likely to be a nice, quiet human rate. If it gets too high, you can fire the girl, you can talk to her, or you can get another girl to watch her and undo the damage. If you catch the error you have a couple of hours' work to undo it. But, if an automatic machine goes awry, it can process at electronic speeds a great deal of stuff that becomes totally botched.

This is a problem that must not be underestimated. It is quite possible to provide as high a degree of reliability in shuffling information inside this machine as you wish. But you pay for it in one of two ways. Either the equipment is more expensive because you are duplicating it, or you are providing extra channels for error-correcting codes and so forth. On the other hand, if the equipment is not more expensive, then you have to make provisions for controls and checks and proofs and settlements in your program. The experience in scientific computation has often been that the programming for taking care of checking and proofing often far outweighs the programming for the routine of the problem, a circumstance probably true in any business application.

I can speak with some confidence only about banking, the only field in which I have had any extensive experience, but the control problem in banking is tremendous. Much effort is required to make sure that things get posted to the right account at the right time and that, when an error occurs, you can find where it occurred and correct it. If a ten dollar check got misread by the machine or, what is more likely, punched by a girl as a million dollar check and is taken off somebody's account, this is serious. It sometimes cannot be prevented, but it must be caught. We have to provide for catching it and for tracing the error, a process whose importance must not be underestimated. I want to reiterate that this is something that strongly influences either the cost of the machinery or the speed at which it will operate, or both.

Let's take a somewhat closer look at the internal structure of the units to give you an idea of how these things really operate inside. In a general purpose data processing machine, these connections do not all exist at one and the same time. The reason for this is that matters would be rather chaotic. You build a general purpose machine because you do not know what the next fellow is going to use it for. And so you cannot possibly provide all the connecting paths because, if you did, the machine would just take off on its own. You would not know what it was doing. So the practice in constructing machines for scientific computations has been to provide a single communication channel or "information transfer bus," the technical term for it, to which these units can then be connected at the proper time and in the proper sequence by the proper instructions. The result is that one of these machines can usually be doing only one thing at a time. This is quite necessary when you are doing scientific computation, because it would be very hard to keep track of several things at one time. It would make life very miserable for a programmer.

But in a business application of a routine nature it is quite conceivable that you might want to do several operations at once. For example, you might want to be reading in data pertaining to the next transaction while you are processing the data for the previous transaction. This is the sort of thing that you like to do in order to take advantage of the speed characteristics of these systems and that could be done in principle but so far hasn't been done to a sufficient extent. And most computers at present adhere to this single information transfer channel where data can be transferred from one unit to another only according to an orderly sequence of instructions called a "program."

On the second slide (Exhibit 2), I'd like to show how a machine is organized on this basis. At the top you see the data transfer bus, which is the main communication channel of the machine. At the left I've shown a few representative storage units. Each one of these units is capable of holding one item of information. This item may be a single number or it may be all the data pertaining to one insurance account or one banking account. When you want to take information out of one of these storage units and transfer it to another one, the machine must be made to close the out-switch, thereby connecting the output of this storage unit to the data transfer bus. If this is the only out-switch that is closed, then, as you see, nothing else is hooked up in the machine to the data transfer bus. We want the data to go, say, from the first storage unit to the second one. And so we close the switch of the second storage unit. There is then a path by which information can flow out of the first unit through the closed out-gate over the data transfer bus through the in-gate and into the second storage unit. I do not know whether anyone has timed me, but it has taken me perhaps close to a minute to describe this simple process,

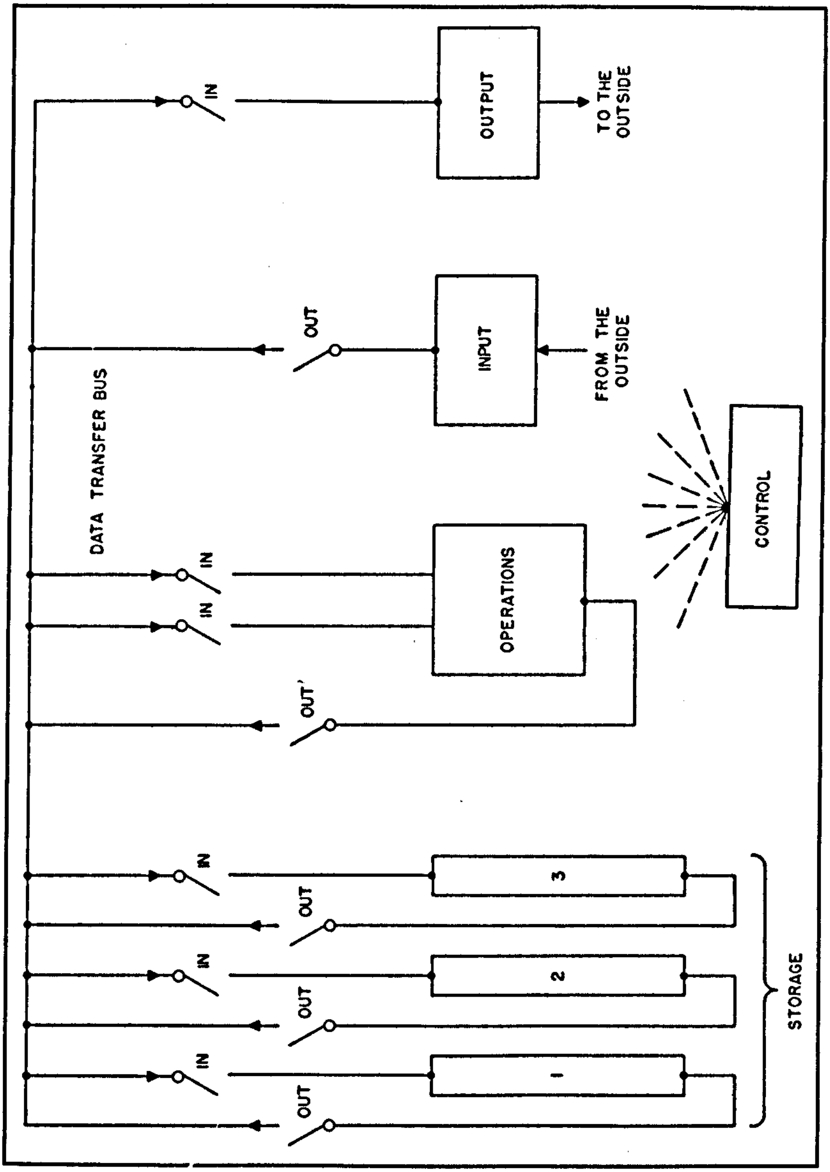


EXHIBIT 2. GENERAL PURPOSE DATA PROCESSING SYSTEM COMMUNICATION CHANNEL

which consists of taking one item of information from one location and transferring it into another. It is an instruction so simple and elementary that one would not dream of giving detailed instructions to a clerk as to how to do it. One would simply ask the clerk to write so and so in such and such a place and let her figure out exactly how she should move her hand. But here you see that just such an elementary operation requires the careful specification of the closing of one gate and the opening of another.

Let us consider another type of operation. The box labelled "operation unit" will be assumed to be a very simple one, one which can only add. A real system can do a lot more than that, but it would be simpler to think of it just as adding. How do we perform addition in this machine? Suppose that we have a number, let us say a credit sitting in Register 1 and the balance to which this credit is to be added sitting in Register 2 and that we want to add the credit to the balance to get a new balance. Well, the first thing that we have to do is to close the out-gate on Register 1 to allow the data to flow onto the bus, and close one in-gate, allowing one of the factors to go into the adding unit. Then we have to close the out-gate on Register 2 to get the second factor onto the transfer bus, close the second in-gate of the adder, and let the number into the arithmetic unit. Finally, to get our answer, we close the out-gate of the adder and we also close the in-gate of one of the registers, say Register 3.

If we want to read in information from the outside, it is obvious that we must close the out-gate of this input unit, let information go to the transfer bus and from there into the register on which the in-gate has been closed, and vice versa for output. We shall close the out-gate for any one of these units, close the in-gate of the output unit, and let the information flow down its path.

The actual physical manner in which any data processing computer performs these gate openings and closings may differ substantially among different machines. In some machines there are actually switches that close and open. The essential point to note here is the extremely elementary nature of these basic operations. You see, each one of these gate closings or openings must be performed under the control of some instruction, which has previously been inserted into the control unit. I have drawn the control unit with tentacles going toward the various other boxes. Its long fingers reach into every other box. Somehow we have to build into the machine the instructions as to what time and how and which gates to close. These instructions are the program, and one program step may consist of simply saying, "transfer information from Register 1 to Register 3." This instruction put into the control unit and properly interpreted by the machine will then cause the proper gates to open and close. Likewise, for addition we should have to say, "put in one factor, put in the other factor, take the sum out." It is very tedious. It is very detailed. It takes a very long time to do, as Mr. Bradshaw already pointed out in his talk.

I think that you want to consider very carefully the very basic nature and the very elementary nature of these instructions, because those who have been accustomed only to giving instructions to a clerk and may have been exasperated by the stupidity of the clerk have not seen anything until they try to instruct one of these machines. And it is something that has been highly underestimated in the past, and, as Mr. Bradshaw has pointed out, it is one of the reasons why the results have only been poor and fair in many applications. People have underestimated the enormous amount of these elementary instructions that are required to perform a sensible business operation.

We come to some of the implications of this fact that I mentioned before. You see, the speed of a machine may be one microsecond per transfer or a thousandth of a second per multiplication or something very fast.

However, it is important to consider, when programming these machines, that a great number of very high-speed elementary operations can result in very slow postings or bill computations. This is particularly true when you have to deal with exceptions. By their very nature exceptions are exceptional. You have either to look up something special or to do a number of special actions. Each one of these special things requires another set of special instructions, and these instructions take time. That slows you down too. The instructions have to be put somewhere inside the machine. This means that either you now have to provide a great deal more storage space for instructions than you thought on the basis of just a routine operation; or you have to store the instructions outside the machine and then, when an exception comes up, read some new instructions in and then start the machine. But if you are doing that, what happens to your electronic speed?

And if you allow enough space inside the machine for all possible instructions that you might need, what happens to the cost of storage? I should like to suggest that the consideration of exceptions and their effect on programming is one of the most serious problems that face you in the study of the applications of these.

The problem of deciding just what problem you are trying to solve, what should be mechanized, and what should be provided for in the program is most difficult. You get into difficulty of either cost of storage, length of time, and so forth. Because many of the exceptions arise as the result of policy decisions which may or may not have a necessary basis, I think it is important in the study of these applications to make a careful note of every exception that arises. All these exceptions are then submitted to the level of management with the authority to determine whether an exception is really necessary. It is a lot cheaper to deal with an exception that does not exist than with one that plagues you, and in many cases it is possible to eliminate the exception.

But the important point is that eliminating, or fitting these exceptions to the system, requires a policy decision. And to leave the decision to the programmer might result in a program that will take care of the exceptions but will reduce the speed of operation of the system to a ridiculously low point. This problem therefore is something that requires very, very careful thought in the planning of the data processing system.

Another point I should like to mention in conclusion is the fact that the elementary operations are so detailed that they force you to give a great deal of thought to small details of your mode of operation you would never before have regarded as problems. Consequently, in the study of programming for these machines, ways are often found to simplify present procedures and to modify existing systems, thus leading to very substantial improvements in operation and reductions in cost without the use of any machinery whatsoever. I think that this simple solution to problems of mechanization is one that should never be overlooked, that there are always, with respect to a particular problem, two ways of solving it — well, really three ways. One is to leave it alone. Another one is to do it by using the same old tools but in a different way. And the third one is to use the latest improvements. You will agree that leaving it alone is the cheapest possible way out, provided that the system you are using is a good one. The next best thing is to use your present equipment but in a much more efficient manner. And, finally, if it turns out that by changing your system and adding this equipment you can save, it is very well and good. I suggest very strongly that the investigation of the operations of your business at the level of detail required to organize one of these electronic data processing systems may reveal a great deal to you about things that can be done without ever needing an automatic machine.

CHAPTER 3

Administrative Problems of the Investigation Phase

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MY TALK will deal with the survey and evaluation of electronic data processing methods. By this I mean the investigation stage in which you determine the applicability of electronic equipment to your own data processing activities. I plan to cover those phases of the investigation that will arise from the time you decide to look into electronic data processing methods until the decision is reached to acquire or not acquire equipment. I should also mention that I intend to discuss the subject from an administrative viewpoint. I shall not get into technical details. Instead, I shall talk in terms of the steps to be taken and the decisions to be made by you or other persons in your firm who have responsibility of investigating the potential for electronic equipment.

I should also mention at this point that the information I am presenting is based on interviews with persons in some 42 companies – 30 of which are users or potential users of electronic equipment, and 12 of which are manufacturers of electronic equipment. Executives in these companies have generously supplied information on the subject of the investigation stage. Needless to say, the approach to the investigation taken by the various users and potential users of equipment has varied considerably. It is not therefore possible to tell you of a commonly approved approach for investigating electronic equipment. It is possible, however, to give you information about how some companies have approached the subject of electronic data processing and what problems they have run into.

So let's begin by examining the specific reasons for undertaking an investigation. In the case of one oil company, the persons in charge of the investigation interviewed 10 users and potential users of electronic data processing equipment. According to a report prepared for the company's top management, the objectives of the interviews with these 10 outside companies were: (1) to determine the reasoning behind their decisions on whether to install large-scale data processing equipment; (2) to determine the degree to which companies that are installing equipment contemplate its use on a service center or data processing center basis to handle clerical, engineering, and data evaluation for management decisions; (3) to determine the basis on which the selection of equipment was made; (4) to determine changeover and other preliminary considerations – planning manpower and time requirements, installation costs, and other preliminary expenditures; (5) to determine methods used to familiarize management and operating personnel with the potential offered by these large-scale machines to increase operations and reduce costs.

Following these outside contacts, the oil company personnel next investigated several of their own data processing applications to determine the cost and savings involved in a computer installation.

The controller of a large manufacturing company mentioned that in his survey and evaluation of the electronic data processing field, he was interested in finding the answers to three questions. His first question was concerned with whether electronic computers could, in fact, perform commercial data processing applications. Secondly, if they could perform such applications, he wanted to obtain data on the cost and savings involved in their application. Thirdly, the controller desired information on the manual and mental effort required to program and operate an electronic computer. In regard to the third point, the controller wished to know about the skills required to handle a computer – and specifically whether members of the controller's staff had the skills required to program and operate a computer.

Of course, the representatives of both these companies were also interested in investigating different types of equipment to determine which kind was most suitable for their respective needs.

Now before discussing some of the particular aspects of the investigation stage, I should like to give, very briefly, a few case examples of the over-all steps taken by several companies during the investigation stage. These cases will serve to illustrate the wide variation among companies in their approaches.

In the case of the Commonwealth Edison Company of Chicago, the investigation phase began in 1950. The investigation included intensive surveys both as to developments outside the company and as to its own applications. After a careful consideration of the cost and savings involved in their utility billing and revenue accounting application, the company executives decided to order a computer in 1954. It is estimated that their investigation, before the decision was reached to acquire a computer, took 15 man-years of work and cost in the neighborhood of $150,000.

Another company, whose name I cannot mention, began its investigation by starting right in to program the gross-to-net payroll application. The only information picked up about what other companies were doing was from the representatives of the computer manufacturer with whom the representatives of the company under discussion were working. Following the successful running of this application on a computer, executives of this company decided to acquire a computer without so much as making any cost and savings estimate. A total of nine man-months was required in this company's investigation, which consisted, in effect, of programming and running the gross-to-net payroll application.

In the case of the two companies just discussed, the executives were all interested in large-scale general purpose equipment. Now let me give examples of situations where special purpose equipment was investigated.

In the case of one shoe manufacturer, whose name I am not at liberty to divulge, a problem existed in the company's orders and production control office. The large amount of data being processed in this office for planning the production and shipment of thousands of sizes and styles of shoes created a major bottleneck. In an attempt to alleviate this problem, a study had been made to change and simplify the system. Without much luck in this endeavor to simplify the system, company executives brought in a consultant in March 1954. The consultant recommended that instead of trying to change the system, the company should mechanize the present system with a combination of special purpose electronic computers and punched card equipment. As a result, representatives of the company, along with the consultant, plotted out on large wallboards the details of the system. They plotted out the way in which they believed a variety of electronic equipment would fulfill the requirements of the existing system in conjunction with the use of five-channel punched paper tape. When they completed the wallboards, they invited several computer manufacturers to come in, look over the system, and then subsequently prepare bids on the equipment. On the basis of the several bids that were submitted, the shoe company chose one of them primarily because of cost. In total, the survey and evaluation, in the case of this shoe manufacturer, required four man-years of work.

Another very interesting example of an approach to surveying and evaluating special purpose electronic equipment is the experience of two utility trade associations. The American Gas Association and the American Electrical Institute, two utility trade associations, engaged the Harvard Computation Laboratory to design utility billing equipment. The Computation Laboratory personnel were to design the equipment using already existing electronic components; they were not primarily engaged to design new electronic components. As the designing of the equipment progressed, a steering committee, made up of members of individual utilities, was to appraise the design from a practical standpoint. At the present time, the equipment is still in the design stage, but the designing should be completed within another two years. One of the major problems facing the design group is to design utility billing equipment that will meet the needs of the large number of different utilities represented by the two trade associations. It is hoped, however, that the equipment can be made sufficiently flexible so that individual utilities, after standardizing their billing procedure to some extent, will be able to make use of the equipment. Once the equipment is designed, each utility can then contract for the manufacture of its own billing equipment to fit its own particular volume of data.

Now I could keep on going and give you more case examples of approaches to the investigation taken by other companies. I could also expand and go into detail concerning the approaches taken by the companies I have already talked about. But I do not think that additional case examples would do any more in the way of illustrating the two main points I hope I have made, namely: first, there is a great variation among companies in the steps they have taken in their investigation of the electronic data processing field; and, secondly, extensive time and manpower requirements are involved in the investigation before the decision to acquire equipment.

I think now that these two points have been made, it is best that we take a look at some general observations and conclusions in regard to the investigation stage – observations and conclusions based on the experience of a large number of companies.

First of all, it can be said that in general there are two distinct stages in most company investigations of electronic data processing methods. The first of these two stages has to do with acquiring knowledge about what the outside developments in the field are and about how computers work. Since most of the people conducting company investigations have come from an office methods and procedures department (or its equivalent), it has been necessary for them first to gain a basic knowledge about what an electronic computer could do in order to evaluate potential applications and recommend future courses of action. To acquire this knowledge about the field in general, they have employed various educational methods. Some company representatives attended training schools sponsored by computer manufacturers and academic institutions; some have consulted computer manufacturers to find out about available equipment; some have called in consultants. Such methods had been supplemented in many cases by visits to users or potential users of computers to pick up information on applications, cost savings involved, organizational methods, and so on. The names of the companies that they could visit were acquired from the computer manufacturers, from literature on the subject, and from users themselves who knew about other companies working on particular computer applications.

The second stage in the investigation period has been an "in-company" survey to determine the applicability of electronics to one's own particular situation. In addition to using such help as that of computer manufacturers and consultants, some firms have gone so far as actually to program and run applications on computer manufacturers' general-purpose computers during the survey period.

It should be pointed out, however, that while there have often been two distinct stages in the investigation period – the outside survey and the "in-company" survey – the two stages sometimes have been undertaken concurrently with one another.

Another significant observation to be made about the investigation stage is the influence of management on the steps taken in the approach. It has been found that the specific work undertaken in the investigation stage has sometimes been a function of where in the organization the idea to investigate the field has come from. Thus, when the impetus for entering the electronic data processing field has come from the top management group, for instance, from the president or senior vice president, no definite statement or proposal has generally been made concerning expected cost savings from the first application. Rather, the idea of an experiment has been set forth, with the understanding that a definite statement on objectives and the future course of action would be forthcoming after experience and actual cost data have been obtained following a trial installation. By contrast, when the idea for getting into the field has been generated at a lower level in the hierarchy, and when the request for funds has required the approval of various divisional groups or a financial committee, fairly extensive surveys of potential applications and cost savings estimates have been made.

Summarizing what has been covered up to this point, I have briefly talked about five topics: the reason for the investigation stage; the variations in company approaches to the investigation of the field; the extensive time and manpower requirements; the two stages of the approach; and finally the influence of management on the steps taken during the investigation stage. I should like now, and for the remainder of my time, to discuss several aspects of the investigation phase with which you will have to deal in your own investigation.

The first aspect concerns the backgrounds of the personnel to be selected to work on the investigation of the electronic data processing field. It has been found that very few companies had men with electronic, mathematical, or engineering backgrounds to deal with their electronic data processing projects. Most of the company personnel had accounting backgrounds. In one case I came across, electronic engineers did participate in the company's investigation. These men also had extensive backgrounds in company management and had a good knowledge of the company's accounting system. They proved to be most valuable in surveying the field and in specifying the firm's needs to the computer manufacturer. You would be lucky to find men with both electronics and accounting backgrounds – they are rare indeed.

For men with only an accounting background, there were generally no problems in understanding the capabilities and limitations of computers, the economics of their operation, and the intricacies of programming and planning inputs and outputs. Where the accountants have fallen down, however, is in their reluctance and sometimes inability to make intensive studies of different equipment and to specify their requirements for equipment. As one authority in the field of electronic data processing has pointed out, "Accountants, unlike engineers, take the equipment as given without bothering to specify their own particular needs."

But after all things are taken into consideration, it is of primary importance that the personnel who are handling the details of the investigation have a good knowledge of the particular application to be studied. Executives in many companies have been dissatisfied with the help received from outsiders who are expert programmers and who know a lot about equipment, but who are unfamiliar with business systems. In some companies executives have found that their own personnel, who know the firm's particular data processing system, after three or four months of experience in which to grasp the logics of the computer and the intricacies of programming, are much more valuable than such outside experts.

Another aspect you will have to consider in undertaking your investigation concerns the formal organization. You will have to determine whether a separate department should be established to undertake the investigation of electronic data processing methods. Some companies have formally established a separate department, usually reporting to the controller, to undertake the investigation. The real need, however, is that the concentration of effort on the project by the company personnel should be on a full-time basis. If it is not, then the project may become secondary to daily operating problems. This full-time concentration can only be achieved by divesting the individuals concerned of their old jobs. To ensure such action, a separate department might be set up, or the men might be physically dissociated from their old jobs as in one case where they were sent to New York, or there may be other means. You will have to decide this for yourself.

Another problem with which you will have to deal in undertaking your investigation concerns the use you will make of committees, consultants, and computer manufacturers' representatives.

You will find that a committee is a useful tool in an electronic data processing project primarily because of its ability to gain interdepartmental cooperation for the project and to gain access to information in each department for the members of the survey team. Committees also serve a useful function in directing and appraising the work of the survey members, in educating members of top management regarding the field, and in gaining top management's support for the project.

The answer to whether you should hire consultants for the project has to be determined in light of your own particular situation. The answer seems, in large measure, to be a function of whether a particular company, desirous of looking into the field, has its own personnel who are capable of undertaking the project, and whether these men could be spared to do the work involved in the project.

There is no doubt that reliable and reputable consultants can make a significant contribution in a company's survey and evaluation of electronic data processing methods. Possibly the greatest contribution of consultants is in the area of equipment selection. Another valuable contribution that consultants can make is through the use of their experience and "know-how" derived from other company situations to outline a plan of attack for the investigation. Consultants, moreover, can be used to direct and supervise the collection of cost and savings information and to develop cost and savings estimates. Furthermore, consultants can give important assistance in training company personnel about computers and programming.

You can also make use of representatives from computer manufacturing concerns. Possibly the greatest problem arising from the use of computer manufacturers' representatives, as you can readily understand, is that they lead customers to thinking in terms of one type and one brand of equipment. According to one manufacturer of special purpose equipment, many prospective customers look upon their punched card salesmen as consultants and take their word as gospel. In such cases, the computer manufacturer said, it was virtually impossible to sell his equipment because the punched card salesman, whose own commissions were at stake, had the customer's confidence. This problem seems to be acute since in the field of electronic data processing the technical aspects are so complex that many of the manufacturers' representatives are unable to evaluate the use of equipment other than that which they sell. Furthermore, in the case of general purpose equipment inasmuch as the mental effort required to learn how to program one particular computer is so great, it is conceivable that once the customer has learned how to use this one computer, he might not be willing to go through the process of learning about other equipment or about the way to program it. As a result, he is easy prey for the computer salesman.

There are, on the other hand, several useful functions being performed by computer manufacturers' representatives. These persons can be of great help in sharing their "know-how" and experience with their customers, in training their customers' personnel about computers, and in finding and evaluating potential data processing applications. Computer manufacturers' representatives can also aid in programming applications although they are often less useful here than the customers' own personnel.

During the investigation stage you will probably be faced with making decisions about cost and savings estimates. The amount of time and effort spent in developing cost and savings estimates varies considerably among the companies I have examined. In some cases no cost and savings estimates were made. In a couple of cases the estimates amounted to no more than "back-of-envelope" calculations. A few companies developed estimates based on the actual volume and detailed data processing steps involved in particular applications. One company went so far as to program and run two different applications on three different makes of computers to develop cost and savings estimates; but the amount of time and effort usually spent in the development of estimates of cost and savings will depend on your own situation.

The need for caution in the appraisal of cost and savings estimates cannot, however, be overemphasized. A couple of companies have found wide variations in the cost and savings estimates developed by independent groups studying the same application. The major explanation for the differences is simply that the figures are estimates based on surveys in which it is practically impossible to visualize all the ramifications and problems of the actual situation. Moreover, cost and savings estimates have sometimes been developed on the basis of incorrect and incomplete specifications of the work the computer was to do.

To be of greatest benefit, estimates of cost and savings should separate the savings associated with changes in accounting systems and procedures from those savings associated with the electronic computer. By doing this, you can better appraise the justification of electronic computers for particular data processing operations. It should be mentioned that many company executives believe that the systems and analysis work alone accounts for much, if not most, of the savings involved in a computer installation. Finally, the base against which the cost and savings estimates of a computer application are measured should be questioned. For instance, should a cost comparison be made between the computer and the present method of doing the job? Or, should a comparison be drawn between the computer and an improved present system that might be put on punched-card tabulating or other mechanical data processing equipment? There is much to be said in favor of the use of different bases against which to measure savings. Some companies have done this, and I can most certainly recommend that you do the same. You'll be surprised at how many times you'll find that a computer is more costly to operate than punched-card equipment, even on large-volume applications.

Another very important aspect of the investigation stage concerns the problem of equipment selection. I have found that, like cost and savings estimates, the problem of equipment selection has received varying degrees of attention from company to company. But, you will ask, how much time and effort should a company spend in attempting to find the least-cost equipment that will result in the greatest data processing economies? Certainly the job of minimizing equipment cost and of maximizing data processing savings requires much long-range planning. It would also require personnel to have an excellent knowledge of the technical aspects of electronic equipment as well as of data processing systems and the needs of management for information.

There are several reasons, however, why almost all companies have compromised with the problem of optimum equipment selection. For one thing, the cost of an intensive equipment investigation would be inordinately high. For another, there is a lack of personnel qualified in both electronics and accounting. Moreover, it is virtually impossible to determine not only the present needs but also the future needs of management for information. Similarly, technological obsolescence of equipment is difficult to predict. To be considered along with these problems is the value of experience to be gained from acquiring and experimenting with equipment as soon as possible. There is also the opportunity cost of delay or, in other words, the savings that might be foregone if the acquisition of a computer were delayed. So, what do you do?

For one thing I can strongly recommend that you do not restrict your investigation to one or two electronic computers. Look at both general purpose and special purpose equipment. Moreover, I urge that you investigate punched-card equipment if you do not already have it. Finally, when you are deciding between various types of equipment consider these factors: relative cost of equipment and savings involved; reputation and experience of the computer manufacturers; services which the manufacturers provide; terms of the lease and/or sales agreements; accuracy of equipment; delivery date of equipment; and, finally, flexibility of equipment to perform different tasks and to meet future data processing requirements.

In the selection of equipment, the question of lease or purchase comes up. This question has many facets too. Sometimes, however, only one of these alternatives is offered the prospective customer. If leases are used, they will probably differ markedly in their terms. For instance, leases differ as to provisions for maintenance, minimum lease periods, and option to purchase. Moreover, lease payments differ depending on the lessor's pricing policies in regard to such factors as: allocation of research costs; estimated maintenance costs; factors for technological obsolescence; competition; profit; market potential; amount of time each day during which the equipment will be used; and so on.

Where both lease and purchase alternatives are available, there are several factors that you should consider in determining which is the better alternative. Some of the major factors to be considered are the following: the cost of leasing *versus* the cost of purchasing;[1] the degree of confidence that the equipment will prove satisfactory; the alternatives available if the equipment does not prove satisfactory; rate of technological obsolescence of the equipment; and, finally, your own cash position. Where both the lease and purchase alternatives are available, probably the most

[1] For a practical method of comparing the costs of leasing *versus* the costs of purchasing, see Robert N. Anthony, *Shoe Machinery: Buy or Lease?* (New York, National Shoe Manufacturers Association, 1955).

common type of contract in existence today is the lease with option to purchase. Because of the many differences existing among lease and purchase agreements, there is no question but that you should examine the various aspects of both lease and purchase.

Another aspect that you may come across in your investigation is the possible centralizing effect of an electronic computer on your data processing activities. Executives in several decentralized companies have expressed to me their concern about the need to centralize data processing and to standardize methods and procedures when using large-size computers. And their concern seems to be justified. There seems to be no question but that the use of electronic computers will have some centralizing effect. It is possible too that the use of electronic data processing methods in a decentralized company may result in conflicts if the computer is to be used by more than one decentralized unit. There are, however, a couple of alternative possibilities that may help to minimize the problems associated with the centralizing tendencies of electronic data processing methods. One possibility is to install equipment, either special purpose or general purpose, in the decentralized unit for the use of the individual unit only. A second is to use a data processing center in which data from various decentralized units of a company are processed. The ability of data processing centers to retain the autonomous nature of the decentralized units remains to be seen. Certainly decisions as to the order in which data are to be processed will have to be made at the data processing center. Such decisions may result in conflicts. There are probably many unforeseen aspects to the concept of the data processing center that will come to light after we have had more experience in its use.

Finally, the last aspect in the investigation stage that I plan to cover concerns the problem of getting top management's support for the project. Such support of top management is not only helpful in promoting company-wide cooperation for the investigation but also is necessary when policy questions are involved and when the decision to acquire equipment is made. You will generally find during the investigation stage that the prime interest of top management is in the cost of the equipment and in its installation and setup costs. You'll find top management is also interested in the advantages to be expected from the project, including clerical savings, and also in the short- and long-run effect of the electronic data processing methods on the company organization.

Where it has been necessary to get top management to back an electronic data processing project, various educational techniques have been used including one-day training seminars. Actual demonstrations of applications on computer manufacturers' equipment have also been found to be very effective. The problem here is to get top management together for such a demonstration. If it has been decided that electronic equipment is desirable, after your investigation has been completed, you might present your findings to members of top management. For example, you could present them with cost and savings estimates and a list of the nonfinancial advantages of an electronic computer as applicable to particular data processing jobs. It is also possible to point out various safeguards and alternative uses of equipment to those in top management so as to allay any fears they may have about what would happen if the equipment proved later to be unsatisfactory or obsolete. For instance, you might point out that you can order the equipment subject to a rigorous acceptance test to be passed by the computer before it will be acceptable to the company. Or, you might use general purpose equipment for engineering or scientific work if the equipment is found unacceptable in performing commercial data processing work. And, there are other safeguards and alternatives that you can follow.

In summary then, gentlemen, we have looked at several topics beginning with the reasons for the investigation and some observations about time and manpower requirements, and the influence of management thinking on the approach. In this last part, several aspects of the investigation with which you will be confronted have been discussed. These aspects included the questions of personnel, organization, the use of committees, consultants and manufacturers' representatives, cost estimating, equipment selection, lease or purchase, the centralizing tendencies of electronic computers, and finally methods to gain the support of top management.

In conclusion, I hope what I have said will be of value to you in your own company investigation. If you have any questions, I will certainly try to answer them.

Discussion: Part One

QUESTION: You said in your assessment of computers that there is limited random access to stored data. Does the new Univac file computer solve this or are you unfamiliar with this device?

DR. OETTINGER: Does a piece of rope come with this question? Well, I think the answer is that the file computer solves the problem if you are willing to pay enough for it. I think that it is safe to say that it is technologically feasible to have as much random access as you want to have. You can fill rooms with it if you are willing to pay for it – and the cost is extremely high. And all you can say is that it just depends on the need you have for this type of storage and how much you are willing to pay for it.

QUESTION: I should like to direct this to the last speaker having to do with the selection of personnel for training in this program. What does their mathematical background have to be?

MR. LAUBACH: The need for personnel with mathematical backgrounds depends primarily on the nature of applications being studied. For many of the commercial data processing applications, such as payroll, inventory control, billing, general accounting, and so on, there is usually no need for personnel with mathematical backgrounds. For these applications the personnel should be familiar with the detailed procedures required to process the data. If, on the other hand, applications utilizing the technique and tools of Operations Research are to be studied, then a mathematical background would be desirable and oftentimes necessary. For example, a mathematical background would be necessary if one were to try to optimize a plant layout or a production schedule.

QUESTION: The question deals with the centralizing tendencies of data processing units on a company-wide basis, the desirability of doing so, and the relationship to punched card processing.

MR. BRADSHAW: I think that you have asked a very important question, certainly one that is bothering a lot of business managements. We have first to differentiate between decentralization of management and decentralization of data processing. I do not think the two are interconnected although I know there are many people that will disagree with me on that. The tendency in recent years toward decentralization of management is very firmly rooted in such things as the need for bettering community relationships, the need for developing more rounded managers, and the necessity for spreading profit throughout the company; and so I think the decentralization trend is pretty firmly anchored.

Data processing itself, I believe, ought to be done wherever it can be most economically done, and that applies whether you are using manual methods or electronic or punched card equipment. And, in turn, that will depend entirely on the size of the operation and the available means of communication. Geographical distance has been our biggest block, in many ways, to developing more effective data processing methods.

Data processing should be regarded as a factory operation, that is, a factory operation producing figures. Once we look upon data processing as a factory operating, we can then apply our factory experience to the problem of producing figures in the most effective way.

I do not mean to suggest that the interpretation of figures or the analytical work should be centralized along with figure production. I think that the analytical function must follow decentralized management. When you give a man profit responsibility, you must give him the tools to do the job. The most important of these tools is a figure interpretation and analysis service.

COMMENT: In either event there would be a factory operation involved. You might say the idea would be a factory operation whether you are talking about data processing by means of punched cards or whether you are going a step further in talking about data processing in terms of electronic computers. Here again the technology of the thing might be a little more powerful for centralization in terms of punched cards.

MR. BRADSHAW: I think there has been a basic organizational trend going on for a number of years that has tended to separate data processing from data analysis. And this development has taken place regardless of the techniques available. You are familiar with the kind of organization, such as at U. S. Steel, where there has been for a number of years now a separation between those who interpret and analyze data and those who process data. In other organizations there has been a separation in such a manner that the analytical group is set up as a control unit reporting direct to the president and the data processing unit is a factory-type operation reporting to the controller. This kind of an organizational trend has been going on for some time — long before electronic equipment and more advanced punched card equipment have come into play. The cause is something deeper than the type of equipment available.

QUESTION: I should like to continue that. We have a very decentralized organization. One of the things that we are constantly running into is the requirement on the part of each manager for different information. Yet when we get into the concepts of which you have been talking, we run into very grave difficulties in trying to standardize such information. Do you restrict the individual and say that he has to have only that information which the centralizing process gives?

MR. BRADSHAW: That is another very good question. I do not think you will ever have a manager with profit responsibility, or any other kind of responsibility, who will not have a black book in his pocket. I do not care what kind of electronic equipment you have, he will always have a black book which contains the figures he runs his business by, and I think we ought to let him have it. I think with the more advanced punched card equipment and electronic equipment we shall be in a position to provide the kind of data that will make his black book less useful. The flexibility of this type of equipment will enable us to provide decentralized managers with the kind of information they need to do their kind of job. Right now I think that we are in the position of changeover. We cannot quite do the job yet. We cannot quite provide the personalized information that they think they need.

Let me add a thought. When I say that a decentralized manager needs the information to do the job, I am thinking in terms of a reporting service. And a reporting service consists of two things. It consists of a set of reports, and it consists of an analytical, interpretive service. I think that, as we move along in this process, we can standardize the reporting a good deal more provided we let the decentralized manager have his own analytical group who will feed information to him in the form that he finds most useful. In other words there are two sides to the coin of a reporting service. There are the reports themselves and the people who do the interpretations. And of the two, I think that the people are more important. But the question you asked is obviously something that you will face in your company for a long time to come. When you give a man proper responsibility, you want him to act as an independent company manager. Yet compromises have to be made.

QUESTION: In the discussion lease *versus* purchase of electronic equipment no mention was made of the advantages of leasing because of the rapid advances in the technological development of electronic equipment. I should like to hear something about that.

MR. LAUBACH: You have certainly put your finger on a subject of great contention. Many companies have leased equipment primarily because of their fear of technological obsolescence. Other companies, however, do not consider technological obsolescence to be of great significance; they point to the continued, full-time use of several computers built during, or shortly after, World War II to back up their opinion. One thing I am sure of is that there will continue to be technological improvements. There is no question about that. But the importance of technological obsolescence insofar as lease *versus* purchase is concerned is one thing that is most difficult to appraise. In regard to this question you might be interested in the remarks of the vice president and controller of the John Hancock Mutual Life Insurance Company which are printed in the July–August 1955 issue of the *Journal of Machine Accounting — Systems and Management.*

PART TWO

Centralized vs. Decentralized Organization for Data Processing

CHAPTER 4

Problems of Decentralization

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When I was asked to talk about the problems of decentralized data processing, I thought that we would have our first large computer by the time of this meeting. Because of delays in the preparation of the building for the computer, our first one will not be delivered until next week. Perhaps this is just as well. Since we do not yet have a computer, no one can misunderstand my position. What I have to say today is the result solely of study and analysis. My comments are in no way based on the practical operation of any large-scale data processing equipment within the Westinghouse Electric Corporation.

For the last decade or more, the modern trend in management of large manufacturing companies has been toward decentralization of control. This has appeared necessary owing to the increase in the size of companies and to the increased complexity of effectively managing companies widely scattered geographically and diversified as to type of business. Westinghouse, for example, operates some 56 major manufacturing plants. Our products range from light bulbs as small as a grain of wheat for the medical profession to complete power plants using nuclear energy for electric utility companies. To attempt to manage in detail such an organization from a central point would be virtually impossible.

Before we get into the problems of decentralized data processing, I think that it is necessary to review briefly the reasons for the trend toward decentralized management. If we could summarize the reasons for decentralization in one sentence, you might say that decentralization has been adopted by large organizations to obtain the advantages inherent in small businesses. What are those advantages? There are undoubtedly many, and we cannot cover the subject fully in a few minutes, but those advantages having to do with information seem to fall into four categories:

1. *Compilation of detailed information*
   The management of a small organization can make decisions with intimate detailed facts obtained by close association with the operation. These facts can be of such a nature and in such detail that they would not necessarily show up in statements. I am speaking now of the kind of facts that a plant manager can obtain by talking to men on the floor as well as to the supervisors of relatively small segments of the organization.

2. *Communications*
   Much more detail and more accurate information can be communicated to the person responsible for making the decision if that communication can be personal or if it does not have to flow through several levels and through several summarizations before it reaches the person responsible for making the decision. The speed with which communications can take place is also important.

3. *Assimilation of information*
   I am sure that every one of you has come up against the problem of too many reports and statements. It seems to be a perpetual battle in a large company to keep the amount of information furnished to top management down to the point that top management has a chance to assimilate that information, analyze it and study it to the point where intelligent decisions can be made. In a small organization, covering a smaller unit of operation, it is easier for management to obtain a complete grasp of the information than is the case where management must understand all the ramifications of a scattered and diversified business.

4. *Action upon information*
   With decentralized management, it is possible to take action quickly. There is not the delay that often occurs when information has to be submitted to a centralized management for decision.

If we are to have decentralized management, our data processing work should contribute to the advantages of decentralization. Westinghouse has followed a policy of decentralization for a number of years. This policy has set up many relatively small units and has given broad authority to local management. Local management is measured principally on the profit it is able to make based on the investment for which it is responsible.

The Company's policy of decentralization had a major bearing on the approach taken in our studies of large computers and the decisions as to how large data processing systems should be applied. Our studies of the use of large electronic data processing machines started several years ago. The original studies consisted largely of a review of much of the material written on the subject so as to obtain a reasonably good knowledge as to what electronic computers or data processing machines were and how soon they would be practical for use in industry. We attended seminars given by computer manufacturers and were consistently kept abreast of the developments being made by these suppliers. We were utilizing the improved small electronic computers which had been brought out by manufacturers. These included the 604 and CPC produced by IBM and the 409 now called the Univac 120 developed by Remington Rand. There appeared to be a long jump between the type of equipment that we were using and the large data processing machines. We experienced difficulty in determining the right approach that should be made for studying the practicality of large computers for our own specific data processing problems. Our Controller, being a very practical man, decided that the best way to make rabbit stew was to first get a rabbit. We did not want to make a substantial commitment for a computer until we knew that it was practical for our use, but we wanted to get practical experience with a computer. We decided the best approach was to use a computer available in a Service Center. Three of us from our Headquarters staff were assigned the responsibility for putting test problems on the equipment and evaluating the potential of computers for use in our operations.

I do not believe our Controller or any of those who were assigned to the job realized at the time we started our studies just what was involved in programming a computer. We did not realize this even though we had heard stories as to the number of man-years that had been spent by others in programming. In a little over three months, about three-quarters of a man-year, we learned programming and did the programming necessary to do the net payroll operation for one of our plants. We ran these programs using the actual payroll records from the plant and thereby obtained actual data as to computer time required for the operation. We could compare these data with records as to time required for performing the same job using the most modern tabulating equipment including an IBM 604 multiplier. We could compare the data with the results of manual payroll operations at other plants. We also put another Accounting Department problem on the machine, which gave us an excellent test of the speed, accuracy, and flexibility of the equipment.

With these two tests completed, we had enough information to evaluate the practicality of the equipment for use on a number of data processing jobs within the Company. We could visualize how the equipment could be used not only in accounting but also in other areas such as inventory control. We could also visualize the possibility of using the equipment for production control and scheduling in some of our plants making large "tailor-made" products. We still believe that this can be done, but I do not think we are much closer to the final answers now than we were when we made our original studies.

All these studies were made by Headquarters staff personnel, although certain of our plants were keeping abreast of the developments in the field. No decisions had been made as to where we might locate computers within the Company.

The next step in our program was to familiarize top management in Headquarters and in our plants with computers and the practical applications of such machines. This was done by a series of seminars, one of which was conducted for plant managers. Several of our plant managers were interested. Electronics committees were set up at some plants to study the application of computers within those plants. Our Headquarters computer group furnished advice and assistance to these committees.

Our engineering organization was further along in the use of electronic computers. They had designed and built analog computers for analyzing electric utility networks. They had also used analog computers for solving other engineering problems. They went into the field of digital computers for engineering calculations. Since the original large electronic computers had been developed primarily for scientific and engineering calculations, much more was known about the use of these machines in this field than was known about the machines for data processing work. Our Atomic Power Division, working with the AEC, was using large electronic computers owned by the AEC and the Bureau of Ships for making the calculations required by their scientists. Other engineering staffs were using Card Programmed Calculators in their own offices and were leasing time on large scientific machines available in Service Centers.

With this background of information, we reached the decision that computers in their present state of development had a practical application in our business. We were convinced that there was much that remained to be learned about the application of these machines to our own work, but we were reasonably sure that the equipment could be made to effect sufficient clerical savings to justify their cost. If we could learn more about our own problems and how to solve them with computers, we should be able to do two things – first, have the machines make many decisions that are normally made at the clerical level; and, second, furnish management with better information and more timely information for the more efficient operation of the Company. Our real need was to get equipment and put it to work and learn from experience how to utilize it fully so as to produce the best results. We felt that we were ready to take the plunge. The decision had to be made as to where the first machine would be located. There seemed to be three possible approaches:

1. We could put a computer in our Headquarters Accounting operation. At first this appeared to be the most practical application. Most of our accounting is done locally, but there are certain centralized operations that have a large volume of work. These include centralized accounts receivable, centralized sales statistics, capital stock dividend disbursing, and one or two smaller operations. The volume of work available appeared to be sufficient to allow us to make savings sufficient to cover the costs of a computer. We could then pull further accounting operations into Headquarters and have a profitable operation.

2. We could have followed the move made by another company and attempted to utilize a central computer for per-

forming the work currently being done in the plants. Obviously accounting would have been the natural function with which to start. To attempt to centralize accounting operations, such as cost accounting, would have required either complete standardization of procedures or a tremendous volume of programming. Cost accounting for a large turbine is materially different from the cost accounting required for electric irons. The needs of local management vary materially with the type of manufacture. They also vary materially with the size of the plant. Obviously a plant of 200 employees does not require the same amount of information for control as a plant of 15,000 employees. If we attempted to give every plant the same type of reports, we should not be serving the needs of management and we should probably be adding to costs. We thought of the possibility of having a centralized payroll, which does have a certain amount of standardization. In most of our major plants, we have an incentive-type payroll. We close our payroll week with the start of the first shift on Monday morning. Paychecks are distributed on the following Thursday and Friday. Our analysis showed that payroll would be impractical at a central location with our present time schedules for several reasons. First, the volume of paper work in connection with the incentive wage payment plan was such that it could not be transmitted practically by present wired communication systems. Secondly, the time schedule made it impractical to ship information into a central point, make the calculations, prepare the paychecks, and return them to the plants and offices on time.

3. The third possibility was to put the first pieces of equipment in our larger plants and use them for performing a series of functions. Before we made our decision, we discussed our problem with Professor Howard Aiken at the Harvard Computation Laboratory. Professor Aiken is a former Westinghouse employee and is somewhat familiar with the type of engineering work involved for our heavy apparatus. He pointed out to us that, while computers were still in the experimental stage as far as data process-

ing is concerned, they have been thoroughly proven in scientific and engineering type problems. It was his opinion that we could use computers in several of our plants for engineering purposes with reasonable assurance that they would be practical and could also apply them to data processing work.

This strengthened our conviction as to the approach that we should use, and it was decided that the first computers should be installed in our larger plants, under the control of local management, with assistance from the Headquarters staff organization. Several of our larger plants are of sufficient size to utilize fully even the largest computers when used for all the operations that we have in mind. This is particularly true when engineering calculations are also done on the machine. Our largest plant has approximately 15,000 employees, and we believe that data processing work alone will utilize a large computer in this plant. A Univac was ordered for our largest plant, and an IBM Type 705 was ordered for our second largest plant. The Univac is intended to be used primarily for data processing work. The 705 will be used for both engineering and data processing. Some engineering work may be done on the Univac at least until the engineering group has available another large computer.

What are the advantages that we expect to get by following this policy? First, we shall not in any way affect the Company's policy of decentralization. If anything, we shall strengthen that policy. Secondly, machines will be available for data processing in several phases of the plant's activity, not accounting alone. They will be available for inventory control which, of course, is closely related to accounting, production scheduling, machine loading, and other types of work that we feel in the long run will be the areas in which computers prove most effective.

By locating computers at our plants, we can better integrate the various functions of those plants to obtain the best operating techniques for those plants.

There is also another advantage of plant operation of computers at the present time. I am sure none of us know all the answers as to the application of computers or the best possible uses of computers. In other words, we are experimenting with our first applications. It does not seem logical to attempt to do experimenting on a company-wide basis when we can do the experimenting at the plant level. If we make some mistakes, as we certainly shall, we shall have disrupted the plant, not the Company. I do not believe that last point is important, since if we were working on a company-wide basis, there would be enough checks to avoid serious mistakes. Perhaps what I want to say is that on a plant level, we have more opportunity to make mistakes. To the extent that having the opportunity to make mistakes speeds up progress in applying computers, it is an advantage. On a plant level, we can work out ideas to meet the particular needs of that plant without the problem of first conforming varying procedures of several plants into a standard pattern.

There are a number of problems and disadvantages to locating large computers in local plants. Unquestionably it requires more trained programming help. I am not sure that this is a disadvantage. It may be an advantage. I believe that in the long run we shall make faster progress by having several staffs working with computers. We have already benefited from this, since we have arranged to have our two main programming groups exchange ideas and information. I am sure this has resulted in faster progress at both locations where we are presently programming. Even though these two groups are programming for different machines, they can trade programming techniques. They have traded their initial analysis work done prior to programming, and this interchange is more important and more time consuming if done properly than the actual writing of the detailed programs for the computer.

There is also another disadvantage of using computers on a decentralized basis. That is the problem of consolidating our statements at Headquarters. If we do our data processing locally, we shall have problems of consolidating it at Headquarters. If we were to force the plants into a set pattern so as to simplify Headquarters problems, we should be creating many more problems locally. At the present time practically all detailed accounting is done locally. Consolidation is relatively simple and does not either contribute materially to the delay in the presentation of statements to top management or add materially to the cost of our accounting operation.

Another problem that still has to be solved is the use of computers by smaller plants where the volume of work, even including the volume of engineering work, will not be sufficient to keep a large data processing machine loaded. We have some plants with less than 200 employees, and most of our plants have less than 5,000 employees. How can small plants obtain the benefits from large computers if we follow a policy of decentralization in the application of these computers? Obviously the answer is that they cannot. Just because our first computers have gone into plants and are to be utilized solely for those plants does not mean that we are committed to a rigid policy. There are several approaches that we can take. First of all, I am not convinced that our smallest plants will ever have any need for the services of a large computer. It may be that the volume of clerical work that is done in a small plant can be more economically done manually than it could be done on a large computer. I think there is some question whether the very smallest plants could afford wired communications and specialized programming for processing of data in a central location.

When you get into the area of medium-sized plants, and here I would classify a medium-sized plant as say from 1,000 to 3,000 employees or perhaps even larger, we have another type of problem. These plants do need mechanized data processing. There appear to be two possible solutions to the problem of medium-sized plants. One is medium-sized computers – the other may be computers on an area service bureau basis. We have not made any decisions on this phase of the problem. We are actively working with some of our medium-sized plants on the application of medium-sized drum computers, such as the IBM 650 or Univac File Computer. We have also talked about the possibility of using large computers on an area basis. For example, in the northern New Jersey area we have five medium-sized plants. One large computer might serve all five of these plants on a service bureau basis, or each of these plants might have its own medium-sized computer. When we have had more experience with the use of large computers and with the use of medium-sized computers, this decision will be made. In the meantime there may be new equipment available which may even alter our earlier decision with respect to our major plants.

To summarize, Westinghouse has followed a policy of decentralization, and each plant operates with a great deal of autonomy. While large data processing computers appear practical, we do not believe that at the present time they should affect our policy of decentralization. Our first computers are being put into our largest plants where they will be under the direction of the plant management and will be used on plant activities. They will be used for data processing work. They will also be used for engineering calculations where this can be done profitably on a computer. We believe this approach has advantages in that we shall gain the experience resulting from the use of computers on various phases of data processing work in the Company, not accounting work only. We are not committed to any policy of having computers solely at the plant level. We may use computers at our smaller and medium-sized plants on an area basis. We may use medium-sized computers in medium-sized plants. There is one thing of which I am sure. There are still many unanswered problems in the field of applying large data processing systems. Westinghouse is committed to solving many of these problems, and when we have solutions to the problems on which we are currently working, we shall be better equipped to answer the problems that are farther down the road. If developments in the data processing field continue at the rate they have been occurring, by the time we have solutions to our present problems, there may be a new set of conditions; or, as the mathematician would say, the parameters may be changed and we shall need to re-solve our problems.

CHAPTER 5

Problems of Centralization

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In order that you may better understand my relationship with automatic data processing equipment and applications, I should like to begin by explaining briefly the organization of our Company and my relation to that organization.

From a broad viewpoint, the Company is divided into *operating components* and *service components.*

The *operating organization* is presently divided into approximately 25 components called divisions. In general, each of these product divisions is further segregated into departments. It is in these decentralized departments – about 100 of them – where the operating is really done. Each product department has its own complete balance sheet and profit and loss statement. The management group is held responsible and accountable for the successful conduct of the business and usually consists of a General Manager and five managers who carry out the principal work functions of engineering, manufacturing, marketing, finance, and employee and community relations. Most of the employees of the Company work in the operating departments.

The *services components* are responsible for assuring Company leadership, not in separate product fields, but in assigned functions such as research, engineering, manufacturing, marketing, accounting, treasury, employee and plant community relations, management consultation, public relations, legal and patent, and corporate services. It is the job of these services groups to assemble and make available funds of functional knowledge and experience. The words which help describe the work the service people do are assisting, teaching, advising, counseling, and recommending.

It is in one of these services components – Accounting Services, which is in charge of the Comptroller – that my work lies. Within the Comptroller's organization, seven kinds of accounting and financial services are rendered: general accounting, personnel accounting, cost accounting, tax accounting, financial personnel development, measurements, and office procedures. I report to the Manager of the last group, Office Procedures. To us, the procedures area means work simplification, work measurement, clerical cost control, and the tools to do the work – automatic data processing equipment, punched cards, and all office equipment. In general, the work done by a procedures unit in an operating department takes it into all areas where paper work exists.

In view of the relationship of our services group to the decentralized product operating departments, you can see that the opinions of any one person in our Company such as myself do not necessarily represent the views of a specific department, of several departments, or of the Company as a whole. Neither do we have such a thing as Company policy on automatic data processors, punched-card equipment, or other procedural tools. Each department makes its own decisions on what equipment to use and places its own orders for that equipment. I do think, however, that my comments will be representative of the experience and knowledge we are gaining as we try to work out plans to get automatic data processing equipment in place at many different locations in a wide variety of businesses within the Company.

I realize that I have taken a great deal of your time on organizational background, but I think it is important to an understanding of the standpoint from which I will talk. I hope you did not come here this morning expecting that Mr. Muns and I would engage in a lively controversy as he discussed problems of decentralization while I discussed problems of centralization – because there are several reasons why I reject the opportunity:

First, I don't think it would be fair to take advantage of my position following Mr. Muns when the conference program does not provide him with an opportunity for rebuttal. The area of competition between our respective companies is already keen enough without extending that area to include automatic data processing – let alone the bringing of any differences here to Aldrich Hall.

Secondly, two associates from my own Company will be on the rostrum tomorrow, and I don't want to invite any divergent views to which *I* could not make rebuttal.

Thirdly, I don't think that we have any real differences of opinion here in terms of the art as it exists in 1955.

I think that the need for this conference recognizes that there are many avenues to be explored and that there is very little experience to draw upon at the present time. The automatic data processing art is still in its infancy and we should expect that procedures and equipment in use five, ten, and fifteen years from now may be quite different from what we have today. Now, I do not mean to imply that today's equipment is unsuitable for automatic data processing. Rather, I think we should make every effort to learn to use today's equipment efficiently and economically. I shall try to talk this morning in terms of equipment available in 1955 and the applications which are practical in 1955 – leaving 1960 and 1965 equipment and plans to others on the program. I shall be talking from the point of view of an industrial manufacturer. If I have counted correctly, there are 180 organizations shown on the list of participants of this conference; and 95, or a little over half, are industrial manufacturers.

In order that there may be no misunderstanding as to terminology, I shall interpret the words, data processing, as used in the title of the conference to mean business data processing. I have in mind the applications with large volumes of input and output data such as payroll, inventory accounting, cost accounting, material and production control, sales and general accounting, etc., all of them ultimately well integrated with each other. In other words, I have in mind the three generally accepted ways in which the automatic data processors can be of assistance in the handling of processing of business data:

First, they can make possible savings in personnel and equipment, mostly through simple cost reductions in cases where present manual or mechanical procedures are satisfactory but too expensive.

Secondly, they can provide better information faster; they can be of direct assistance to management by producing more extensive information more quickly than is possible with conventional methods. Conversely, of course, they are capable of turning out more wrong information faster than any device yet devised by man.

Thirdly, they can provide information never before available. This will often involve direct use of the equipment in the estimation and evaluation of mathematical probabilities and includes some of the problems of linear programming, operations research, industrial engineering, statistics, projections, forecasting, management control reporting, management decision, and so forth.

It is in the first two areas, saving money and saving time, that we are currently concentrating our efforts. There is a tremendous amount of work to be done here, not the least of which is the elimination of clerical drudgery. You might say that we have more than we can say grace over with the more mundane facts of life. In the third area, sometimes referred to as advanced data processing, our early ventures will probably be in the area of projections and forecasts based on current data and in the preparation of reports for management. Ultimately, it is in this area of measurements and management decision where we expect the data processor to make its name; but this work is farther away in our timetables.

One of the big reasons why large centralized data processing centers are in place is that the large automatic systems were available earlier than the smaller ones.

Another reason lies in the economics. The August issue of the bulletin of the National Association of Cost Accountants tells of a study made for the purpose of comparing these three possibilities:

1. Decentralized operation with a number of small equipments.
2. Centralized operation with the same number of small equipments.
3. One large centralized operation.

The study concluded that the economies were overwhelmingly in favor of the third proposition – one large centralized operation.

In our own Company, I think it is the emphasis on economics that has focused early attention on centralization where it exists, and I should like to tell you how this centralization came about in the case of two large-scale installations.

As many of you know, the first installation of a large automatic data processor in our Company was completed by our Major Appliance Division in Louisville, Kentucky, in 1954. The equipment became productively operative in October 1954. It is located in the Home Laundry Department and serves four other operating departments of the division: the Household Refrigerator Department, the Range and Water Heater Department, the Room Air Conditioner Department, and the Dishwasher and Disposal Department.

These five operating departments have similar business — they are all in the Major Appliance business — and they are all located in one plant. They have a combined total of around 10,000 employees. The original feasibility study indicated that substantial savings in personnel, space, and equipment could be expected from four applications:

(1) payroll;
(2) material scheduling and inventory control;
(3) commercial, or order service; and
(4) general and cost accounting,

if the computer were used centrally by all five departments. The project was approved on this basis. The object here was to pay for the automatic data processor with the four clerical applications which I have mentioned and ultimately make it available for use in the more advanced applications in the area of forecasting, management control reporting, decision making, etc., which I referred to as advanced data processing. Mr. G. M. Sheehan, Manager — Finance, Home Laundry Department, who has responsibility for the large automatic data processing system in Louisville will discuss some of the experiences of that operation tomorrow afternoon. The preparation of weekly payrolls for almost a year now has proven this new equipment can satisfactorily accomplish clerical tasks on an operating basis.

A second large automatic data processor will be installed in Schenectady, New York, next month for the preparation of payrolls and related reports. This equipment will be used as a service bureau by fourteen departments with about 30,000 employees —

all located in Schenectady. These fourteen components represent seven or eight different product divisions. They are in the heavy electrical apparatus business for the most part, but their businesses are not nearly so similar to each other as in the case of the five departments at Louisville. Here again by the combining of like work in different departments, payroll and related reports, a feasibility study indicated that savings in personnel, space, and equipment could be expected; and the project was approved. Further applications will follow, cost accounting being the most likely candidate for the second job of any size.

These are two examples of centralization from an operations point of view. We do not think of them as model applications. They are, presently, rather specialized and narrow; they are not now very well integrated with the other data processing needs of the departments to the degree that will be developed as we move along. We think these installations are providing us with early experience, proof of procedural feasibility, and the opportunity for training while saving money.

The third installation of a large automatic data processor is an example of decentralization. The equipment is located in, and serves, a single operating department in Richland, Washington. I should like to emphasize that while this is an example of decentralization from the operations point of view, there will be at the same time a pulling together or a centralization within the department of some of the functions which I mentioned previously. Thus the data processor serves the interests of engineering, manufacturing, and finance – three of those five basic functions into which the work of the operating departments is usually divided in General Electric. The data processor is being used for large, more or less continuous scientific calculations about one third of the time, for smaller, one-time mathematical calculations another third of the time, and for the performance of clerical work the other third of the time.

These then are the three installations of large automatic data processors in the Company at the present time. It appears that there will not be very many more opportunities for installations of large equipments in the Company in the near future. There are just two installations of large equipment which are being considered seriously. One would involve centralization of functions with a single, decentralized department. The other would involve centralization of these same functions in a large operating division.

Now at this point I want you to know that it is my personal conviction that decentralization is here to stay – in my Company and in most of your companies too. Decentralization certainly promises greater over-all savings to management than an automatic data processor does. It also gives the decision-making power to the men on the scene, at the lowest practical level, where it belongs. In contrast to this, the user of large electronic equipment is faced with its tendency to centralize. I do not know that any user has specifically factored this effect into or out of its policies. It is probably too early to expect this. Many of you are already familiar with the strong conviction of one user which Dr. Anthony mentioned earlier. That user maintains that its centralized data processing center with one of the large automatic equipments will not take away any decision-making power from anyone.

Now let us turn to some of the problems which appear to be showing up in connection with centralized operation of the large automatic data processing systems:

First is the problem of obtaining and maintaining enthusiasm for the project in decentralized areas. In many cases, it seems to be the practice to start a project by appointing a committee. This group usually operates from a central location, obtains its data, and makes the recommendation to get equipment. The natural reaction of the employees in the decentralized operating areas is negative. And you would agree with them if you were in their shoes. Someone outside their work area has arranged to deliver a mystic monster which can do more work better than it was ever done before. If you do not make plans to condition this attitude and work to obtain the cooperation of all present employees, the period of conversion when the automatic data processing organization needs all possible help can be most difficult and unhappy. One cure for this illness appears to be education of the workers in the lowest echelon as soon as possible. Then keep them very well informed and solicit their suggestions. If possible, make the lowest workers think they got the idea to get the data processor or, next best, make them think they came up with most of the ideas incorporated in the program.

Secondly, there is the problem of resolving differences in procedures among operating groups. Offhand you would think that popular application – payroll – would provide a great deal of uniformity if anything would. But such is not the case. In the Schenectady payroll application, which I mentioned earlier, the number of possible different payroll deductions was finally sifted down to 86. The number was even higher before the procedures analysts whittled it down, but it's still high enough to make block diagramming and coding more difficult than it would be if only one decentralized department were involved. The maximum number of different payroll deductions in any one department was only about half the grand total.

A *third* problem involves a decision as to whether it is better to write a separate program to perform like work for each decentralized department or to use a longer, more complicated program, which will fit the needs of all. There are advantages and disadvantages to both approaches.

A *fourth* problem is that of using the huge speeds and capacities of the *large* data processors usually found in the centralized data processing centers. Admittedly, our clerical work with its dearth of arithmetic when compared to scientific calculations often fails to use the expensive, central part of the data processor well. Some relief is promised in new multiplexing devices and programming techniques which will permit a programmer to time-share the equipment by performing, say, four or five jobs at one time instead of doing only one job at a time.

A *fifth* consideration is that the sorting problem tends to be increased in the case of centralized operations. As I am certain most of you know, sorting is the thing that automatic data processors probably do least well or not well at all. Some relief is promised in coming electronic sorters, and in large magnetic drums if you can afford them; but the best solution seems to be to throw the burden back on the punched-card equipment.

A *sixth* problem is the control of input and output data. We are finding that control of data requires more attention than was first expected. Involved here are the problems of physically transporting volumes of documents or punched cards to and from the data processor.

The problem of making corrections in input data is also increased in a centralized operation. The equipment is so much more exacting that more human errors are detected. One solution is increased programming to handle errors.

A *seventh* problem is that of standardization of the form of input and output. As in the case of automation in the factory, compromise in the numbers of input and output models must be made.

A final illustration is accentuation of the problem of scheduling the work load at a centralized, large-scale installation. Again using the analogy of the factory, the job cannot proceed until all the materials are on hand. If input deadlines are not precisely met, a very expensive data production line must be shut down.

Now let's leave the problems and look at the other side of the picture for a moment. I think we can agree that the large, centralized automatic data processing systems do have some advantages. Among the advantages are these:

1. The job done by the big equipment is much more complete and need not be done in pieces, or approached in piecemeal fusion.
2. They usually handle alphabetic characters as well as numeric characters.
3. Longer automatic programs are possible.
4. They have a wider variety of input and output media and devices.
5. They are equipped to handle much larger masses of data and to operate on larger numbers or names.
6. Fewer applications are required to justify the first equipment. The decentralized user of smaller equipment has a real problem here because he must investigate, design, and code more applications. And he is the one who can least afford it.

In conclusion, I should like to re-emphasize that the first systems to become available were the large ones. This tended to cause centralization. Since it takes a year or so to determine procedural and economic feasibility and another year to convert procedures, it was the natural and probably sound trend to create volume and justify expense by centralizing operations. Now the intermediate machines are becoming available. The possibilities for decentralized operation appear to be very good. Unfortunately the larger number of applications required to justify the intermediate equipment and the resulting increased requirements for manpower to do the job work to the disadvantage of the decentralized user. In the end the final gauge usually is economics.

Discussion: Part Two

QUESTION: I was wondering about the relationship between your Headquarters staff and the staff that may be set up at the plant.

MR. MUNS: Our Headquarters staff is a service group. We have no direct authority over the operations in the plants. It is expected that a Headquarters staff will be made up of men with ability and experience and that they will be able to give the divisions guidance and assistance particularly in the planning of their operations. There is a close working relationship between the Headquarters group and the plant staffs, but of course there is no direct line responsibility.

QUESTION: Do I understand from what you have said about your application that at the present time the machines you are putting in will serve only one particular organization, and in no case will they be trying to serve several organizations reporting to different people?

MR. MUNS: The first machines that we are putting in are going into operating divisions and will be servicing only the operating divisions in which the machines are located. They will be servicing a number of departments within a division, but all of the work that they will be performing will be divisional work, work that comes under one operating head.

QUESTION: After you finish your investigating phase and decide to order equipment, how do you organize for completing the programming? Does your central staff do that?

MR. MUNS: Our Headquarters staff does not do the actual programming for the equipment. We work with local plant management in helping them set up their organization, pick the people who will do the programming, and get the training programs under way. We have also given assistance in developing the problems that they want to put on the equipment and have given them assistance in getting their detailed programming started. But the local plant personnel, once they are trained, take over and do the actual programming work.

QUESTION: Do you expect that the person who is supervising the programming of the computer will be the same person who will supervise the operation when the computer is installed and is doing production work?

MR. MUNS: I doubt it. You probably need a higher caliber of men during the earlier stages of programming than will be required when the initial programming work is done and the computer is operating in a more or less routine fashion. In order to get ready for our East Pittsburgh computer, I transferred the best man that I had on my staff to East Pittsburgh to be in charge of the programming and installation of their computer. When their computer is in operation and men from their own staff have had sufficient experience to take over, my staff man will be transferred back to Headquarters.

QUESTION: Does that not imply that although you said earlier programming is not being done by the Headquarters staff, there is a Headquarters man who is temporarily put on the plant payroll and that he has a Headquarters point of view in many things?

MR. MUNS: Yes. The man temporarily in charge of the East Pittsburgh installation is from Headquarters. When the East Pittsburgh installation is in operation, he will again be a Headquarters man. However, the group of 10 to 15 programmers who are actually doing the programming work at East Pittsburgh are men from that plant.

QUESTION: You said that you expected to use the computer for both engineering work and accounting work. Who is going to arbitrate between the engineers and the accountants?

MR. MUNS: That is a good question. I can tell you how we are attempting to set up our organization so as to eliminate as much friction as possible. In both the plants where we shall be putting in large computers, the people responsible for the computer operations are reporting to the Assistant to the Plant Manager. The computers will not be the responsibility of either the Accounting Department or the Engineering Department, although their work will be done on the computers. It will be the responsibility of the persons in charge of the computers to schedule the machines. Undoubtedly problems will arise. An engineer may have a problem on the computer that takes longer than he anticipated. On the other hand, trouble may have developed and payroll may not be completed by the time an engineer is scheduled for the machine. Since we have to pay our people on time, payroll will have to have first priority. If a proper job is done in scheduling, we should avoid most of the arguments.

QUESTION: Is payroll the only data processing job you have or plan to put on the computer?

MR. MUNS: No. We have a number of jobs on which we are currently working. Payroll is ready to run in one plant as soon as we get the computer operating. Inventory control is in the process of being programmed. Several other jobs are being studied and will be available for programming as soon as the first jobs are operating.

QUESTION: Do you propose to run parallel, that is on present equipment and on the computer, in payroll?

MR. MUNS: We propose to run parallel for one month on our salary payroll and for two weeks on our hourly payroll.

QUESTION: Does that mean one pay?

MR. MUNS: One pay for the salary roll and two pays for the hourly group.

QUESTION: At the central Headquarters operation, do you propose to have the same type of staff and operating relationship?

MR. MUNS: We have not yet decided to put a machine in our central Headquarters.

QUESTION: Does your office report to any function in top management?

MR. MUNS: I report direct to the Controller, but our charter of operations covers a wider area than just accounting.

QUESTION: From whom do you get your approvals for the general program? Do you get them from the Controller or do you get them from a wider segment of top management?

MR. MUNS: I get my instructions from the Controller, although we have worked fairly closely with the top operating officers in Headquarters.

QUESTION: Have you formalized any top management committee on data processing?

MR. MUNS: No.

QUESTION: What is your feeling on that? Is it necessary?

MR. MUNS: Such a top management committee might be desirable, although I do not believe we have been held back in our work by not having such a committee.

QUESTION: Who actually made the decision to put the computers into the plants?

MR. MUNS: The Vice Presidents in charge of the plants had the authority and made the decisions. The Product Group Vice President to whom the plant Vice Presidents report was aware of the moves and even encouraged the plant men to secure computers.

QUESTION: Will these activities pay off on the installation of these machines?

MR. MUNS: We expect them to or we would not be putting them in.

QUESTION: What percentage of the available machine time do you expect to use for payroll?

MR. MUNS: Until we have our machines in operation, I do not want to answer that question. We have calculated theoretical times, but I feel we should wait until we have actual operating experience before we attempt to answer that question.

QUESTION: What equipment do you put in the category of large and small?

MR. PONTIUS: In the large size I would think of the two presently available, the Univac I System and the 702, and to become available in the future, the Univac II System and the 705, and the Bizmac. In medium-size equipment, I would think of the 650, the Univac file computer, the Datatron, the Elecom 125, the NCR303, etc. As to dollars in the large category, I would think in terms of a purchase price of a million dollars or a rental cost of $250,000 a year. In the small class, where you seem to run into a rental proposition more often, it would be $50,000 to $75,000 a year for rental.

QUESTION: You mentioned before that you saw the present trend of large computers possibly going into small ones and back to large again. What is your feeling as to the compatibility for the integration of several large ones in a company such as yours plus some medium-sized ones?

MR. PONTIUS: If you consider the line of equipment offered by any one manufacturer, the compatibility will be there. But if you try to integrate the equipment of different manufacturers, you probably will not have that ease of compatibility. In view of your question, you probably are thinking in terms of the compatibility of magnetic tape. The next best media would be punched cards. If you take the time and trouble to go back to punched cards, you might say you have compatibility between manufacturers. In our own company I do not foresee that we shall in the near future try to achieve real integration between locations and between computers. There will not be a great number of data processors in place soon and those that are used will not be sufficiently interrelated in their operations for any lack of compatibility to become a problem.

QUESTION: In this Schenectady setup where you would have 30,000 people, how is the payroll handled before you put it on the calculator?

MR. PONTIUS: In almost every possible way payrolls were prepared manually, on bookkeeping machines and with punched cards. There were 14 different payroll units and each of them will retain its separate identity. Each payroll will transport input data to the data processor at a central location.

QUESTION: Do I understand correctly that the philosophy on the payroll is that there will be no uniformity in "the clothes that come to this laundry"? There is no standardization of payroll activity. It will be a centrally processed thing in a common numerical "laundry"?

MR. PONTIUS: Yes, the payrolls will be processed at a central laundry. An attempt was made to achieve as much uniformity as possible. It was recommended that each department use the same design of punched card input, that the cards be prepared back in the payrolls, and that the input be delivered to the data processor in the form of punched cards. There are many kinds of cards, of course. Not all the departments chose to use the same forms but they were accommodated in one way or another.

PART THREE

Criteria for Selection of Equipment

CHAPTER 6

An Evaluation of Electronic Data Processing Equipment

DR. SAMUEL N. ALEXANDER

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I WANT to take this opportunity to explain in more detail why you can hope to benefit in your areas of interest by listening to the remarks of a member of the scientific staff of the National Bureau of Standards. I would like to emphasize particularly appropriate items of experience by recounting how NBS entered the data processing field and perhaps give you a little better understanding of our present position in the field. The purpose is not to impress you but to permit you to apply your own scaling factor on opinions that I may express this afternoon.

Our work at NBS started in 1946 as collaborator with the Bureau of the Census, a sister agency in the Department of Commerce. At that time, the Bureau of the Census could begin to recognize diminishing returns in further application of standard punched-card techniques to the handling of their steadily increasing work load. They saw a reasonable possibility of entering a census-taking period with the prospect of being unable to process properly the gathered data in the remainder of the official three-year period allotted to the decennial census. Moreover, there are definite reasons for reducing the period for processing the data to less than three years rather than embrace the unsatisfactory alternative of extending the period beyond three years. Thus, the Bureau of the Census was readily interested in reports that electronic techniques were being applied to certain military tasks that might also be applied to their job of tabulating the census data. In addition to their massive population census every ten years, the Bureau of the Census has sizeable work loads in intervening years such as Census of Agriculture, Census of Business and

Commerce, and the monthly reports on Foreign Trade and Labor Force Statistics. Thus, their over-all work load was a large and growing one and there was precedent for pioneering with new techniques. Punched-card techniques were first tried during the Census of 1890 and had their first extensive use during the Census of 1900. The Bureau of the Census decided to pioneer in the electronic tabulating equipment field in 1946. The Department of Commerce sanctioned the adventure with the proviso that NBS also be a party to the experiment because of the many technical uncertainties that were present. NBS was directed to provide the necessary technical backup to this program to insure the availability of equipment during the census of 1950.

This activity underwent an unexpected growth, and NBS eventually had the responsibility for the specification and acceptance for the Government of the first three commercially supplied computers, UNIVACs. The first one went to the Bureau of the Census, the second one went to the Comptroller's Office of the U. S. Air Force Headquarters, and the third one went to the Army Map Service of the Corps of Engineers. It is an interesting commentary on the nature of this field to observe that these three agencies were acquiring nearly identical equipment installations, yet one was to tabulate census data, a second was to carry out budget prediction procedures, and the third was to transfer survey control points from the conventional military grid system to universal earth-coordinate system. Certainly, one would not expect in advance an acceptable level of performance for three such different tasks out of an identical set of equipment specifications. This points up, I believe, the most important characteristic of the data processing systems: their amazing flexibility, which is available to you if you can patiently work through the task of describing your problem to it.

The next bit of history I would like to relate about NBS is that during the same period there was an urgent internal requirement for a computer to aid our scientific work. There were strong technical reasons for expediting the construction of the SEAC. Not only did we need to complete many computations for our own purposes, but there was also a need of assisting several Government agencies that were planning to obtain more complete installations. They needed to complete the training of their staff by actual prototype problem solutions. It was very difficult for rest-less imaginative people to confine all of their preparation to paper work. I believe a similar topic came up in a talk earlier this morning. Certainly, it is understandable that after a year of planning on paper there is a strong desire at least to be able to run prototype computations. This was one of the very important additional reasons why it was necessary for NBS to build the SEAC machine.

It is rather interesting to observe that in addition to the fact that NBS needed to meet its own internal requirements, a major work load grew up in connection with other groups throughout the Government that wanted technical advice of much the same sort as the Bureau of the Census. These agencies did not have the technical staff suitable for estimating the technical gamble and the program difficulties that were involved in procuring data processing systems for their operations. Thus, NBS became actively engaged in supplying technical advice in the selection and use of equipment suitable for the work of other agencies of Government.

I might add that serving this function in a new field has been both trying and rewarding. We found that it was futile to discuss this new equipment in terms of engineering characteristics with the groups which wished to apply it to their problem. It was not sufficient to discuss the calculating speed, the memory capacity, the data rates for the magnetic tapes, and other such characteristics about which we could be very definite. Such information would not serve the purposes of people who sought our advice in terms of "how much of my work load will this new kind of equipment carry for me?" We found it necessary to become reasonably conversant with the nature of the work that they wished to accomplish, how this work was now being accomplished, and in what way would they consider changing the working procedures in order to adjust to these new techniques. Much to our annoyance, we were becoming amateur systems-analysts. Later on, this enforced broadening of our fields of interest proved decidedly advantageous, since many important interactions appeared between the work to be done and the characteristics of the equipment. Exploring these interactions has now become one of our major activities. We hope that it will result in concepts for both equipment and application development that will be of benefit to both the user and builder of such equipment. This concludes my explanatory remarks about the NBS activities, and I hope that now you can better gage the pertinence of my remarks in relationship to the interests of your organizations.

Turning to the specific purposes of this session, I should like to say that I heartily approve of the theme used: automatic data processing. The emphasis is placed where it should be — on "automatic." It has become rather common usage to preface the "data processing" with the adjective "electronic." This emphasis on "electronic" is not meaningful for you, since it is not the primary feature that concerns those people who are going to use the equipment. The maintenance man, and to some extent the console operator, is deeply concerned with the fact that electronic techniques have been used, but not so for the man who is planning work for the system. The user must cope with the fact that he is using an essentially automatic system and consequently must develop a plan that permits a high degree of automaticity in executing the work.

I am neutral regarding the earlier discussion as to whether the component part of these systems should be called machines or equipment. Many of you were present at the session where these distinctions were discussed, and good reasons were advanced for both points of view. I am inclined to favor the "suffix system" as being more appropriate to the user's point of view and recommend that they be referred to as automatic data processing systems. Planning of work for them brings you immediately in contact with the fact that there are several aspects to the tasks which are usually embodied in different pieces of equipment. You have to prepare the data, you often need to transcribe the source data, it must be in specialized format to be entered into the computer, the partly processed results may be removed from the machine to be re-entered several times, and the end results are finally removed in a form suitable for printing out. All these operations must have planned interrelationships, and in selecting the plan for the flow of work consideration must be given to the interactions of operating rates, elapsed time, and costs. One must plan the over-all task in terms of a complete system for executing the work.

I would like to emphasize this point by an example from the Bureau of the Census experience. The people at the Bureau of the Census recognize that the cost for doing their over-all task had a major item of expenditure in connection with going from door to door to gather the source data. Indeed, this item often accounted for more than half of the total cost. Roughly a quarter of the total cost was devoted to the transcription of the source data in preparation for processing. The remaining quarter was devoted to processing. As a result of their recent experience with the UNIVAC and their long experience with punched-card techniques, their request for an additional UNIVAC before the Appropriation Committees of the Congress was based on the confidence that it was now possible to do certain tabulations for fifty cents by the new techniques, tabulations which would require a dollar to do by conventional means. Thus, there is likely to be a significant reduction in that quarter of the cost relating to the processing of the data.

We are trying to help them improve the preparation of source data for processing. The still larger cost of collecting the source data remains as a major consideration in planning the flow of the work. There are interrelationships that must be kept in mind. One could easily, in an effort to simplify the transcribing or the processing of the data by the machine, increase the cost of gathering the data by a small percentage and have a net loss on the over-all operation. Therefore, I strongly urge that in planning the work the relation of the equipment to the task be considered as a system. Accordingly, the planning of work for such a system tends to be a far more integrated task than has heretofore been the case. In addition, the automaticity of these systems puts a tremendous emphasis on complete and exact detail. It is the combination of the "automatic" and the "systems" aspects which are the ones that will be your major concern in applying it.

The next topic I wish to discuss concerns the general features that characterize data processing machines. I have already de-emphasized the significance of the electronic nature of current equipments. Equivalent technical means for obtaining the necessary speed and flexibility would be acceptable. I would like to call your attention to three salient features that are present in these equipments. These are: (1) the ability to transmit and receive information as a telegram-type message; (2) the ability to restore and selectively recover any designated telegraphic message; and (3) the ability to process the content of the telegraphic messages in accordance with the rules of arithmetic or simple logic. The data processors consist of a blending of all three of these techniques. While there exist other physical means of achieving these effects, electronic techniques offer the high speed and flexibility that are used to produce an effective and economical installation.

The first of these features, the telegraphic means for communicating information, goes back about 100 years. Here we had for the first time an effective means of transmitting information from one place to another without transporting a material body to which the information is attached. The information is communicated through the transfer of electrical energy rather than by the transmission of a material body such as a marked sheet of paper or a punched card.

To make full use of this high communication speed there usually needs to be means for temporarily storing and recovering information that would be needed later in the flow of the work. The receiving and dispatching of information had to be fitted to the average rates at which they were to be used. This effect is usually obtained through the conversion of the received energy into a physical medium such as a magnetized area on a tape, by blackened areas on a photographic plate, by holes punched into paper tape, and by a host of schemes that have been developed for this purpose. It is equally important to be able selectively to recover this stored information as electrical signals. The intermediate medium for information storage must be capable of receiving electrical signals and, when interrogated, of giving out equivalent electrical signals.

The combination of the two foregoing features provides a flexible means of handling and routing information. However, if one wishes to perform the usual office procedures such as the preparation of a fiscal report, it is also necessary to be able to process the data in accordance with the rules of arithmetic and the logic that pertains to such procedures. Perhaps a few words of explanation are in order regarding what is meant here by logic. This refers to such simple concepts as: "Does this item belong in category A or not; if not, try it against another category and continue until a match is found." Another example: "Is this item larger than that one; if so, then refer to line 3 for the next step; if not, refer to line 1 for the next step." The ability to make logical comparisons and adjust the course of the procedures in accordance with such comparisons provides a flexible means for informing the machine of our wants and causing it to do the necessary arithmetic in the right order and at the right time.

All three of these features were recognized in the early planning of Charles Babage around 1830. However, the first successful embodiment occurred through both the use of electro-mechanical devices and the use of telephone relay devices during World War II. Electronic devices were successfully used for these purposes just after the close of the War. Thus, one must recognize that the actual combination of the three essential features into a data processing system is of relatively recent origin. Indeed, one may wonder at the extremely rapid transition that this technology has made from the laboratory to the office.

Because of the high arithmetic speeds that can be attained through the use of electronics, there has been unwarranted concern that such characteristics are not needed for data processing. Some clarification is needed here, since the equipment in the arithmetic unit is not used solely to do such tasks as adding long lists of figures and forming percentages. It is also used to perform the elementary logic that guides the machine through the list of instructions that represent the processes that you wish to apply to the data. These "housekeeping" operations can keep the arithmetic unit very busy. As we gain experience in adapting more elaborate and intricate office procedures to these data processors, the more fully we will be able to utilize the processing speeds. However, the characteristics of the high-speed internal storage of the equipment has a considerable effect on the extent to which we can now utilize the arithmetic speeds. As the volume and accessibility of these internal stores are increased, we can expect much greater over-all performance of the processing system.

The office tasks that interest you gentlemen often involve extremely large volumes of stored data and it is not practical to hold all of this within the internal storage. Thus, there must be means for rapidly loading and unloading the internal part of the machine through input-output facilities associated with the system. It is in the character of these input-output facilities that the data processor tends to differ from conventional electronic calculating machines. This part of the equipment also tends to represent a considerable fraction of the total cost of the data processing system.

I think I can best explain one of the important functions of the input-output system by a rather crude analogy. Consider an efficient manufacturing plant in which the internal machinery has been organized to a remarkable degree of effectiveness. However, there is insufficient storeroom space within the plant to satisfactorily hold the partially fabricated parts that are produced and being held for the next stage of the operation. Since it is not feasible to increase the storeroom space in the plant, a warehouse must be obtained in the very far suburbs, and it is necessary to carefully plan the flow of work to get the partially fabricated parts out of the plant into the warehouse and back from the warehouse into the plant at the appropriate time for the next set of operations. It is apparent that the effectiveness of this arrangement depends on matching the flow to and from the warehouse with the production rate of the plant. Following this analogy, there are classes of problems in data processing where this arrangement is suitable. One can easily identify other problems in which the input-output characteristics, corresponding to the transfer to and from the warehouse, become the limiting factor.

We must recognize that the situation is improving steadily. As an example, initially the data was read into the computer from punched cards at something less than 1,000 characters per second. Today we can read from magnetic tapes at data rates up to 15,000 characters per second. Nevertheless, the flow of data to and from magnetic tapes is still around 50 times slower than the internal data rate associated with the arithmetic unit. Thus, considerable ingenuity has had to be exercised to reduce this imbalance and yet not reduce the effective internal speed of the data processing. If reducing the internal speed would result in significantly less expensive and more reliable equipment, this would be a reasonable thing to do. However, there is not much to be saved by reducing the operating speed of the electronics; this when done usually tends to include other compromises with the inherent flexibility of the installation. There is no general agreement among equipment designers regarding the proper balance among these considerations, and consequently the equipment on the market exhibits many gradations in design balance.

Thus, choosing among available machines tends to become a reflection of the value placed on flexibility and capacity for growth. If you have a stabilized processing operation that can be expected to continue in its present form, you can probably justify the selection of a specialized data processing machine in which balance has been achieved for the particular job. However, you must recognize that this choice may severely restrict incorporation of future changes. However, experience with automatic data processing systems tends to change one's attitude toward the amount and kind of data processing that is needed in modern office operations. This is a strong argument for selecting equipment with considerable flexibility and reserve capacity in order to take advantage of the fact that only hindsight can be expected to have 20/20 vision.

Since there is considerable importance attached to the relationship between the input-output characteristics of the machine and the kind of jobs that it can efficiently perform, a few further remarks on this point are in order. The original electronic calculators employed a relatively elementary means of controlling the input-output equipment. They simply employed the central control equipment and arithmetic unit of the calculator for monitoring the transfer of information into and out of the internal memory. This was not a particularly effective way to accomplish the result because the internal pace of the machine was 100 times faster than the transfer rates. Under these circumstances, the calculator essentially waited patiently while the next hole in the punched card was being moved into position. Indeed, the calculator even loafs while the characters are being read off a fast magnetic tape. Since this machine organization requires the minimum amount of equipment, this plan has been used in a number of the current installations.

The obvious next step was to provide special equipment to monitor the transfer functions while the arithmetic operations were being performed on a batch of input data that had been transferred into the machine at an earlier step. In the UNIVAC there is a separate reservoir for assembling the incoming information from the magnetic tapes and still another reservoir to assemble the outgoing information which the computer is sending to the magnetic tapes. Thus, calculations can be in progress while the subsidiary control system is monitoring the previously designated inputs and outputs. If the work is characterized by a straight-through process, then the flow-in and flow-out can probably be matched in such a way that an input and an output tape can be kept in motion most of the time. In a data limited operation, this is about the best that can be achieved.

Since arithmetic units can readily be designed that will process the data faster than a single tape can deliver it to or remove it from the processor, additional performance can be obtained by being able to transfer from several tapes at once. This general plan was incorporated into the RAYDAC. Each tape unit was provided with its own local reservior out of which the arithmetic unit could operate as readily as out of the main internal memory. When the data can be properly organized, it becomes possible to transfer enough data into the machine to keep the arithmetic unit fully occupied. More recent variations on this plan propose to have the tapes transfer directly into the internal memory and avoid the need for special reservoirs associated with each tape unit.

Thus, by either of these two procedures, an effectively higher rate of transfer into and out of the processor can be achieved and the operation brought more or less into balance at a high level of performance. Thus, it is no longer a question of whether you can achieve these higher performances but rather whether this represents an economic investment in equipment for your job. Furthermore, the same type of machine organization can be adapted to "on-line" operations. This would make it feasible to have 50 or 100 keyboards located with the various cash registers throughout a department store. As each sale is rung up, this operation would transfer the pertinent information about this new transaction directly into the central machine. This transfer into the central machine could be efficiently interlaced with the base work load of developing the various totals needed in the store's operation.

I believe I have dwelled overlong on some features; I trust that they have been of interest to you. I have been unable to include the problems associated with transmitting source and process data of wire communication facilities. If there is interest, I would be glad to comment during the Question Period on some of the considerations relating to the transmission of data.

CHAPTER 7

The Role of Special Purpose Equipment

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THE CURRENT interest in automatic data processing was first aroused by the success of the large general purpose scientific computer. Since then the general purpose computer has continued to hold the center of the stage. Whatever the applications – payroll, inventory, order processing, sales analysis, or revenue accounting – all are recommended to the same general type of automatic machine.

To the layman, impressed though he be with the power of modern computers, this approach may appear strange. Are not the main characteristics of business data processing repetition and large volume? Are these not also the characteristics of those mass production operations that have lent themselves so well to the application of special purpose machines? Where small production runs are required, versatile general purpose machines are necessary, but for volume production do not simpler special purpose machines prove more efficient in operation and less troublesome to maintain?

To the mathematician or engineer, naive businesswise, this analogy appears too striking to be ignored. Admittedly, the design of special purpose equipment first requires a complete knowledge of the operation to be undertaken, but the elementary operations of accounting are clearly so simple as to give no pause at this. In the words of the British computer expert, B. V. Bowden, "It always outrages pure mathematicians when they encounter commercial work for the first time to find how difficult it is."[1]

[1] B. V. Bowden, *Faster Than Thought*, Sir Isaac Pitman & Sons, Ltd., page 258.

When he has been finally convinced of the complexities of business data processing and of the difficulties of designing machinery for a given accounting function, the mathematician may next rail at the complicated business policies, the haphazard accretion of procedures, and the rigidity of the complex systems. Although his convictions in these matters may remain, he is soon convinced that it is he that must adapt, not the system. Finally, he concludes that the complexity of the application requires correspondingly complex machinery and falls again under the spell of the general purpose computer. This is no idle conjecture; projects for the design of special purpose business data processing systems have indeed passed through these same phases and have finally resulted in general purpose machines.

General purpose computers do not, however, provide a wholly satisfactory solution. Not only does their high cost exclude them from the consideration of smaller organizations, but even the largest firms may find it difficult to justify their use purely on a cost basis. Better solutions are needed. While a naive approach must be avoided and the complexities squarely faced, the voluminous, repetitive nature of figure-production operations does impel consideration of special purpose equipment.

Before we consider the design problems of special purpose machinery, it will be well to discuss the distinction between general and special purpose machines. A general purpose machine is one which may easily be adapted to perform any one of a large range of tasks. In this sense the human hand is the epitome of general purpose instruments. A special purpose machine, on the other hand, is constructed for the performance of a specific task and is usually designed to take advantage of any simplifications made possible by the nature of the task. Actually most special purpose machines will perform not only a single task, but also a narrow range of tasks; even a can opener may be expected to operate on a variety of shapes and sizes. Thus the difference between general and special purpose is one of degree only, but is generally so great as to make the distinction a useful one.

A number of factors have contributed to the present emphasis on general purpose computers for business applications. The first is the unquestioned success of such machines in their first application to scientific computing. This has encouraged the use of the same approach in business data processing even though these applications do not always use the costly flexibility of a general purpose computer.

A second factor is the past practice of the tabulating machine industry. I refer to the production of a line of machines, each of limited capability, which together suffice for the synthesis of systems of great complexity. The tabulating machines, while individually very limited, together provide a truly general purpose system, a result achieved because each machine is built and used for the performance of a single function, such as sorting, merging, adding, reproducing, or printing.

Such a synthesis leaves considerable manual labor in the scheduling of operations on successive machines and in the feeding of information from one machine to the next. Nevertheless, this approach allowed the production of a standard limited line of machines that could be applied to any data processing problem whatever, subject only to considerations of cost. Although later developments in automatic machinery have made more complex machines practical, the same approach to mechanization persists in the attempt to solve all types of problems with a single machine or line of machines.

A third factor often cited in favor, indirectly, of general purpose machines is the necessity of a thorough and detailed knowledge of the job to be done before special purpose equipment can be successfully designed. In most applications such knowledge is lacking, and indeed the failure of certain attempts to use specially designed machinery may be laid primarily to this lack.

The purported inflexibility of special purpose machines is a fourth factor to be mentioned. It has been noted, however, that "special purpose" is a matter of degree, and any well-designed machine should include the possibility of adaptation to a reasonable range of expected practices. Carried to extremes this would simply result in a general purpose machine. Yet, electric power billing, for example, has long been based on kilowatt-hour consumption, peak demand, and a set of "rate steps," and a machine capable of producing electric bills under any likely variation of this procedure can still be simpler than a general purpose machine designed to handle property and stores accounting, as well.

Of the four factors cited, two are purely historical and only the last two offer any compelling objection to the special purpose approach. In many applications special purpose equipment appears to warrant serious consideration. We at Harvard are currently investigating a number of possibilities, including public utility billing, payroll accounting, and check-handling in the banking system. In the check-handling problem, a number of manufacturers have already recognized the unsuitability of the general purpose computer and are at work on special equipment for this task. Finally, it should be remarked that the American Airlines Reservisor, one of the first pieces of electronic apparatus to be successfully applied to a commercial function, is a special purpose machine which, because of careful planning, has given a very good account of itself.

The first step in the design of special purpose equipment is a detailed study of the system to be mechanized. This prerequisite has already been mentioned as one objection to the special purpose approach. Nevertheless, it must be realized that the programming of general purpose equipment requires the same detailed study, except that it may be performed after the equipment is built. The essential difference is that the results of the study can be used to simplify equipment and reduce cost when performed as a preliminary to machine design but can only serve to adapt existing general purpose equipment when performed later.

One school of thought holds that the savings to be expected from the immediate application of general purpose computers are so great as to make a waiting period of even a year or two for the development of specialized equipment financially intolerable. Experience to date has failed to substantiate these beliefs, and such savings as do result are usually attributable more to the system reorganization than to the computers. Moreover, the lengthy period required for programming produces a substantial delay even in the use of general purpose machinery.

The use of general purpose computers, however, may prove extremely valuable in the systems study as a tool to force a complete description and crystallization of procedures. For, as every system analyst has remarked with vigor at one time or another, it is extremely difficult to locate and exorcise all the minor inconsistencies which, although tolerable in a manual system, would be fatal to the success of a completely mechanized system. Trial operation on a general purpose computer can be used to locate and remove such "bugs," and the resulting programs are in effect complete and consistent descriptions of system operation. This approach, however, runs the risk that the analysis will be so molded by the limitations of the particular general purpose computer used that an optimum system will not result. Care must therefore be taken to split the investigation cleanly between function analysis and machine adaptation.

The nature of a study preliminary to the mechanization of an accounting system has often been presented as nothing more than a complete description of the presently operating system. It has already been noted that an effective study also requires considerable analysis, for the location and removal of inconsistencies. But the analytic nature of the study required must go even deeper than this, and its importance cannot be overstressed. A few examples may help to clarify the nature of this analysis.

The basic problem in a business data processing system is one of order. The operations required at each transaction are relatively simple. Complications arise because of the fact that all processing is serial but the information may be grouped in different orders. Premium bills are dispatched in an order determined by the dates of insurance policies; they return in a different order, dependent on the paying habits of policy holders, and must be credited not only to the paid accounts but also to agents' commission accounts arranged in a still different order.

The importance of order arises from the fact that it is much easier and faster to process items in the "serial" order in which they are filed than it is to select successive items here and there at random. This is particularly true if mechanical devices are used. The selection of an item at random from among a group recorded on a reel of punched paper tape requires reading through all intervening items to reach the one selected. Unlike the continuous tape, a punched-card file allows a single item to be plucked out at random without passing through all intervening items. Reliable mechanical equipment to effect such selection, however, is either impractical or at least very costly and again mechanical devices normally handle card files serially. Thus mechanical posting of the premium payments of the previous example would require that the payments first be rearranged to the same order as the main files by several passes through a sorting machine.

This problem of different orders arises in all but the very simplest operations. In small manual systems it is handled fairly easily and may not even be recognized as a basic problem, mainly because of the human faculties for rapid search and for extremely complex "translations" from one coding system, such as customer's name, to another, such as address or account number. The versatility of the human is sorely missed in dealing mechanically with multiordered systems.

The importance of multiorderedness may be appreciated by considering the simplicity with which a mailing machine effects a mono-ordered function. In fact, the punched card was introduced solely to handle multiordered operations, and their use proved successful because of the ease with which cards could be sorted from one order to another.

Since the time required for reference to files (e.g., the reading of a punched card) usually constitutes the greater part of the time required for the entire operation in an automatic machine, the number of "passes" of the information through the machine is an important variable and should always be held to a minimum. The number of passes must be at least equal to the number of "orders" inherent in the system, and each pass must be followed by a sort. In the preceding example this means that one pass of the receipts in policy-holders' account order is used to post payments, and this must be followed by a second pass of the receipts arranged in the order of agents' accounts to post credits to their commission accounts.

In the case of conventional punched card equipment this relation of the minimum number of passes to number of necessary different orders is obscured by the extra passes caused by the limited capabilities of each type of machine. This relation, however, sets a lower limit to the number of passes for small machines.

Modern techniques have changed this picture somewhat by the introduction of random access storage devices of large capacity. These allow a reduction in the number of passes if one has enough random access storage to accommodate all those items which must be selected in other than the primary order. Returning again to our example, the agents' commission accounts can be posted during the same pass used for posting to each policy if random access storage is provided for the quantities in each of the commission accounts. If there are, say, one thousand policy holders for each agent, the cost of double handling of each posting would perhaps outweigh the cost of random access storage for the relatively small number of commission accounts. If, however, the ratio were only ten to one, repeated handling would likely be preferred.

In addition to the random access storage, more complex decision functions must be provided in machinery designed to reduce the number of passes. In our example numerous decisions may be required in the posting operation. Special action may be required if the policy has lapsed. If the payment is only partial, the account may be either rebilled or left in arrears depending both on the amount of the deficiency and on the length of the billing period of the particular account. Similar complexities arise in posting to commission accounts. These may be handled by separating or sorting out the various categories of complexities, but single minimal pass operation necessitates very complicated decision functions. Thus the number of passes may be reduced at the cost of increased random access storage and greater complexity, and the point at which this ceases to be economical must be determined in the system design. In any case, order multiplicity is an important parameter, and nonessential multiplicity must be eliminated to reduce the demands on input and output equipment.

The end-purposes served by each output required of a data processing system must be understood by the systems analyst; for the forms of the outputs provided have been shaped not only by the purposes in view but also by the data processing tools available and by circumstances of development. Consequently the application of new tools may call for outputs radically changed to serve the desired ends better.

In the design of special equipment this consideration of end-purposes is doubly important because of the greater need for accurate prediction of the range of expected requirements. This prediction may be much more safely based on the final purposes presently served by a data processing system, that is, on the substance of the output, than on its present form.

These fundamental considerations of desirable end-purposes, of basic ordering problems, of decision functions and number of passes illustrate what is meant by the analytic approach to systems study. This approach brings an enlightenment rarely found in reports of systems study teams or of management consultants, for the fundamental mathematical approach is alien to their experience and training.

It is clear that such analysis will require the services of specially trained people. To avoid the frequent schism between the potential users of machinery on the one hand and machine designers on the other, such specially trained persons should be grounded in the fundamentals of computing machines and versed in the practical needs and procedures of business. They should have a facility for logical analysis such as that expected from an education in mathematics, physics, law, or accounting.

The supply of persons possessing this combination of skills and interests is very short. It will remain so until educational programs adjust to the needs of this new discipline, which straddles the recognized fields of business and engineering. In the meantime, needs are partially met either by giving operating personnel a short course in computers or by bringing mathematicians or engineers in to learn business procedures. Neither practice should be used alone, and each study group should contain some people of each sort.

Certain general remarks on the training of analysts may be in order. First, the training in computing machine engineering should be much more thorough than that offered by courses in computer programming. Secondly, while a general orientation in business practices can be achieved by a study of cases, experience in teaching these techniques has demonstrated the need for an early distillation of principles and instruction in these. The stopgap nature of short training courses must be recognized and steps taken to direct young men in the field toward sounder and broader educational programs.

Unless the results are negative, a system study should eventually lead to the specification and purchase of machinery. At this point it becomes clear that the systems analyst, like the lawyer, broker, or doctor, must offer to his retainer not only professional competence, but loyalty as well. Thus the study should be made either by company people or by independent consultants, and undue reliance must not be placed on equipment manufacturers.

Although these points may appear too obvious to require emphasis, they are frequently ignored in studies of accounting systems. One ingredient or the other is usually missing: loyalty because the study is conducted or guided by a manufacturer; or competence because the consultants or company teams are admittedly learning while they earn.

This is not the place to present sample specifications for a special purpose system even if one were already worked out in detail. Still it may be useful to provide examples of how these specifications may be expected to differ from those of a general purpose machine.

First, the speed of the computing unit should be matched to the job. Extremely high speed is costly and is difficult to utilize in commercial applications because of the essentially slow speed at which information inputs and outputs can be handled. This speed mismatch is usually met by providing high speed magnetic tape input and output devices on the computer itself and slower devices such as tape-to-print and card-to-tape converters to use and to prepare these tapes.

These converters are themselves very costly and their use could be avoided if only the speed of the computing unit were matched to the input and output units. With present high-cost general purpose computers this would not be practical, but lower cost, low speed, special purpose computing equipment would change this situation radically.

The cost of high speed equipment reflects itself not only in initial costs but in maintenance. The unreliability of vacuum tubes has come to be accepted as a necessary evil in the scientific computers that require their speed. Slower devices may yet deserve development. The largest special purpose computer in existence is based primarily on relays, and most of us can attest to its reliability. I refer, of course, to the telephone system, which automatically selects any one of millions of lines at the direction of the caller, and in some cases even performs the necessary accounting as well. It is possible, of course, that new devices in the offing may give us both speed and reliability at low cost.

Secondly, only needed capacity should be provided in the computer. In programming a general purpose computer, one hears that the machine is limited by tape speed in one operation, by computing speed in another, and by memory capacity in a third. Such a situation implies an excess capacity of some facility or other in any one of these operations, although all may be essential to the whole complement of different accounting functions undertaken. In a special purpose machine, needs would be balanced by sufficient equipment and no more.

Thirdly, the design objective must always be the most efficient system, not necessarily the most automatic. Too often the emphasis is placed on eliminating as many people as possible rather than on using their skills effectively.

Let me illustrate these points by recounting briefly the development of one limited, but promising, special purpose system. The problem attacked was large-volume order handling for a stock of about 60,000 items. The investigation passed through several phases. The first objective was complete mechanization. But it was found that a magnetic drum would be required to provide sufficiently rapid random access and that the size of the drum required would be eight feet in diameter and sixty-five feet long. So much for the first phase.

The second phase was a study of available general purpose computers. It was concluded that none offered economies in this particular application. Finally a more limited objective was adopted, restricted essentially to the writing of orders with necessary descriptive data, price per item, extension, and total, all entered automatically.

Random access to the large body of catalog information is obtained as follows. Magnetic cards are used with several items recorded on each card in mechanically readable magnetic spots on one side and in printed characters on the other. An operator types in the variable information such as customer name and address, quantity, etc., selects the appropriate magnetic card and drops it into a reader. The information is read and the card returned immediately. While the next card is being selected this information is being typed, the price extended and typed, etc. Essentially, magnetic recording is used to reduce the files to an easily accessible volume, and the skill of the operator is utilized in making the random selection of cards. In this way the output of the operation is increased about three- or fourfold over present production. A working prototype indicates that the cost in even limited quantities will allow substantial savings.

The original design cost was mentioned as an important objection to special purpose equipment, because it would probably have to be distributed over a smaller total number of machines. This would not necessarily be true, since the production of more modest equipment for a specific purpose may bring the cost down to reach a large market in small businesses even for a specific task, whereas the high cost of general purpose equipment excludes this same market. Moreover, when one adds to the cost of general purpose equipment the very high cost of programming it for a specific application (perhaps forty man-years or more), then the original design cost of special equipment appears less formidable. Nevertheless original design cost and limited production runs are important factors, but there are several means of mitigating their effect.

First, is the choice of the function to be mechanized. Special purpose machines designed for such widespread and large-volume functions as payroll accounting and public utility billing would enjoy a wide market even though highly specialized. It is unfortunately true, however, that a payroll machine designed to handle every type of payroll extant would perforce be general purpose in every sense of the word. It is believed, however, that a much simpler system can be designed to handle the majority of payroll operations, and one of the studies mentioned is being conducted in this area.

Some standardization before the fact would be necessary in many applications. This leads to a second approach, namely, industry-wide cooperation on specifications. This cooperation may be expected first in the less competitive industries such as public utilities. For example, the American Gas Association and Edison Electric Institute are already sponsoring a joint research project in the mechanization of accounting functions. It is clearly desirable that the user play a larger role in framing specifications than at present, and cooperation of this kind can so distribute the cost of the necessary research as to make it feasible.

A satisfactory answer to the limited production runs expected for specialized equipment may be provided by "unitized construction." This unitized construction refers to the production of standardized components or units that are easily assembled in different combinations for the synthesis of a variety of larger systems.

It is interesting to speculate on the type of units that should be provided. These building blocks should not be too small in terms of capability but should certainly be larger than the packaged switching elements now offered for the unitized construction of computers. Functionally complete components such as arithmetic, memory, input, and output units would be more suitable elements. On the other hand, units such as the common tabulating machines are probably too large. Nevertheless their individual components such as card feeds, card punches, or printers would probably be very desirable units if obtainable separately.

Manufacturers might be expected to resist the unitized approach since it could lead to increased competition from producers incapable of offering complete systems. A move toward unitization, however, can be seen in recently announced equipment. In any case, specifications for the type of units best suited to the synthesis of data processing systems have yet to be drawn. They can emerge only from analysis of the type here proposed for the design of special purpose equipment.

The problems of the final phases of mechanization, cutover from the present system, personnel displacement, and operation, will all have to be faced in the installation of special purpose machinery. Since they have each been treated at length with regard to general purpose computers, we shall only note certain factors that reduce the problems encountered with special purpose equipment.

First, the cutover will be eased by the fact that a change in only one function is involved. Of course, the cutover of a general purpose installation also is always piecemeal because of the difficulties involved, but as a result the potential power of costly equipment may be unused for a considerable period.

In operation too the problems will be reduced. The maintenance of a computer is a sizable item and over its useful life may even equal or exceed the initial cost. The use of simpler equipment may significantly reduce not only the first cost but installation and maintenance costs as well. Unnecessary complexity in a machine should not be accepted even as a gift since reliable and continuous operation is made more difficult.

Let me return now to our mathematician whose objections to the complicated policies and processing systems were so summarily dismissed. Can the full benefits of automatic machines be realized without streamlining and systematizing policies and procedures? I firmly believe they cannot and have in fact been assured by several different users that a large part of the benefits to be derived from a computer installation was attributable to the accompanying simplification of policies and procedures, and that the computer served as a tool to gain the necessary cooperation within the firm.

Special purpose equipment, then, requires more careful study in its design, but it promises to provide great economies in areas now yielding to general purpose computers and to reach other areas as well, particularly in the smaller firms. Studies should, so far as possible, be carried out either by the user or by competent consultants in order to correct the present extreme reliance on manufacturers.

It may be felt that these are matters concerning the accountant and the engineer rather than management. Perhaps so, but the purchase or rental of a computer and the subsequent cutover not only require the expenditure of large sums of money but also may necessitate considerable reorganization as well, thereby involving important decisions for management. It is essential that members of management recognize both the limitations and potentials of automatic devices so as to encourage a study of their own needs and the development of equipment to fill these needs.

CHAPTER 8

Selecting an Application for Mechanization

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LET US first tell you something of the team that is doing this information processing study, something of what has been done and then something of what we have found to be generalizations that might apply to other data processing studies.

At Mellon Institute of Industrial Research, three of us constitute the Information Processing Fellowship. Each of us has been associated with electronic digital computers on the scientific computation side for six to ten years. Two of us have done military operations research for two to three years; and Mr. Dillon, the Senior Fellow, in addition, is familiar with the problems of management from broad experience in that field. We are doing research in information processing for one of the 500 largest manufacturing firms in the United States, and more specific information on the project may be released shortly by the company. We might say here that the motivation for the entire study has come from the office of the president, a circumstance which has meant that our communications with the company have been excellent, our relations good, and our job easier.

Starting a year or so ago, a mirror image of the Fellowship was formed at the company, consisting of several men who had had about 20 years' experience with the company or other similar experience in management and accounting. It has turned out that the first year's work for the team was to study the company's operations with a view toward mechanization, to decide which areas, if any, should be mechanized, and to choose the combination of machines, that is, a complete system, best suited to the problem. The next year will be spent in preparation for the system installation with a considerably enlarged staff at the company. From this you can gather that our answer on mechanization was in the affirmative.

Incidentally, in the remainder of the report, when we use the term "mechanization" we restrict its meaning to automatic processing of data and paperwork over communications nets and on large- or medium-scale electronic digital computer-like devices. We shall probably call them computers from time to time. We shall also distinguish between *data*, which may be a list of numbers or names, and *information*, which may exist separately, or be derived, from data and is a set of facts useful to the operation of the company.

The prime purpose of the Fellowship is to discover how the information that flows into the firm continually could be used in running the business better, more effectively, or more profitably. In other words, how can such information be captured initially, processed, and subsequently presented to management so that it can decide Operations Research and management-science types of questions, for example:

1. How many salesmen should the company have?
2. How large should inventories be?
3. Where should warehouses, if any, be located?
4. In what size lots should goods be manufactured?
5. What should next year's sales and production program be?

The answers to these are actually further results and extensions of the answers to such questions as:

1. How are certain product lines selling? Are there any upward, downward, seasonal, or regional trends in the sales?
2. What is the cost, for each product, of manufacture, of distribution to the warehouses, of warehousing, transportation, and sales?

In many firms this second set of questions may possibly be answered easily – if so, such firms are very fortunate, for we have found in most cases that the data to answer such questions do not exist in readily accessible or usable form and the cost of obtaining these data manually on a daily basis is very high. Further, the problem of obtaining some historical data, say product data for a five-year period, is very costly.

In nearly every problem proposed to us — and this appears to be the general case — the data needed for its solution existed somewhere within the company, but in scattered or suppressed form. Hence, information that would be immensely valuable to management in making its decisions is so buried in the day-to-day paperwork of the firm that quite often it is very difficult to extract it. Hence we are led to consider the reduction of data to more usable information as our prime motive for introducing new clerical methods and procedures into the firm.

When we consider data processing by means of large-scale electronic digital equipment and associated devices, there appear to us to be the following possible aims:

1. To enable management to retain, or regain, control of the firm.
2. To increase over-all productivity within the company, by reducing the unit cost of a transaction or process (inclusive of clerical burden), and either in reducing the clerical effort required for the present production or in handling a larger production with the same clerical force.

These goals may be approached by achieving three more direct and immediate ones, namely:

1. To produce information sooner.
2. To produce more information from available data.
3. To process paperwork cheaper, or with less human error or bias, or combinations of these.

Let us elaborate on these immediate goals. Concerning the first point, production of information sooner, there may be, for example, considerable value to a company in having its monthly report by the second day of the month instead of the fifteenth or twentieth day. Again, better customer service and more even factory loading result from the manufacturing division's knowing today, rather than a week hence, what orders for manufacture have been placed today. Or, the knowledge that a certain product line has increased in sales volume can also help both customer service and factory loading and scheduling if known as soon as the data appear.

It is possible to extend this list (and we are sure that you have examples of your own), to illustrate that delays in processing information, both that destined for management and that for customers, are costly in terms of customer service and the firm's operation. These delays extend the pipeline between the plant's back door, where raw materials flow in, and its front door, where finished goods flow out; and each delay between the two costs the firm money. In other words, there is a real dollar value in the possession of timely information.

The same remarks are true of the second point, on the extraction of more information from the available data. The data for determining which products are showing a profit, and how much, the data to indicate whether low-price trial orders are successful and whether there are seasonal or other trends in the sales of each product, or the data to indicate how sales of each product are correlated with the activities of other industries, all are available somewhere within the firm, but to find where and to extract the data manually are immensely time-consuming and expensive.

On the third point, the processing of paperwork more cheaply or accurately, this may be possible in certain areas, difficult in others. In the present study we try to optimize the cost of getting information *versus* the increased value of the information obtained, where the value of the new information is not assessable but is known to be high. It turns out that in the areas selected mechanization will show a considerable saving over the methods presently in use. Errors in manual processing, in some areas, have been serious enough to make increased accuracy a factor in the selection of areas for mechanization, and increased accuracy is expected to result. We have some data on the number, and kinds, of errors in the present system; and they are surprisingly costly. With machine processing, we are sure we shall become acutely aware of any errors made.

There are great differences in cost among the various systems one may select. Therefore, whether or not economies in paperwork processing are sought, the choice and correct use of the components of any data processing system — the computers themselves, the peripheral equipment, and communications — must be carefully considered. We shall return to this point later.

In selecting areas for mechanization, there are two prime characteristics of large-scale digital devices that should be kept in mind. These are:

1. They work well on data that is inside them.
2. They have great difficulty in communicating with the outside world.

On the first point, that of computers doing well on internal data, we do not wish to deny that there are many improvements that must be forthcoming. Yet, since few complete data processing installations are now in operation, it is not altogether clear what these improvements ought to be, although we think we know some of them. Present data processing equipment is at most one step removed from the general purpose scientific calculator and can only be expected to be an approximation of what we want for business information processing. The available machines, however, are now in the state where they will do a reasonable job of data processing as is illustrated by the installations that show savings in doing it.

The second point, their difficulty in communication with the outside world, is very easily and frequently overlooked. The output devices have seen comparatively high technological advances, and one can now buy printers reaching the speeds of 500 to 1,000 or more lines per minute, each line having up to 120 to 130 characters. But, it must now be remembered that, particularly for the processing of business data, each and every one of these 120,000 characters printed every minute has at one time or another been inserted into the machine by a person at a keyboard. We know of no way at present that data can be inserted into any electronic data processing device other than by a human being's laboriously reading a character from a page, then pressing the corresponding key on a typewriter-like device, and later checking and rechecking to make sure that he pressed the right key.

With many operations being performed on data thus inserted and many operational and legal documents resulting therefrom, the requirements for accuracy are very high indeed, and double or triple preparation is frequently called for. This single operation of pressing typewriter keys to insert data must be done with as near absolute accuracy as is possible, yet this operation is slower by factors of hundreds and thousands than the machine's internal conversion and its output. This operation, namely, the entry of data into a system, is one whose importance and cost are easily slighted in system design.

These two characteristics of machines:

(1) their ability to work well on data within them;
(2) their difficulty in communication with the outside world,

together with the three direct reasons for applying mechanization:

(1) to obtain information faster;
(2) to obtain more information;
(3) to process paper cheaper,

determine to a large extent which areas of the company's paperwork are the best candidates for electronic data processing.

The present divisions of paperwork were developed to facilitate manual or tab card processing, but they are somewhat artificial divisions of a highly interconnected whole. What may be a good block diagram or flow chart for manual processing may not necessarily be good at all for a mechanized system, and the divisions may become altered considerably by the introduction of electronic equipment. In most cases, however, the present arrangement and flow of paperwork provide a good starting point. If one considers a typical set of clerical divisions, he will find a great number of interconnecting paths along which information and documents pass. For example, some typical divisions of clerical functions might be: customer order processing, sales analysis and forecasting, inventory control, factory loading and scheduling, payroll, billing, and accounting.

In Exhibit 1 are shown these functions and some of the interconnections between them. This is a simplified diagram that may not correspond to any company in particular but should illustrate the point. The arrows indicate the flow of information from one area to another via documents or other means. For instance, the operation of customer order processing gives information to the inventory records to adjust balances and receives information on the availability of items. Inventory control informs the manufacturing division on items that need to be manufactured for stock replenishment, as does customer order processing on non-

EXHIBIT 1.

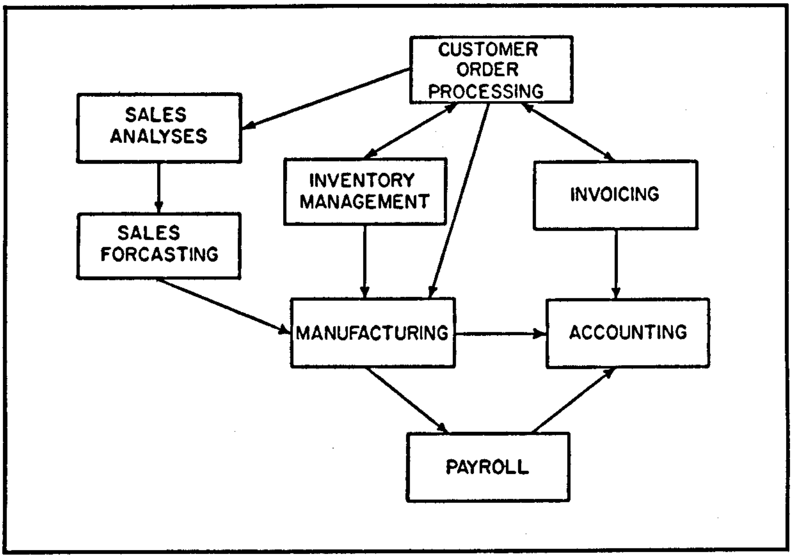
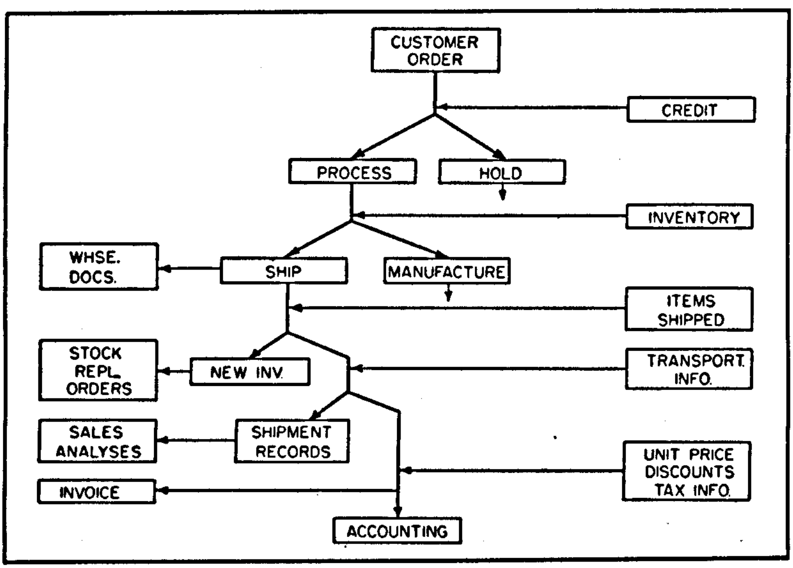


EXHIBIT 2.



stock items. Sales analysis, using data provided by customer order processing, supplies information to sales forecasting, which in turn informs and should influence factory loading and scheduling, and so on.

As soon as charting of this sort is done, several things become more obvious. For instance, if the mechanization of a single area were being considered, say inventory control, one would want to study seriously the amount of input and output data required, as well as delays encountered by preparation of these data. Again, if one were to consider two areas for mechanization, it is wise to select adjacent ones so that information may be passed between them on the machine's medium – magnetic tape, paper tape, or cards. The closer one starts to the source documents, the simpler these interconnections are.

This can be illustrated in another way by looking at the problem in slightly more detail. In Exhibit 2 is shown one of the many chains of operations that input information goes through. Again the customer's order has been taken as the source document. This particular piece of paper, or other documents prepared from it, flows downward through the paths shown and at several points along the way can subsequently go along one of two or more possible paths. For instance, the first thing that is done with our orders is to apply information from files on the credit rating of the customer – if favorable, the order is processed, if other than favorable, the order is held for further action, initiating another chain of action. For orders to be processed, inventory information on the availability of the item is then added and the decision can then be made to ship, manufacture, or, possibly a third category, back order, which is not shown here, with these last two again starting chains of this sort. If the item is to be shipped, shipping documents extract information at this point for use by the warehouse, which then adds the information that this has been accomplished. From the new aggregate of information we get the new inventory position and perhaps another document reordering that item for stock replenishment. Next, transportation information can be added from warehouse data, producing a shipment record and documents for sales analyses. Unit prices, discounts, and tax information added from files complete the information needed for invoicing, and all of this ends up in accounting, with further chains of actions following from there.

There are two things significant in a diagram such as this:

First, at each step information is added from files or elsewhere, and then one of several things happens as a result of the new total information available. The unit step in data processing is the addition of new information and a subsequent action on what is now the aggregate. This new information must be inserted by hand into any parts of the system that are mechanized or else found within files contained within the equipment. Less manual data insertion is involved in mechanizing those steps that draw on file data.

Secondly, if one were to begin the mechanization at any particular level, the further along the chain one begins, the more data have been accumulated on the document in question and the more of this tedious typing and checking must be done to insert the document into the data processing system. One should again try to begin mechanization close to the source document and include particularly those steps drawing on file data. There is a great advantage in having nearly static data in files, that is, data that need be typed and verified once and for all rather than repeatedly day after day as the orders occur.

Any such charts as these for an entire firm are greatly detailed and difficult to follow. By simplifying somewhat, the Senior Fellow found it possible to produce the chart shown in Exhibit 3 (to be found in flap on back cover). It illustrates in general all the functions that connect the customers, the stockholders, and the factory, and it is from this that we have done much of our planning about the areas to be mechanized.

It can be seen that the payroll operation at the bottom of the page and the periodic reporting and accounting at the lower right are fairly self-contained so that they can be considered independently of the complex of operations shown in the center. This chart is not divided into areas, such as customer order processing, accounting, billing, and so forth, as the previous ones were, but consists of source, file and product documents, shown with square corners, and operations performed on them, shown with rounded corners.

To find areas most fruitful for mechanization in a diagram such as this, each block should be inspected and the following questions should be asked:

1. Would it be of value to management or to the operation of the company to get more information from this operation or document?
2. Would it be of value to the company to perform this operation faster or obtain this document sooner?
3. Are the operations performed here of the sort that lend themselves to electronic data processing techniques? That is, can all decisions be made by fixed sets of rules or are the data rearranged by some logical scheme?
4. Is the amount of data that must be manually inserted small?
5. Finally, is there a large number of man-hours involved in the operation so that some real direct dollar saving may result?

Usually it is not difficult to find a set of areas to which the answer to some of these questions is "yes." These areas will generally be scattered and separated on such a diagram, and these prime candidates for mechanization will indicate some secondary ones, that is, some intervening ones that might be mechanized in order to enable whole chains of operations to be performed by the proposed equipment.

There is another case to justify mechanization in which one might also find certain complete sequences of operations wherein delays are causing difficulties or faster operation would give, say, better customer service or less scheduling difficulties. Yet in such a sequence there may be no single operation taking excessive time. In such cases one would want to consider seriously mechanization of a large portion of the sequence in order to benefit from the properties of electronic data processing devices. Since much valuable information exists within the paperwork of a firm, it is worthwhile to consider means of propagating it to the places where it will do the most good. For instance, there may be considerable gain in customer service and plant scheduling in the factory by knowing today the details of this day's or this week's sales so that the production manager can tell a week or two sooner what raw materials will be required and what must be manufactured soon.

By performing an operation faster, we do not necessarily mean that we do the addition or sorting, and so forth in a few microseconds or milliseconds – we may mean such things as knowing a few hours after the data appear when a certain item is reaching its reorder point or, if an item needs replenishment in one district, whether the other districts are close enough to their reorder points to warrant manufacture for them in the same lot.

Using Exhibit 3 in our particular study, we found that the customer order processing operation, appearing at the left, had the following characteristics: after a preliminary censoring operation, most of the operations on the order were repetitive and consistent, and they involved a great number of people. We found that information needed to get through this chain much faster and that the company as a whole could benefit more from information contained here than from any other source. We found also, and this is probably true of most firms, that almost all the operations within the company react and are controlled by that single document, namely, the customer order. This all-important document can be reduced greatly in length to, say, a 6-or 7-digit customer number, a 6-or7-digit product number and a 5-or 6-digit quantity per product. In other words, introducing a 20-digit number describing the order is necessary and sufficient to start off all the remainder of the company's activities. With a 7-digit product number and the order quantity, we can determine, for any product, whether we ought to ship from stock, back order, or manufacture. We can reduce the inventory balances and then determine whether replacement of stock is necessary. Again with the 7-digit customer number we can determine the customer credit rating, his location, his discount chain and his tax computation; and with the product number we can find the unit price and the quantity discounts. Hence we are now in a position to do the invoicing operation. From the day-to-day record of such sales we can then do sales analysis and forecast, which also lead to raw material forecast, factory loading, and so on.

In our problem we have not gone to a high degree of coding but have carried other information at the input, such at date, our order number and the customer order number, salesman credit, and so forth. Nevertheless, it is true that the input by which the whole firm's operations are geared can be a sequence of 30-or 40-

digit numbers that start and directly control so much of the firm's operations.

Exhibit 3 illustrates how easily a given mechanized operation can expand to the right or to subsequent operations (see the insert at the back of the book). This expansion always entails the addition of file or operating data, generally a small amount of the latter, the establishing of some new machine routines or programs and the printing out of data for human consumption as needed. It can also be seen that expansion to the left or to prior operations is rather difficult. One must not only establish new procedures for the operations to the left and for the operations that branch from them, but one must design new forms for input data and new machine routines and procedures as well. Again, when one is considering expansion of mechanization, it is extremely important to begin the processing as close to the source documents as possible.

In the selection of the correct computer or data-processing device, the choice is naturally intimately connected with the choice of areas to be mechanized since capabilities of particular devices vary widely. We sincerely wish that we could give you a simple and direct method for choosing the best equipment for a given firm, but we know of no way of making the choice other than detailed consideration of all present and future data processors. Many can be eliminated by early considerations, and of the few that remain one needs to consider the total cost of:

1. Equipment
   a. the communications net
   b. an on-line device (one tied to the communications net)
   c. an off-line device
   d. printers
   e. day-to-day insertion by typing or keypunching
2. Facilities
3. Personnel
   a. the preparatory operations
   b. routine operations after installation of the system

This detailed study must give costs and time estimates not only for the several different types or brands of computers available, but also for different combinations of each, such as a single large computer *versus* one small and one large *versus* several small ones. Again the evaluation must be done for many combinations of the possible jobs that the devices can do. One must then choose the combination of equipment and tasks that gives the largest saving or else determine what the representatives of the company want and what they are willing to pay for it. This evaluation must in many cases be carried to the actual detailed final programming of the problems on the machines, for serious errors can be made in making gross estimations. As an illustration, we compared in detail two computers that appeared to be nearly identical on the surface. When their compatible equipment systems were compared for the same set of tasks, one was found to cost just twice as much as the other.

Again, we made a detailed comparison of several techniques of applying a single computer to certain tasks in order processing. These techniques appeared at first to have little advantage over each other and a good programmer might pick any one of them as a first solution — yet there was a factor of ten in the extremes in the time required and hence in the cost. Needless to say, certainly a factor of ten and generally a factor of two will make the difference between financial success and failure of the project. Only the detail in the study can put one on safe ground.

Something that must be considered is the cost of introducing any mechanization project, which again will vary between possible computer systems. Our case is not unusual. There is a sizable investment of man-years in training the coders, creating tape files on customers, products, and so on, in the programming of the functions to be mechanized, and the integration of functions, if any presently mechanized, into the new system. There are also the invested changeover costs of the facilities, expenditures for design and procurement of new forms, and so on. The total cost is high, and what it has brought has zero market value; the money is completely gone and must be amortized and added to the machine running costs. Nevertheless, the cost is not economically unfeasible. Ultimately we expect to schedule about 50% of the system's capacity on day-to-day work, leaving room for the management science, Operations Research studies, and the preparation of special reports and studies. It is in these areas that we feel the real value of our research will lie.

Prorating all the small- and medium-size computers, there exist presently the equivalent of about a hundred large-scale digital calculators in scientific use in the United States. These may be considered as being between 5,000 and 20,000 times as fast as human calculators. Thus, every day many millions of man-hours of human calculation can be performed. This means that for every hour that a scientist or engineer sits at his desk there exists the capability of doing between 2 to 10 hours of hand-calculation for him. Needless to say, the same assistance does not exist for management and the clerical staff. Could they use such assistance? We think that at least some is in order, but like all new tools, automatic data processing will have to be applied and its value discovered by management and clerical staffs alike.

Discussion: Part Three

QUESTION: Dr. Alexander has been asked to amplify his statement about the cost of wire communications over long distances.

DR. ALEXANDER: The problem of transmission over long distances is much more a problem of economics than one of technology. The telephone and telegraph companies are ready, willing, and able to provide a variety of services now. They are also looking toward the specialization of their services to better fit the data processing field.

The time-honored teletyped network is available. Most of you are familiar with it in connection with your ordinary sales information. If you are in the transportation business, you are heavy users of communcation services and are quite familiar with the sizeable cost that comes with it. There has been some worry that the amount of data you can transmit is limited. This is not quite true. An ordinary teletype link will handle, I believe, up to 100 pulses a second, if you push it. There is terminal equipment to use it. (I refer to pulses in the sense of binary digits; divide such numbers roughly by four to make them equal to decimal numbers.)

Representatives of the Bell Telephone Laboratories have recently reported that their present voice telephone circuits are capable of being used up to 700 pulses a second. These representatives would be very happy to make arrangements for terminal equipments for this sort of thing. The punched card transceiver systems can be used over the telephone circuits at their full capacity. I understand that when a transceiver is connected to a teletype link they must run at reduced speed; if connected to a telephone circuit, which is a higher cost service, the full capacity of the transceiver is available. The telephone company representatives indicate that it is feasible to multiplex up to four of the punched-card transceivers simultaneously onto one standard telephone circuit.

They can provide even higher capacity circuits of the sort that are used for voice programs for broadcasting which would transmit up to 3,000 or 4,000 pulses a second. Moreover, if you wanted to rent off-hour time on some of their television co-axial links, these can be operated at higher than 50,000 pulses a second. One of the economic difficulties associated with these higher performance circuits is the limited number of people with whom to share such facilities. Therefore, there isn't a good sliding rate structure. You can't rent a few hours at a time; time is only available in scheduled intervals.

I do not know whether this is an adequate answer to your question. The Bell Laboratories people made the comment that there was still additional capacity that could be installed at any time there was the economic justification. They could easily parallel their present microwave links, which have a tremendous band width, and so be able to send a lot more data.

The Bell Laboratories people asked this interesting question: "How much of your transaction data do you want to send?" They recognize that on short hauls and for very large volumes air mail service for a dozen rolls of magnetic tape is a highly competitive service. Therefore, they offer a word of caution with respect to how much of your data is worth sending over a communication facility. This may become a question of the relative economics of the telephone system *versus* the air mail. I think the airlines ought to get busy and start planning for extra space for air cargo. They might load up their night runs with magnetic tapes from people who have this kind of requirement.

Since data delivered to the data processor has a price tag attached to it, you must decide whether you want to pay that price. In fact, if the data is on magnetic tape, there is an added consideration; there is a price tag associated with the privilege of seeing it printed out on a piece of paper. You now have to evaluate whether you want to pay that price in terms of the question: "Who is going to look at it and for what purpose?"

If you arrange a system of management by exception, you can minimize this cost. The exceptions can be flagged within the computer by a fairly straightforward standardization of procedures. In this case you begin to see that all these things interact. You are going to have to live for a while with the fact that the efficient part of the data processing system is in a world different from ours, and the cost of going into that world and back out has to be reckoned with. Maybe improved technology will minimize this consideration, but at the moment this is an operational problem that you must live with. If you keep your data in a mechanizable form, you can transmit it and store it; you can do quite a few things with it. In the final analysis, however, you must bring it back out into the real world on a piece of paper before people can deal with it.

QUESTION: In an appraisal of the relative merit of alternative machines for particular application, one approach would be to work out each system in detail and compare cost and saving under each alternative. What short cuts to this brute-force approach can you suggest?

MR. MARSHALL: I should like to refer the question back to Dr. Alexander.

But I can say this: We know of none. There may be some, but they should be viewed with caution.

DR. ALEXANDER: This state of affairs results partly from unjustified optimism in advance of experience. There have been entirely too many glamorous claims in the advertising for this field that are not going to be realized for some time to come. It happens that the relative advantage between the present method and the initial change over is not as great as has been implied in the optimistic claims. It is very easy for the results to fall to one side or the other. For this reason you have to examine quite carefully the exact balance sheet for the job.

Nobody can examine it better than the people who know the business being conducted. They can look at the procedures and make some honest estimate: "Is it reasonable in the conduct of my business to alter these procedures so that I can make the machine do a better job?" You cannot expect a man trying to sell you equipment to tell you that you are not running your business very well. He just won't. This realization must be generated from within, and you must make a very careful appraisal. This leads to a very painful thing that we have run into in government. It is that most management improvement budgets are really mighty small. They are built on the fact that for years you have been improving things by an extrapolation from what you're doing and making it a little better, an improvement that nicks 10%, 15% off. It is, I think, an acceptable return on the effort.

Take the example I gave you of the Census case in which they are now able to say, "We can do for 50¢ on the dollar." But they put a lot of manpower into learning how to do it for 50¢ on the dollar. When they gave this figure to the Congress they did not budget in what it cost to get to this point. They said that given this machinery, they could do the job; they put the only cost against the job. There were other previous expenditures on arriving at this point and these have to be actually counted in some place. This shooting for a sizeable improvement which, I think, is inherently there, needs management improvement budgets and a little courage behind this money so that the people can sit still and think long enough and hard enough to do the job right.

I think that here lies the real challenge for you people in this audience – the ability to recognize the changes you want and go after them and budget them. You do not need to have a commitment for a machine in order to get yourself going. You can rent time on machines in service bureaus; you can borrow time from various people until you know your costs by thinking down through this chain: doing the pre-programming and getting a result. It has been seriously recommended in the government that there be a prove-in facility so that you cannot come to the Bureau of the Budget for a request for machinery without having your evidence that you have proved it by going through the details. These are pretty harsh and pretty severe standards, but it is the way the thinking is going.

QUESTION: Concerning the procedure shown on the chart, if it is the present procedure, shouldn't one of the questions be, "Can't we eliminate some of the blocks?" – or if it is the proposed procedure, "How did you get it?"

MR. MARSHALL: This is the present procedure. I think that is a very good point – that what we ought to ask is a sixth question, "Can a block be eliminated entirely?" We have asked this in several cases; in fact, we asked reasons for the existence of some of the operations, and we got embarrassed answers that they did not know why some of them existed. Does that answer your question?

QUESTION: When you found out that they didn't know why, was it only that the fellow didn't know why or could you by research find out that there really was a good business reason for the procedure that you might eliminate?

MR. MARSHALL: We generally found that it was something like this: For many companies, it has been years and years since a good survey has been made on internal procedures. I do not think it is unusual in a lot of existing companies that there are policies made a long time ago that have been passed from hand to hand within the company. The policies have not recently been questioned, and the reasons for making them are not only forgotten, but no longer valid. Does that answer your question?

QUESTION: That answers half of it; did you find the other as well?

MR. MARSHALL: We did find cases where one individual would not know why a policy existed, but later found there was a good reason for it.

QUESTION: Were they pretty hard to find sometimes?

MR. MARSHALL: They were very hard to find sometimes, yes.

QUESTION: Are you familiar with this so-called *in-line data processing,* as opposed to *batch processing,* where you take the transactions as they come and do a receivable one time and a payable the next time and something else the next time? Do you have any opinion on it?

DR. IVERSON: I think, first of all, this latter process probably implies the use of very large random access storage. Certainly in some applications this is the way of getting around mismatch between the speed of your computing apparatus and the speed of your inputs and outputs. In other words, this allows you to multiplex the inputs and outputs and to program the main computer in such a way that operations will be interrupted and new operations will be instituted. The slower input and output devices can be operating simultaneously but under the control of the central computer.

DR. ALEXANDER: Would this be a special purpose device?

DR. IVERSON: Certainly it is one approach that should be investigated. Again, this comes back to what we mean by a special purpose device, but I still think the thesis holds, namely, that those who know their applications should study them with a view to applying any techniques of this kind which can be found.

QUESTION: Sometimes the applications that are easiest to put on electronic machines, or appear to be the easiest, often turn out in the long run to involve the smallest savings. Some that appear very complex and difficult to put on may, in the long run, turn out to have the greatest savings. Does your experience bear that out? Do you confirm or deny that?

MR. MARSHALL: I think my answer is only a confirmation of your second case. We did find places where very complex things did appear to be difficult to program but were not so difficult after we got into them. On the other case, we have no experience on it.

DR. ALEXANDER: May I quote a rather interesting bit of experience – you will probably think I do not know anything except what happened at the Census Bureau, since I am always quoting experience in the Bureau. They chose for operational reasons to put all their source data on punched cards and transcribe the cards. They ran a quality control check on how good the arrangement was when it was finally in the machine. Try as they would, they could not get from the original data through sorters, through the card converter, and into the machine without a reasonable number of cards out of order. This result surprised them and, incidentally, upholds their thesis that they believe that if you can just get the people out of the system, you have a better system even though it does not cost one cent less for equipment rental. This is an example of a problem that is perplexing. They could not find an efficient way, or so far they have not found an efficient way, to take an almost ordered batch of data that is very large and efficiently get it exactly ordered to the degree that a modern machine can do it. They found that if they got into regions of – I think they were struggling with 10% out of order – they might as well start over, a conclusion which rather astonishes me. I am pretty sure that this answer will change with further experience.

Here's a case of what looks like an extremely simple problem. You punch the cards, sort them on a sorter, transcribe them into the machine and that is all very easy. They had some of their best people struggling with this problem to try to make it as efficient as it ought to have been.

QUESTION: What are some of the differences in equipment between general purpose and special purpose installations? Is the distinction rather between general *versus* special application of the same basic equipment?

DR. IVERSON: This depends on what you mean by the term, "basic equipment." Certainly the same materials are used in this equipment, if you want to go that far back. As far as being different in an essential sense, certainly there are great differences. Take the automatic message accounting system, a special purpose accounting system developed by the Bell Telephone Laboratories. It is certainly completely different from the type of equipment that we have been talking about today. For one thing, it is not electronic; it uses punched tape.

It is extremely hard to draw the line here. Certainly I'm not proposing that we go out and develop something other than vacuum tubes or other than relays and so on, but I don't see why we should try to draw a line between general and special applications.

QUESTION: Might you say that the difference is that a special purpose machine simply has the program built in, instead of stored in?

DR. IVERSON: What is the distinction between "built in" and "stored in?" Is it built in wire? In spots on the magnetic drum? In punched tape? In the "stored in" and "built in" there is not a clear distinction that you can make. Certainly in a special purpose machine there would be no need to have the program easily changed. That is possibly a distinction.

QUESTION: That was not my question, but you make quite a distinction between special purpose and general purpose equipment. I think the question is, what are some of those distinctions?

DR. IVERSON: I tried to indicate some of the distinctions, simply not that it is different equipment but that it is equipment chosen for the particular application. In other words, if you can have a machine for particular application, which will do the job that you want, then you will not pay an extra 10¢ for any more speed in that piece of equipment. In some applications of general purpose machinery, the plan is made to use the machine for sorting with tapes. This operation may take up to a couple of hours of machine time. When you start to price this out, you begin to wonder how you can use an expensive machine like this for the sorting speeds that you get when you can do it more cheaply with card equipment. You ask the question, "Why not do this sorting when the information is on cards, as most incoming information is at some time or other?" The answer is, of course, that we have this machine here; that we are not using the full time on our application; and therefore that it is more convenient to do it on the machine. You can chase this thing around. With respect to any particular job that you put your finger on you can say, "Could I do this more efficiently by some other piece of equipment?" and the answer would be, "Perhaps, but we have the machine, we use the time for this." It gets very difficult to pin down exactly where the costs are assigned. If you ask this question, of course, "Which of these jobs is really paying the way?" the answer is that they all are. This is a way of saving money, but it is hardly good design.

QUESTION: One might interpret that special purpose computers are relatively inexpensive. What evidence exists to support this premise? Where do design engineers come from to design these economical, special purpose systems?

DR. IVERSON: First of all, I have cited a couple of examples where special purpose equipment is cheaper. I doubt that anyone could program one of these large-scale machines to, for example, do what the airlines reservisor does and do it cheaply enough to make it economical. Likewise, it could not be done in the automatic message accounting system.

As far as the question of where these people can come to do this job, this is, of course, one of the problems that I have mentioned. We do have to have more people prepared for this type of work. I might go back to this example cited – of the special purpose device using the magnetic cards. These people, too, had exactly the same problem – where to get the design engineers. It so happens that they had a radio and television division. So they grabbed some engineers from the television division. This does not show proper respect for the mystic art of computing, of course; but the television engineers have a few tricks of their own, and they did come up with a system.

QUESTION: Would Dr. Iverson explain a little more about the magnetic cards, which he referred to?

DR. IVERSON: I cannot give much detail, but essentially, the same type of magnetic medium is used as is used on magnetic tapes and magnetic drums. The only thing is that it is put on a card in such a way that you can have immediate access to it by picking out the particular card. In this particular application, I think that the dimensions were something like 5″ x 8″, and this is what I used as a basis. The storage density on the cards is of roughly the same order as that used on tapes, because the same limitations apply. It is on the basis of these dimensions that I estimated a quarter of a billion characters in a volume easily accessible to a single person. It is not commercially available.

I might mention, just as a sidelight here on a remark Dr. Alexander made about keeping human errors out of the system, that if the system is properly designed, human errors can be detected in much the same way as other errors. In the card application, for example, if the stock item number is punched in, it will be a trivial job to have the machine check this against the card number. I think in the examples that he was giving, namely, with respect to using punched cards and the difficulties of handling them, he has picked an example where the method used for recording the data on the cards just does not allow for self-checking coding. The punched cards with which you are familiar have a single entry for each column. There is no redundance in the coding; so I do not think that this is exactly a fair example. I see no reason why the techniques of automatic detection of error, error correction, etc., cannot be applied to those parts of the system which involve human beings.

Another example of this sort of thing is the account number. Systematic redundancy can be introduced into any type of account number, so that an incorrectly punched account number will be automatically rejected.

DR. ALEXANDER: I agree with you, with the idea of the checking scheme. But this will not catch what the trouble was. The laborer loading the cards from the ordered array into the hopper that fed the converter just let a few drop on the floor; and since he is on the kind of batch-work production rate, he simply stuffs them back in. How does any checking code discover that, except the checking code that sees they are in sequence after they are in the machine? I might say that people in the Census Bureau have a very systematic scheme of quality control in checking their work, because they know something about the answers. They have statistical quality control on their product, and they have unmistakable evidence that people who do not like their work and do not give a darn about the end product make all kinds of foolish mistakes because they do not pay attention to their business. Therefore this is something that you cannot attribute to the machine. The machine has no preferences for being at the ball game over doing what it's doing; it pays as much attention to its work as the maintenance man insures. It passes on items that are not checkable except by overall gross balances. This, I think, is very important. You find out that a mistake has been made, but it is pretty late in the day to correct for it. You can find out that a mistake has been made, but it is very difficult to correct for it, except in the Census case. Since they are working with statistics, they do not always attempt to correct inconsistencies; they can adjust for a small number of them. You can't do this in financial accounting.

PART FOUR

Case Studies of Applications

CHAPTER 9

Order Processing and Production Planning

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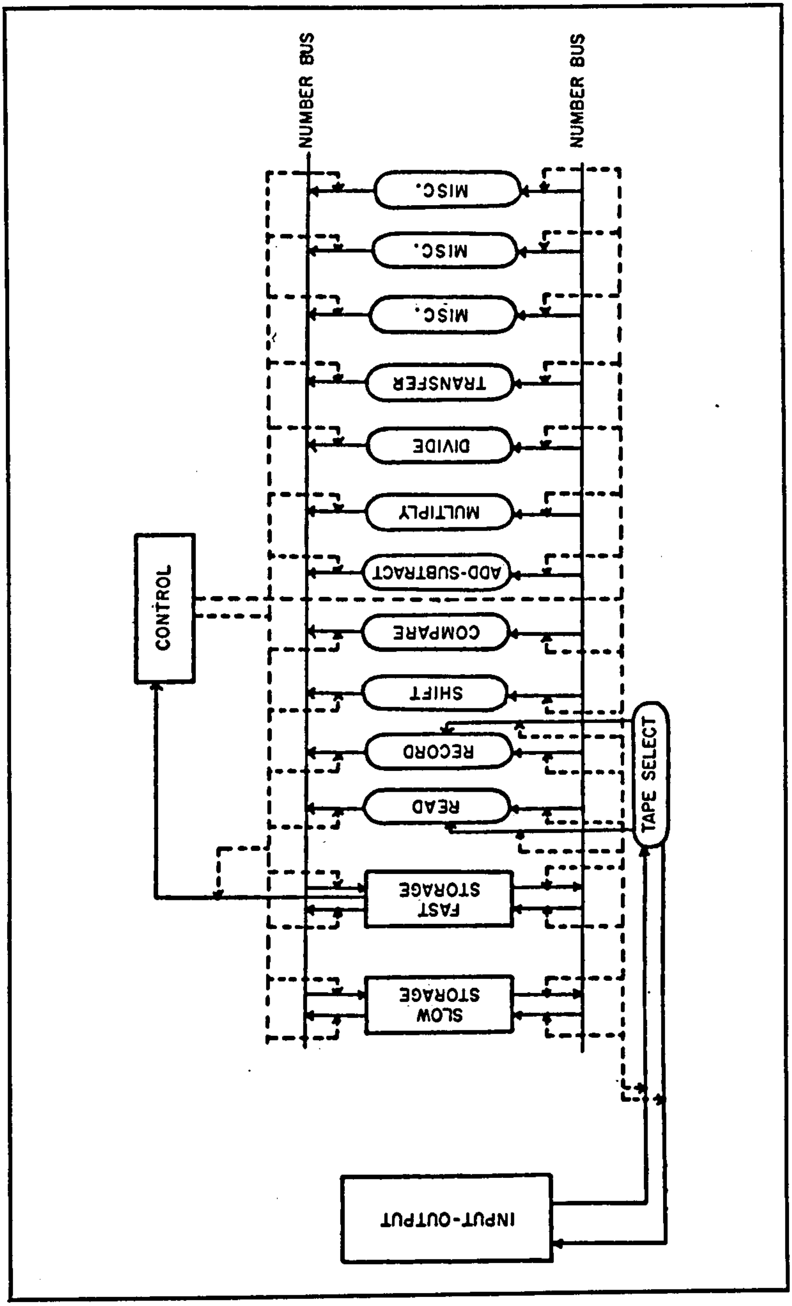
IN THE TIME allotted me this morning, I should like to discuss briefly one class of data processing equipment which has proved to be of considerable importance to business, even though it is ordinarily of special design. These are the so-called drum storage machines designed for file maintenance where high access speeds are of substantial economic importance.

Actually, such machines are only one of a group of data processing devices making use of a revolving storage medium and fixed read-record mechanisms. By the rotation of the storage medium, it is possible to reduce significantly the time required to find information selected at random from such a file. In order to accomplish this, however, higher storage costs are incurred. These added costs reflect the number of read-record mechanisms employed in the equipment and the added control circuity necessary to provide the random access feature.

Exhibit 1 illustrates the general principles employed. Each file is divided into areas and every area (or channel) has its own read-record mechanism. By random selection of channels and serial search within a channel, the average access time to filed information is reduced by roughly the number of channels on the drum. For example, if the information to be stored requires the whole of a roll of magnetic tape that can be searched from one end to another in four minutes, the average access time to any item on that tape is two minutes. On the other hand, if this same information were put on a 100-channel drum rotating at the same speed as the tape mechanism, the average access time would be roughly 1/100 of two minutes, or approximately one second.

Exhibit 1.


NUMBER BUS
NUMBER BUS
CONTROL
MISC.
MISC.
MISC.
TRANSFER
DIVIDE
MULTIPLY
ADD-SUBTRACT
COMPARE
SHIFT
RECORD
READ
TAPE SELECT
FAST STORAGE
SLOW STORAGE
INPUT-OUTPUT

These figures are intended for simple comparison purposes as far as the two media are concerned. Actual situations will differ because of variations in rotation speeds, density of information storage, time required to select the proper drum channel, and the need for including file indicators amongst the data stored on the tape – a requirement not necessary on a drum.

While such equipment has the advantage of enhanced access speeds, this speed has been obtained at higher costs of storage. Ordinarily, these higher costs are partly offset by a reduction in the storage capacity of the drum. The result is that drum storage equipment is, at present, limited to several hundred thousand words of storage. The access time to any one of these words, however, is in the order of several thousandths of a second.

The basic problems then are where the application of this type of equipment can be justified in business, why it is better than the alternatives, and what it can contribute in the way of more frequent, or more useful, information. A general answer to these questions would, I'm afraid, leave little for you to go by, and so what I have planned here today is an illustration of how one company proposes to use this equipment and the benefits it expects to derive from it.

Present Company Procedures

This particular company is a shoe manufacturer which produces and sells millions of pairs of footwear a year. In its lines there are some 18,000 different items, including width and size variables; about 30% of its footwear is severely affected by style factors. There exists a definite seasonal pattern to sales, which the company offsets by leveling the total volume of monthly production. As a consequence, inventories of finished footwear are high – averaging approximately 30% of a year's sales.

All this footwear is distributed either through company warehouses or direct from the factory to the customers. The main office therefore must handle two types of orders – one, from the warehouses; the other, from the customer. Delivery requirements on both can call for either immediate or deferred shipment. The latter type includes the majority of all orders, and the deferral period for these orders may be anywhere from two to six months.

Present company plans are to apply the proposed equipment to two areas of operation:

1. Order processing (including inventory records).
2. Production planning.

At present these two areas have manual systems, which are both expensive and slow. The management of the company does not feel any real lack of information at present but does recognize that the information it is now getting takes too much effort to compile.

All inventory records are kept in stock ledgers, and all additions and deductions from them are done by hand. Furthermore, the company now summarizes pairage on warehouse and customer order by sizes of each item, and this operation is also done by hand. For that matter, so too are all the recording of the release of stock and the writing of such releases. The record-keeping work alone now requires over fifty clerks to keep information up to date and to draw from the records the necessary data for production planning.

In its order processing the company encounters several problems other than those associated with clerical costs. In the first place, it takes about five days from the time footwear is received in the warehouse until the information on its receipt is posted to the inventory records. Because of this time lag, at the company's production rate of about 40,000 pairs of footwear a day, there are 200,000 pairs of shoes in inventory which are not known to be there.

To facilitate its releasing procedure, the company fragments each order as it comes in. By this I mean each item on an order is transferred to a separate item-order slip, which is filed by item and date of requested delivery. There are several reasons for this procedure. First of all, it facilitates the allocation of limited stocks amongst the various orders; and secondly, it permits releasing to be done by items, thereby keeping the inventory clerks from interfering with one another. The procedure, however, has several disadvantages. It tends to increase partial shipments where the order could be withheld; that is, the clerks use partial shipment as a ready solution to most problems. And, the release of merchandise by geographical location is not possible. Thus, most direct shipments to customers go by less-than-truckload lots.

In addition to the order processing operation, the company makes use of inventory and order information in its production planning. All production planning is done on a monthly basis and comes down to the question of how the company will split its monthly production budgets for each footwear line among the various items in each line. The budgets themselves are developed by top management on the basis of sales estimates by lines for each year.

In making the monthly breakdown of budgeted production among various items, top management of the company follows a policy of balancing the stock availability (i.e., present inventory plus production on order) on all items, one against another. By balancing is meant that the percentage of stock availability in excess of current orders is the same percentage of estimated sales on one item as on another. The making of this calculation requires the following information on each item:

1. Present inventory.
2. Current production on order.
3. Outstanding balance on customer order.
4. Estimated sales.

Three of these four types of information are factual and therefore derivable from the records. Present inventory reflects the current balances in the stock ledgers. Production-on-order information is maintained in a separate record where the results of each production order initiated are shown. And balance on customer order is provided by the company's keeping records of the quantity of pairage of each item ordered. Only the estimated item of sales must be planned.

The problems the company encounters in its monthly production planning, like those of order processing, stem in large measure from the fact that its present system is slow. There is now a lag of two and a half months between the time such planning starts and the time manufacturing takes place. One month of this is devoted to the preparation of information upon which the planning is actually done. With style and other influences affecting sales and production at a rate of a half million pairs a month, the ability of production planning to keep merchandise on order and inventory in balance with demand is seriously impaired.

Furthermore, there is the fact that customer demand cannot be timed; that is, the company now has no way of knowing whether a customer order calls for delivery this month or six months from now. All receive the same treatment and, as a result, production not needed for months will be planned, whereas the balance on other items may be allowed to slip to precarious levels.

Proposal

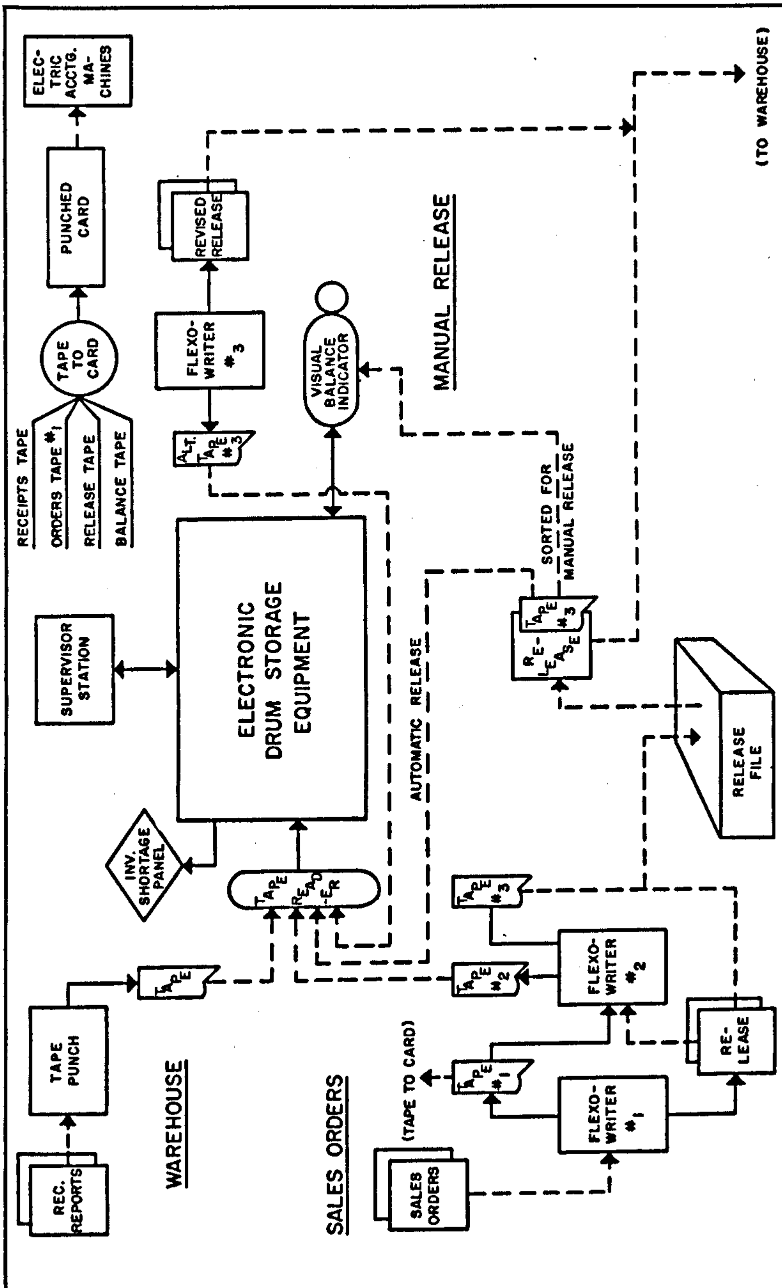
What the company now proposes is to use drum storage equipment both to speed up the processing and to reduce the costs of the current system. Only inventory and order balances would be stored on this equipment; consequently, arrangements have been made to tie the electronic equipment to electronic and electromechanical punched card equipment in order to perform the analysis work.

Exhibit 2 is a simple schematic diagram of the proposed system. It contains three elements, all of which are fully integrated:

1. Peripheral equipment both for creating tape inputs to the drum storage machines and typed copy for processing uses outside the department.
2. The drum storage equipment to carry inventory and order balances on each item.
3. Tape-to-card converter, and conventional punched card machines.

In the warehouse there will be a tape punch upon which clerks will code the stock number, size, and quantity of incoming footwear. Four times a day these tapes will be sent to the main office where they will be entered into storage and then sent to the tape-to-card converter.

On incoming orders, Flexowriters will be used, first, to create simultaneously a typed copy of the shipping releases and a tape containing all the information included on the order. Following this, a second Flexowriter will be used to verify the first tape and to create two additional ones. One of these will contain only the stock number, size, and pairage on order; the other will be the same as the first tape except that it will be cut at the end of each release.



REC. REPORTS
TAPE PUNCH
TAPE
WAREHOUSE
SALES ORDERS
SALES ORDERS
FLEXO-WRITER #1
TAPE #1
(TAPE TO CARD)
RE-LEASE
FLEXO-WRITER #2
TAPE #2
TAPE #3
INV. SHORTAGE PANEL
TAPE READER
ELECTRONIC DRUM STORAGE EQUIPMENT
SUPERVISOR STATION
AUTOMATIC RELEASE
RELEASE FILE
RE-LEASE TAPE #3
SORTED FOR MANUAL RELEASE
RECEIPTS TAPE
ORDERS TAPE #1
RELEASE TAPE
BALANCE TAPE
TAPE TO CARD
PUNCHED CARD
ELEC-TRIC ACCTG. MA-CHINES
ALT. TAPE #3
FLEXO-WRITER #3
REVISED RELEASE
VISUAL BALANCE INDICATOR
MANUAL RELEASE
(TO WAREHOUSE)

Exhibit 2.

The first tape will be sent daily to the tape-to-card converter; the second will serve as input to the drum for the order recapitulation; and the third will be filed with the release by due date and geographical location.

In the releasing operation, the order supervisor will have the task of planning the daily release. This is to be done on a geographical location basis in order to minimize less-than-truckload shipments. It should also improve customer service by eliminating delays in filling orders after they are released. Delays now occur because the warehouse accumulates these releases until it has a carload for shipment to a given destination.

In directing the release operation, the supervisor will divide the releases into two groups: those that can be handled automatically; and those that require interrogation of inventory balances before the release takes place. The question of whether or not a release should be handled automatically or by the manual procedure is to be decided by the supervisor on the basis of information on current stock balance. This balance can be obtained from a nightly run-off of inventory balances, which will be printed and available for the next day's planning.

Orders segregated for automatic release will have the release tapes detached from the typed copies of the releases, and each will be fed directly into a tape reader. The machine will deduct the balances from both inventory and outstanding order information on the drum. Since a release may be erroneously classified as automatic when there is insufficient stock on hand, provision has been made to stop tape reading at this point and signal the stock number and size of the item-size in short supply. This will be marked on the tape, and the tape will be removed from the reader. The release and tape will then be classified as a manual release.

In order that such an event does not necessitate partial shipment, the drum storage equipment has sufficient buffer storage to handle all quantities requested on a release. Actual deduction of the quantities from balances of stock and from the orders on the drum does not take place until the entire release is completed without shortage. If the release tape is removed prior to this, the drum balances remain as they were before such a release was started.

Manual releasing involves visual interrogation of inventory balances before actual release. On those items where shortages may exist, the clerk can call up present balances for all sizes of the item. A decision can then be made as to what quantity is to be released, if any, and how much will be back ordered. A new release tape and typed release copy will be created on a Flexowriter; the tape will be run against drum balances; and the release will be forwarded for shipment. Another clerk will create the back order and back order release tape, both of which will be refiled. It is the company's objective to minimize partial shipments by directing release to be withheld wherever this is possible.

In addition to accomplishing the foregoing, the equipment will produce tape output containing present balances of all items in inventory and on order by customers. This tape, together with those of warehouse receipts, releases created, and releases made, will all go through the tape-to-card converter to create the punched cards used for purpose of analysis. All the basic information needed to create the reports on stock availability *versus* outstanding customer orders is available except for data on outstanding production orders. This information will be obtained by punching cards for each order and other cards for each part of an order produced. The balance will be outstanding pairage on order by item.

In addition to the usual analysis of the excess of stock availability on each item over pairage on order, a second analysis is planned which will give both the present situation in total and broken down by months. Exhibit 3 illustrates this. Its purpose is to indicate to the production planner the urgency of current demands. This urgency he can determine from the analysis at a glance, and therefore he will not run the risk of producing to meet apparent shortages that will not actually occur for several months hence.

By mechanizing this area of data processing, the company expects to reduce the total time required in preparing statistical analyses by virtually one month. The importance of this in terms of greater ability to meet changes in demand patterns is difficult to qualify but is considered to be of tremendous importance. When coupled with the ability to see order timing, rather than just totals, this change in the limitations on production planning is conceived as being among the very first of the benefits of the new system.

Commentary

In review, it can be said that drum storage equipment offers the company some things no other system could provide. The company needs random access, and high-speed access, in order to avoid fragmenting orders and to plan a release as a whole. The quantity of possible shortages is large so that serial procedures based upon sorting encounter serious difficulties. When a shortage occurs a decision is needed at that moment as to whether a partial shipment should be made or the order withheld. If such a shipment is to be made, it may be all or part of available stock depending upon the judgment of customer or warehouse needs at that point. Frequently, partial shipments are made to the warehouses in order to keep them from carrying too much stock for the storage space they have available.

EXHIBIT 3

STOCK-ORDER STATUS REPORT

Stock No. 621	*Total*	*Jan.*	*Feb.*	*March*	*April*	*May*
Stock available	2,100	2,100	1,800	1,300	700	–
On order	2,300	300	500	600	700	200
Net	(200)*	1,800	1,300	700	–	(200)*

* Parentheses indicate negative totals.

The use of electric and electromechanical punched card equipment to perform the analyses is necessary because drum storage equipment does not have this flexibility. Most of this work involves sorting and summing, which can be done quite economically on the conventional equipment. Furthermore, these analyses may change from time to time and such changes can be handled easily where all that is involved is a change of plugboard wiring.

Finally, punched tape is used to integrate all parts of the system and to minimize the amount of manual transfer of information from one form to another – an obvious advantage in almost any situation.

CHAPTER 10

An Application to Payroll

G. M. SHEEHAN

Manager — Finance,
Home Laundry Equipment Dept.,
General Electric Company

NEXT MONTH is a significant anniversary in our pioneering effort with an electronic computer at Appliance Park. In October 1953, two years ago, the board of directors of the General Electric Company approved our request for the appropriation of approximately three-quarters of a million dollars to acquire a computer and certain peripheral equipment on a two-year rental plan. Within the following year the installation of a UNIVAC System was completed. Almost one year ago, October 1954, we began paying a portion of the hourly employees, using our UNIVAC payroll program.

I shall attempt to give you a realistic appraisal of what we have done, what we are doing, and what we hope to do in the future.

First, some background on our business as it relates to the problems of using a computer.

The Major Appliance Division at Louisville operates under a decentralized form of management. Five separate departments manufacture a complete line of major household appliances. The departments vary in size from 700 to 5,000 employees. Each department has a general manager, supported by four functional managers; a Manager of Finance, Manufacturing, Engineering and Marketing. The management of each department is completely responsible for operating at a profit. Within this organizational structure, the successful operation of our UNIVAC installation is one of my responsibilities as Manager of Finance for the Home Laundry Department. Our computer installation functions as a service bureau for all five departments.

Prior to the consolidation of the Major Appliance Division in Louisville, the five operating departments were located in various parts of the country. Because of this and their variance in size, they naturally developed somewhat different routines for such functions as payroll, material control, and so forth, all, of course, consistent with general company policy. These differences presented a challenge to establishing standardized programs for a computer. The fact that all our clients are now located at Appliance Park does eliminate communication problems resulting from various locations. With this brief background on our business, let's consider our approach to acquiring and utilizing a complete electronic computing system.

Recognizing the capabilities of electronic computers, as demonstrated in government and scientific applications, we envisioned the challenging opportunity of applying them to business applications. Our first steps were a critical analysis of the economic justification of a high-speed computer system in our business, the developing of a master plan of action, and the selecting of the proper equipment to accomplish our objectives. At the very beginning we found it necessary to cut through a maze of part fact – part fiction concepts throughout industry in regard to using electronic data processing equipment for business applications. The problem had to be attacked with an open mind. We obtained all pertinent facts by:

1. Sending selected individuals to orientation courses conducted by computer manufacturers.
2. Studying books, articles, and reports on the subject.
3. Conferring with consultant firms experienced in computer procedures and applications.
4. Meeting with computer manufacturer's business research personnel.
5. Visiting other installations to observe their actual performance.

After the facts were gathered, they were subjected to cold, hard analysis coupled with as much vision and foresight as we could bring to bear upon the problem. In addition to our own appraisal we employed an independent management consultant firm to assist us in arriving at an objective opinion as to the economic justification of an electronic computer in our business.

We got down to brass tacks immediately by concentrating first on the smallest possible areas in which savings can be equated to computer cost. For our initial study of possible business applications, we selected existing procedures having substantial amounts of clerical and routine effort. These areas were payroll, material control, order service and billing, and general and cost accounting. This approach permits completion of a survey and a decision on the possible installation of a computer within a reasonably short period of time. It stresses the consideration of existing business routines and lessens the natural pessimism concerning "blue sky" automation. The results of such a study are easily explained to members of management, who are familiar with existing procedures.

Our philosophy regarding electronic equipment may, at first glance, seem impractical. We decided to start at the top of available equipment, pricewise and capacitywise, and then, if this could not be economically justified, to work down. This approach was based upon the reasoning that long-range applications should not be overlooked in selecting equipment for initial conversion. By the acquisition of the most versatile equipment economically justifiable, growth possibilities of applications are almost unlimited.

We limited our study of equipment to complete systems – not just a computer alone. We insisted on a high speed, general purpose, alpha-numeric tape computer, and adequate input and output devices all available from one company. We needed a complete system, guaranteed to operate as a system.

Our study was also limited to equipment currently on the market, eliminating that still on the drawing board. We decided not to wait for next year's model when savings and experience could be gained by our utilizing what was actually available.

We determined that the UNIVAC system met most of our requirements and was economically justifiable on the basis of converting the four business areas surveyed: payroll, material control, order service and billing, and general and cost accounting. Our survey of business routines and evaluation of equipment was started in April 1953 and completed by the following September. As mentioned earlier, our request for the necessary funds was approved in October 1953.

Looking ahead, we saw the need for a realistic, coordinated plan of action. In addition to the four initial areas (payroll, material control, order service and billing, and general and cost accounting) we asked all managers and supervisors to review their operations and search for activities in which high-speed data processing could be helpful. We requested that they report all possible applications. We suggested that they include any areas of desired new information which heretofore may have seemed impossible to obtain, because of the sheer bulk of data manipulation, intricacies of computation, or clerical effort involved. Such new areas of information were now within the realm of possibility with a high-speed computer.

Our plan of action was specifically aimed at solving department problems. We recognized that profit-conscious executives would want initial conversions of existing business routines to prove themselves in experience before extending applications to a more complete, integrated system. Thinking ahead, we determined to program each area approved for conversion so as to permit maximum use of common input data and to permit utilizing its output data as input to other applications. In this way we are prepared to extend the integration of applications as experience dictates its feasibility.

Another basic objective of our plan of action is to minimize the number and complexity of reports. We feel that operating reports for management should emphasize conditions requiring management attention instead of reporting a sheer mass of data. Such operating reports would permit management to determine quickly and precisely where corrective action is required. The only prerequisite for carrying out this "control by exception" principle is that management provide the necessary relationships and tolerances of operating performance. The computer can be programmed accordingly.

Our plan of action also includes the concept of a data processing center. How do you cope with the natural resistance from a decentralized management to a giant electronic brain operating on a centralized basis? How do you assure those in management that you are not taking certain of their management prerogatives away from them? If the computer installation were to be effective, we had to make certain that we did not interfere with the decentralized form of management which has proven so successful in the General Electric Company. We feel that the scope of activities we have established for our data processing center is the answer. The data processing center includes all equipment and functions constituting the complete computer installation. Source documents are sent to it by each of the operating departments. Immediately after the source documents are processed, they are returned to the department together with output reports and records. The important concept here is that the data processing center is not a centralized data or record retention office. It merely processes data to serve the needs of the departments. It is strictly a service bureau.

Notwithstanding our success of minimizing this problem, the question still remains — shouldn't we have computers for each operating component? The answer to this problem will of necessity come sometime later. It will depend in part upon the ability of the manufacturer to make computers at a lower cost. But probably the greatest factor will depend upon the success of the user to develop many more worthwhile projects to utilize effectively the equipment. So much for the past.

What is our status today after almost one full year of practical experience? It has been a challenging and stimulating year. We feel justifiably proud of the progress we have made. On the other hand, it is amazing and discouraging to think of the amount of time required to do this type of work. We have learned a lot. The kind of learning that can only come from down-to-earth everyday experience. Several of our programs are operating actualities; others are in various stages of completion.

Our first major project was the development of a complete and integrated payroll system. We started paying hourly employees in October 1954. Following an established plan of conversion of departments, we are now paying approximately 8,500 hourly employees using the UNIVAC payroll system. This number represents about 95% of the job on factory employees that we originally set out to do. We expect to complete the remaining 5% by the year end. Our payroll requirements are as complex as any to be found in modern, mass production industry. Factory employees are paid generally by three basic methods; daywork, individual incentive, and group incentive. During a single pay period, any factory employee may perform work involving all three basic pay methods. As you can readily appreciate, this considerably complicates the programming of payroll for processing by a computer. In our payroll application, the computer extends the mass of time cards, piecework tickets, and group production sheets, all resulting in the computation of gross pay. In the processing from gross to net pay, the computer calculates Federal, State and Social Security taxes as well as any of the 26 different types of deductions authorized by the employee. The final output includes the paychecks, the gross pay register, the deductions and net pay register, quarterly, semiannual, annual tax reports and all necessary accounting entries and employee reports.

Developing such a program for computer processing involves a tremendous amount of meticulous work – far more than we realized in the beginning. What have been the results?

1. We proved that the job could be done.
2. We quickly found out that a number of revisions could and should be made to obtain greater efficiency and lower costs.
3. Cost savings, based on initial performances, would only approximate half of what our original studies predicted. Displacement of clerical personnel, however, appears to be reasonably close to original estimates.

Final program revisions to reduce the computer time required for each weekly payroll are to be installed within another month. With the revised program, we expect over-all payroll costs may be reduced some 10% to 15% from the cost of a manual system. Based on this anticipated savings, it will require approximately three years' operation to recover starting costs including the programming expense. Within another six months, cost comparisons can be prepared which should be significant, if not conclusive.

If we had this to do over, I think we would again start with the same project. Despite the fact that it is probably one of the most complicated projects, payroll does permit displacement of the greatest number of clerical personnel and thus helps to defray expensive starting costs. Further, it has provided an excellent basis for accumulating a lot of good experience on how to use computers.

The material control program has been operating in one of the departments for the past three months. In fact, they are satisfied with its operation to the extent that they have abandoned the old manual system. Other departments are scheduled to be converted within the next few months.

In contrast to the payroll application, the material control program produces *new* information of great value. This new information is in the form of overage and timely critical shortage reports, showing details by item. A monthly inventory analysis by class of material compares budgeted inventory with actual. Other significant indicators of performance are also produced. All operating reports emphasize the control-by-exception technique. By pointing out potential trouble areas, material control people can take corrective action before crises occur.

The manual "explosion" of production schedules in terms of new requirements for every part is a slow, cumbersome, and tedious job. With UNIVAC we can do the job in a fraction of the time. This, of course, means that we now have the ability to adjust material schedules to meet new production requirements rapidly, accurately, and efficiently. This is a "must" in our highly competitive industry. UNIVAC explodes a production schedule into terms of parts and raw material requirements for all models on the schedule, factors in stocks on hand, the lead-time and loss factor for each part, and also reports the quantity of each part and raw material that must be scheduled to meet the new requirements. UNIVAC can do all these things for a 20-week production schedule involving 30 models, 1,000 purchased parts and 350 raw material items in approximately 2 hours.

It is much too soon to judge the results of this project. Our feasibility study did not attempt to predict savings beyond the point of reduced clerical personnel. In my opinion, the greatest savings should come from lower investment in inventories. As you can appreciate, this is an intangible which is always hard to measure. If we assume a modest 10% reduction in inventories, and use current interest rates, the possible savings for our entire Louisville operation looks very attractive.

The third project in our original plan, general and cost accounting, has reached the point where the bookkeeping for two of the departments have been substantially mechanized. A trial balance of all accounts has been prepared on the machines for the past two months.

The design of new financial statements has been completed and will permit the preparation of reports on the high-speed printer. Our schedule calls for all October reports to be prepared on the new basis. In short, our objective is to issue all financial reports within the week following the close of the month. This will include a profit and loss statement, balance sheet, and expense statements for all functional areas, together with supplementary details where required. With the goal now in sight, our boys feel quite enthusiastic over the prospects of this job.

Billing, which is the fourth and last project in our initial plan, is approaching completion of the "de-bugging" stage. Conversions should start sometime this fall and be completed shortly after the first of the year.

As you might expect, we have been able to capitalize upon our experience with previous projects to the extent that our work here is much easier and more effective. Further, we have been able to design the system not only to perform the customer billing function, but also to provide input data for sales reporting, financial reports, and budget applications.

Now, let's take a look at Marketing. Here we have a report that the computer has been issuing since the first of the year. This project was not in the original plan. It has taken less than nine months to develop and program; and it promises to yield results equal to, if not greater than, any other single project.

Briefly, this report gives the status of sales and inventories, in units, for all appliances at the three levels of distribution – factory, wholesale, and retail. This information is segregated by model and by each of our six sales regions for the entire country. It also estimates unit sales for the year based on present sales volume, seasonal characteristics, and any other variables injected into the formula by our Marketing Research group. From these projections, the computer calculates the required levels of inventory and production schedules to support such a sales volume.

Approximately 75% of the information shown is historical and was previously furnished on various reports and in varying forms at later dates. The remainder, mostly related to sales projections, is new. The fact that this information is all condensed on a relatively few sheets of paper, with reference details available if required, and issued within a few days after the close of the month, provides management with information such as we have never had before.

Incidentally, it is this type of work where the presently designed computers seem to be most efficient.

Another interesting application is the preparation of budgets and operating forecasts. Preparing an annual budget and interim forecasts throughout the year by conventional methods is a staggering job. Our objective is specifically aimed at reducing this tremendous workload and providing management with more timely and realistic forecasts. Briefly, this system works as follows:

Departments furnish the data processing center with all the basic data, such as models, manufacturing costs related to various production levels, and corresponding costs in all functional areas. This information becomes a part of the basic file and is retained in the computer area.

Requests for analysis of proposed operating plans must therefore be accompanied by details, such as sales quantities, model mix, sales allowances, and any other variables or "judgment changes" from normal.

The computer can prepare a profit and loss statement for each plan of action within a very short time. To be able to pre-analyze the profit results of alternative courses of action, management is in a position to make decisions on what is ahead instead of having to rely on dusty records of past performance.

One department is preparing its annual 1956 budget using this new method. A second department is well along the way toward completing the project.

We have not attempted to evaluate the savings on this project, nor the one previously mentioned on sales, production, and inventory statistics. This is difficult, because, for the most part, it supplies information not previously available. We believe, however, that these two projects are examples where costs will not be a factor in determining their value.

We are presently completing our first application in the area of factory scheduling and machine loading for one department. In this program UNIVAC prepares schedule sheets and loading reports for machine stations. The schedule sheets are essentially the same as those prepared manually by the production control section. But the schedule sheets produced by UNIVAC are prepared more rapidly and with greater accuracy because of precise consideration of factors that heretofore have been considered more or less intuitively by the scheduler. These include, for example, manufacturing lead time, economical production quantities, and percentage loss during fabrication. The machine load reports prepared by UNIVAC are new. They have not been prepared before because of the sheer bulk of computation and clerical work involved. The machine load reports, before the start of a production schedule, show potential overloaded and underloaded machine stations. Thus, the production control section can take corrective action before the trouble occurs.

Our business research people have been working on analytical techniques, suitable for computer computation, to determine the best assignment of labor on assembly lines. In a test case, it took an experienced planner several days to re-balance one assembly line. UNIVAC re-balanced the same assembly line in a matter of minutes of computer time. More significant, the computer balance, through proper labor distribution, indicated a direct labor requirement which was somewhat less than that obtained by manual methods.

This problem illustrated an interesting by-product of studies to determine possible computer applications. We are forced to think effectively. A computer must be told exactly and precisely every operation it is to perform in a program. This demands that those who are studying a possible application must consider exactly and precisely every logical step in the program. While investigating the assembly line balancing problem in this manner, the production personnel in one of our departments were motivated to make improvements that resulted in lower costs without using UNIVAC. This application has its greatest value in being able to supply quick answers particularly when production schedules are susceptible to constantly changing rates.

Another area of application we are gradually working into is engineering. Recently, engineers in one of the departments had a design problem on a certain component part. One method of solution would have been to construct pilot models at a cost of several thousand dollars. An alternative was to establish mathematical equations representing the complex conditions and let the computer do the computation. The problem was programmed. It is estimated that the results will effect substantial savings in material costs and time. Additional engineering problems are being considered for computer application.

This, I hope, has given you a brief picture of some of the things we have done, what we are doing, and what we are planning for the future.

What Have We Learned in This One Year of Practical Computer Experience?

1. The initial overenthusiasm, which inevitably accompanies a project of this scope, can and does make the job harder.

Too many people had the impression that this was the answer to all problems. Perhaps it is, but we haven't been smart enough to develop all of them. This project is quite parallel in nature to many research projects sponsored by our Company. It takes time, patience, perseverance, and a lot of hard work.

2. Some of our original thinking has been partly confirmed in that the greatest benefits to be derived from a computer will probably consist of information impossible to obtain previously.

To develop ideas for new projects requires an educational program in order to properly acquaint management and operating personnel with the computer, its achievements, and its possibilities. This is, perhaps, one of our greatest problems. It is a very basic problem, I think, in that experience has taught us that the ideas and execution thereof must, to a large degree, be done by people in the various operating groups. It cannot be effectively done *solely* by so-called "experts" called in from a central or staff group.

3. Questions are continually asked about the design and performance characteristics of computers.

Our experience has shown that the computer is more adaptable to some projects than others. It appears, however, that our total requirements may eventually cover a rather broad field and therefore the design may be somewhat different from applications employing only a relatively few projects. Frankly, this seems to be a problem where the users are not sure of their requirements. Until more experience is obtained, progress will undoubtedly be hampered.

4. Programmers should be recruited within your own company. They should be men with above-average intelligence and experienced in the fields considered for computer applications. In short, it is easier to teach men the required computer and program

techniques than to acquaint them properly with the complex procedures and routines of modern-day industry.

We have also learned from experience such prosaic things as:

1. Applications have to be programmed so that they can be processed by the computer with a reasonable allowance for human error. For example, out of the many items of source data fed into the computer, there are bound to be some inconsistencies. For efficient utilization of the computer, programs must be designed so that such inconsistencies or errors are identified and handled as a general rule rather than as an exception. I doubt if it is possible to overemphasize the desirability of providing for convenient corrections or deletion of errors in data.

2. Some refinements which at first glance may seem desirable to include in an application may not warrant the programming and computer time required to handle them. The computer can be programmed to handle any exception to normal routines. Some exceptions, however, are so rare that the cost of programming and processing may not justify their inclusion in the application.

3. The maximum justifiable amount of flexibility for extending or integrating applications must be included in the initial programming.

4. Our experience has made clear the economies of pre-sequencing payroll input data on tabulating equipment before computer processing. Sorting is one of the least efficient operations of the computer.

5. Decentralizing keypunch and balancing functions removes certain bottlenecks and reduces errors, all essential to a smoother operation. In other words, responsibility for checking the accuracy of input data and correction of any errors must be done at the source as opposed to being done by another group in the computer section.

Albert Einstein once said, "Concepts can only acquire content when they are connected, however indirectly, with sensible experience. But no logical investigation can reveal this connection, it can only be experienced." Similarly, we feel that our down-to-earth operating experience has given form to our original concepts. Our experience has verified many of our original concepts of computer application. In other instances it has indicated that some modifications are necessary. We do not consider any of our applications to be in a static state. They are continually subjected to appraisal for improvement. As changes are warranted, they are made.

In conclusion, it is my humble opinion that computers are here to stay. We have got to increase our efforts toward understanding them and knowing how best to use the equipment. Further, we have to do more experimenting with new fields that ultimately should utilize the equipment to a greater degree and thus return greater dividends.

PART FIVE

Operations Research and Data Processing

CHAPTER 11

Operations Research—Its Relationship to Data Processing

DR. RUSSEL L. ACKOFF

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ONE CHARACTERISTIC of most conferences is that success for projects are reported in the lecture hall and failures are reported out in the corridors. In order to get a balanced program I think it is only fair that we start off with a record of at least one failure.

At a recent conference I overheard one practitioner of Operations Research tell another that he had a problem. He asked for his friend's advice. He explained that several years earlier he had been hired by his firm in order to start an O. R. activity in it. The firm's executives were very enthusiastic about O. R. They asked him to do a complete evaluation of their production system. He organized an O. R. team and went to work, and after a year and a half came out with a set of proposals that the executives greeted with considerable enthusiasm. They immediately carried out the proposals. Unfortunately, after a short time the accountants reported that production costs had increased by ten per cent. The executives of the company reconsidered, then returned to their original production system. They called the O. R. man in again, and told him that they were still enthusiastic, and that they understood that every research project had a probability of failing. The executives suggested that the Operations Researcher make a fresh start on a smaller piece of the problem. He did so, by concentrating on the scheduling of parts-production. After a year, recommendations were made, again were enthusiastically received, put into effect with the result that parts-production costs went up by five per cent. The executives again returned to their original system and gave the O. R. man a proverbial third chance, this time on a rather restricted problem of deciding what the best purchase quantities were. After six months he came up with a solution which was enthusiastically received and put into effect. This time production costs increased by three per cent. The O. R. man in the quandary then asked his friend, "If you were in my position, what would you do?" The friend answered without any hesitation, "Quit your job. The company is bad luck."

It is very likely that many of you have never heard of Operations Research. Rather than try to define it in one sentence I would like to spend a little time tracing its development as it relates to the development of industry itself. Up until the turn of this century, to a large extent industry was a one-man-managed type of operation. There was a boss who performed the production control function, the marketing function. He did the selling; he took care of the books, for the most part in his head. He had a work force in some garage, or some small plant located around the edges of the city. The tremendous developments of industry that accompanied the industrial revolution in this country brought a major change in the organization of industrial effort. We had what we call a functional division of labor: that is, the industrial concern grew so much that a single man could not any longer control all its phases. Consequently management began to be segmented along functional lines so that it was characteristic in most companies, for example, to develop a production department, a marketing department, a finance department, personnel, engineering, research and development, and so forth, with a manager put in charge of each.

Science, which had to a large extent been responsible for the development of the tools that had created the industrial revolution, naturally turned its attention to some of the resulting management problems. As a result, for example, in the field of production at least three major fields of applied science were developed in the early part of the century, mechanical engineering, chemical engineering, and more recently industrial engineering (which considers not only the machines involved in the production but also their relation to, and inter-relationship with, man). In the field of marketing, most recently marketing analysis, or market research, has become an identifiable and relatively respected profession. Applications engineering has been identified as an area in which a man can seek and attain professional competence. In the field of finance, economics even humbled itself to develop an applied branch; and, of course, the field of accounting appeared. In personnel there evolved industrial psychology, social psychology, the field of industrial relations. We could go through each one of the industrial functions and observe how science addressed itself to these new functions with the objective of providing tools to facilitate the job of this new type of management.

While modern industry was producing the production manager, the marketing manager, the personnel manager, and so on (each one of whom can be served by some kind of scientific staff function), it was also creating a whole new class of problems for the executive. This class of problems arose out of conflicts that appeared among the newly created functional departments. For example, consider the inventory problem. The finance department wants to minimize the amount of capital invested in inventory. On the other hand, the production department knows that it can effectively reduce production cost by making long runs of a small number of products. But this results in a large inventory. Furthermore, the ability to build up inventory allows the production department to stabilize its work force. Consequently, production and finance have different ideas as to how much inventory to keep. Marketing also wants a large inventory to allow for immediate delivery of every item. It wants to keep a completely flexible production department so that it may produce any item on short notice. The production department wants to have long lead times so that it can plan its operations efficiently. The task of the executive in this type of intra-organizational conflict is to mediate the conflicts that arise out of this division of management, and to do so not from the viewpoint of any one function, but from the point of view of the organization as a whole. It is only natural that specialists in this class of problems should arise. They did. The result was the development of the now thriving profession of management consultants.

Management consultants address themselves to the solution of "executive-type" problems involving the interaction of organizational components. The main things that the management consultant has to offer the executive is the experience gained from his experience with similar problems in a number of other companies. He can bring this experience to bear in other similar situations so as to help the executives in their specific situation. Over and above his experience the management consultant sells his ability to observe and his personal judgment. He is an expert on the problem, not an expert on how to go about solving it.

It was only natural that somewhere along the line the scientist should begin to look at this type of problem and say, "I wonder whether science can be used to assist the executive in making decisions of this kind." The answer was, "Yes, it could be," and gradually scientists started to explore this area, particularly in the domain of the military executive in World War II. These scientists eventually came together to discuss their common problems. They identified their endeavors as "Operation Research," and a new scientific discipline and profession was born.

A perfectly natural question to ask, in light of this very brief discussion is: "Is it true then that Operations Research can only effectively serve the executive of the company? Does it always have to be worried about the president's problem, or the executive vice president's problem?" The answer is "No," because industry has entered a third stage in the evolution of organization. Organizations grew so rapidly that, for example, the production department itself was segmented into further subcomponents. Thus, a large production department will have a manager of quality control, a purchasing manager, a shop manager, a maintenance manager, and so forth. Hence, in the production department there was developed a series of sections all of which come into conflict with one another. The maintenance section has an ideal maintenance policy, but unfortunately it interrupts work in the shop. Somewhere a balance has to be maintained between these two in order to give the best decision for the department as a whole. And so Operations Research can enter to assist a department manager where there is a conflict of functional interest within the department.

Summarizing briefly, then, three essential components in Operations Research are: First of all, scientific method is used to assist in making decisions. Secondly, the decisions studied involve the interaction of functionally distinct parts of an organization. Thirdly, Operations Research tries to get the *best* decision in terms of the interests of the organization as a whole.

Such a characterization of Operations Research always raises certain obvious questions that I should like to dispose of before we go any further. The first question that always comes up is: What are you trying to do, replace the quality control man, the marketing researcher, the industrial engineer, and so on? The answer is "No." As a matter of fact, the development of Operations Research has considerably stimulated the growth of these fields. Let me give an illustration. Suppose management comes to a quality control group and says: "We have a new product. Here is a set of specifications. We should like you to develop a sampling plan and inspection procedure which will permit us to get the quality we want in 95% of the material we ship." This is a typical statement of a quality control problem, and an Operations Researcher could not help you so long as you accept this formulation of the problem. That is "straight" quality control.

Suppose, on the other hand, this question were brought to an Operations Research group, what would the group do? Most likely the first questions this group would ask are: "Where did these specifications come from, and are they properly established? Should we have a higher or a lower quality?" Let us look at the implications of this last question. How will quality affect the marketability of this product and the price that you can get for it? To answer this, one must become deeply involved in marketing questions. Furthermore, how is the maintenance of various quality levels reflected in the cost of production? Now we are involved in production itself. What will improved quality require in terms of investment in new equipment? Now we are involved in finance. Therefore, by taking a "systems" approach a problem that was initially a simple quality control problem becomes a problem involving all the functions of a business. This is an Operations Research problem. But notice that even if this broad approach to the problem is taken, it is still necessary to select a sampling plan and to design an inspection procedure relative to some set of specifications, and so the job of industrial quality control remains. This job is by no means wiped out. Its importance is accentuated because its effect on other phases of the business has been made explicit.

The second question that management is inclined to ask after listening to this is, "What are you fellows trying to do, take over our job?" The usual response is, "No, there are always certain components of the problem that we cannot get at, and we shall always need you people around to handle those. There are always sloppy, intangible parts of the problem requiring the use of managerial judgment."

The answer is correct but it seems to me that this question is on the wrong foot. Operations Research is not going to take over management but, on the contrary, management is going to take over Operations Research.

The scientists who are involved in this class of problems today are interested in them because they represent a real challenge. They are a new class of problems for which routine approaches have not yet been developed. The scientists are gradually developing the tools which will reduce solutions of such problems to a routine. In ten or fifteen years one will be able to study these routines in handbooks and perhaps have sets of tables so that one can solve such things as production control problems by reference to them. When Operations Research has become a technology, I am relatively sure it will be required of anybody who is being trained to become a manager in industry. The tools today that are quite exciting, new, and difficult will in ten or fifteen years be a part of the kit of tools that any respectable manager will be expected to have.

If I were you, I should not worry too much about scientists coming in and taking over your job. What is going to happen, I believe, is that your successors will be required to take over our present job and our successors will move on to new management areas that represent challenges at that time. Scientists are quickly bored with repetition. As soon as their problems become repetitious, they will look for ways of handing them over to you, and then they will look for pastures that appear greener to them.

So much for a general introduction of Operations Research. I should like now to connect it with some of the problems of data processing and communication. Operations Research, as I pointed out, is essentially concerned with the decision-making process, that is, with control. A decision requires both an input and an output of information. Information is the grist on which the decision mill operates. Furthermore, once a decision is made, it must be put into action; so there must be communication out of the control point as well as into it. The procedure of taking a problem in the abstract, looking at it on paper, and coming out with a nice solution on paper does not represent a change in actual operation. Consequently, in an Operations Research project it becomes essential to consider the organization and the communication system that filters information into a control point and out of it so that decisions can be made at the right time and at the right place on the right subject.

What I should like to do is to take two specific cases and illustrate how, in the study of a control system for a decision process by Operations Research, communications and data processing considerations became central. These cases are quite different, and they illustrate, in a sense, two different types of failings of data processing and communication, both of which have to be corrected before an adequate control system can be installed in a company.

The first instance involves a machine tool manufacturer which is the largest of its type in the country. The company produces approximately fifteen different models of a large piece of equipment that range in cost from about $10,000 to $40,000. Included in these fifteen models, or approximately fifteen models, there are about 25,000 different parts. Of these 25,000 parts approximately 18,000 are made by the company itself. The problem that was tackled here was one of getting some control over the production of parts so that an optimum balance between manufacturing and inventory carrying costs could be attained.

This project had a very, very unfortunate experience at a relatively early stage. Models were developed, that is, the mathematical tools for solving the problem; and trial runs were made. The result that came out was very distressing. Although it indicated that a large potential savings was possible, it advised an increase of inventory by a factor of three. Regardless of what economic justification is given to management for tripling inventory, such a prospect is frightening, particularly to a company initially committed to a reduction of inventory. In the effort to make this outcome of the research practical, a number of questions had to be answered. I should like to concentrate on two of these in particular.

The first problem relates to the required increase in storage space. The executives were opposed to renting additional space for storing the increased inventory. Therefore, a search was started to try to find additional space inside the company. An examination of the space used for raw material inventory and parts inventory indicated that some additional space could be obtained, but not nearly enough. Consequently at this stage of the project it looked very much as though shortage of storage space might be an obstacle that could not be overcome.

The second problem that arose was this: Even if the proposed production control system went into effect, one characteristic of the operations of the shop threatened to wipe out any advantages that might come through rational control of the production process. This threat resulted from the fact that a very large percentage of the production orders going through the shop at any one time were marked "shortage." For some peculiar reason, despite what appeared to be a very adequate stock control system, certain required parts were found to be out of stock at the time they were needed for assembly. Immediately a shortage notice would be sent out, and the shop would be instructed to rush this order, thereby disrupting and interrupting planned production.

Something had to be done about these two problems. No one was quite sure what could be done. Luck, however, was with us. At about this time we were asked to give consideration to the production of parts for filling orders for replacement parts as well as parts used in assembling machines.

Since this company produced a very durable machine, the order department (which handles orders for replacement parts) had come into existence long after the company had begun operations. The machines had been out on the market for quite awhile before the replacement parts order business became large enough to justify a separate department. At the time of this study, the replacement-part business represented approximately one-fifth of the total gross sales.

Organizationally the order department had grown up as sort of a side circuit in the normal communication process. To better understand its operation let's consider first how parts production was planned. A master machine-assembly schedule was prepared monthly by an executive planning committee. This was sent to a production-planning group. The production-planning group expanded this assembly schedule into parts requirements. Clerks examined the very complete stock record system, determined which parts they would have enough of and which they would not have enough of at the time of assembly. The planning clerks took the steps necessary to initiate production or purchase of parts that were in short supply. At the proper time, the production control group issued an order to the stock room which released the necessary parts to the assembly line.

The production planning group maintained a stock record card for each part, on which the amount in stock was posted daily. Consequently, this department had fairly good information about the actual inventory situation. But the time at which a decision was made whether or not to produce or purchase more parts was considerably in advance of the time of assembly. The members of the production planning group would look at the stock card and, in view of the requirements over the period of time between the moment at which they inspected the card and the moment at which assembly would take place, they would decide whether or not the stock was adequate to carry them through this period.

Now let's look at the process for handling orders for replacement parts. The orders came into the sales department and were sent to the order department. The order department prepared releases for these parts which were sent to the stock room. The stock room collected and shipped the parts when they were available and sent an information copy of the release to the production planning group. This copy was used for posting production planning's stock record cards.

At first glance the two processes just described may seem compatible but a second look reveals a basic conflict. The production planning department, in deciding whether or not to schedule production of a part, not only has to determine what are the requirements for assembly of any given part but also has to forecast replacement part requirements over the period up to the time of assembly. They look at the past replacement requirements and may decide that stock is more than adequate to handle any replacement requirements that can be expected to occur. But frequently one or a group of customers come along in the interim and place an unusually large order for replacement parts. The order department has no idea at all what the production planning group has planned for assembly, it issues a release and the stock clerk ships the parts. If there were, say, 30 parts of a type in stock and of these only 25 were needed for assembly and normally five were more than enough to cover replacement requirements; and if a customer ordered six of them, the stock clerk might have shipped six a few days before assembly was to begin. Then if a release comes through from production planning for 25, but only 24 are in stock, a shortage exists. This shortage is created only because there is a division of control on releases from the stock room. Consequently, it was natural to suggest a centralization of releases from the stock room so that simultaneous consideration could be given to the alternatives: (1) delaying a customer on replacement parts and (2) delaying assembly and/or disrupting production putting through a shortage order. This centralization of control over stock releases was effected and resulted in considerable improvement in the shortage situation.

Another aspect of the replacement-order process attracted our attention. The stock clerk, on receipt of a list of parts that were required for replacements, would take a cart and walk around from storage bin to storage bin selecting the designated parts. He would go to the first bin, take parts from it and put them on the cart; then go to the second bin and get the required parts, and so on. Eventually he might come to a bin that did not contain the necessary number of parts. Then he would skip this one and go on to the next bin, and so on. He might find that two of the parts were out of stock. He might delay making the shipment because he knows that those two parts will be in stock shortly or because he knows the parts he has collected are of no use without those that are missing. It is a lot of trouble to take the cart back to the bins and replace the parts. Consequently, he does not unload the cart but marks it as an incomplete order and places it in a temporary storage area. When we examined this storage space, our mouths began to water. We saw a tremendous area occupied by carts with such uncompleted orders on them.

By a relatively simple change in the replacement-part processing system it was possible to eliminate the need for most of this space. The orders that are prepared by the order department are checked against the stock-record cards before release to the stock room in order to determine in advance whether or not the parts are available. If the parts are not available, the parts that are available can be reserved by proper notation on the stock-record cards. This procedure not only avoids extra handling but also removes the need for a large amount of storage space.

I have cited these two problems and their solution in order to illustrate how, in an attempt to put a scientifically based decision process into effect, it may be necessary to provide centralized control and proper processing of data to carry out that decision process. I should like now to cite briefly a second illustration quite different in character.

This illustration involves a manufacturer of motors used for marine and automotive purposes. The company involved has grown very rapidly over the past few years. It has grown at such a rate that its organizational development has not been able to keep pace with its increased production and marketing activities. The executives of the company began to get alarmed at some rather incredible statistics that appeared. The first statistic indicated that considerably more than half of the motors coming off the assembly line were incomplete because of lack of parts. These motors were sent into temporary storage where they were retained until the parts became available. The assembly was subsequently completed on each machine individually at an extremely high cost. Furthermore, the amount of time required to fill an order was increasing at such a rate that their competitive position was seriously threatened since they could not truthfully promise the speediness in delivery that they had been able to promise several years earlier.

They examined the situation and decided that the main difficulty was the frequent occurrence of part-shortages. The parts were not at the assembly line at the right time; for if they had been, then this large percentage of motors would not come off the assembly line uncompleted.

An Operations Research group therefore was asked to develop a system for controlling the production of parts and for making sure the required parts were at the assembly line at the right time. Production-quantity-decision rules were developed by the Operations Research team. But in the process of developing them a "little" fact appeared which was rather disconcerting. In the use of any decision rule controlling the number of parts produced, one of the required items of information is the number of units that are in stock at the time of the decision. This information was kept on stock-record cards. The process of posting these cards was carefully examined. It was learned that the average period of time between a withdrawal of stock and the posting on the stock record card was *forty days.* Obviously, the use of any sophisticated production decision rule applied to stock data forty days old is seriously handicapped. Consequently, a new data processing system had to be developed that would provide information at least no more than a day old with respect to the current status of inventories.

Another important fact appeared. In general, the lead time required from the time an order came in until the time the motor left the factory was approximately 30 days. We found that more than 75% of this time was occupied by paper processing and that normally the shop was not notified about the order until approximately five days before actual shipment was to be made. This apportionment of time seemed to be out of balance; so we did some investigating of the processing of the orders. We learned that, of the total time being spent in the processing of paper, only 11 hours of actual work was required. During the rest of the time the papers in process were waiting on desks or in transit between departments. Furthermore, we found considerable duplications of functions and in some instances a division of a single function among different departments. A new organization of the process was developed which will reduce the amount of time required to approximately five and a half days. Such a reduction of time in paper processing allows enough time so that, even if there were not an improved decision process, the parts found to be short have a better chance of being produced before assembly begins. This organizational and data processing improvement, combined with the new decision rule, is going to give the company an extremely condensed lead-time period with a considerable increase in the number of machines coming off in a completed state.

You may be interested in the fact that the system installed involves the use of an IBM 650. When the installation is completed, this computer will process approximately 30,000 parts. Not only does the machine keep the stock records but it uses a decision rule worked out by the Operations Research team to decide how many of each part to produce or purchase and when. The reorder point (at which inventory should be replenished) is on the stock record card, as well as the reorder quantity. The computer will sort through the cards daily and pull out those that require replenishment. It will then print a schedule for the production and purchasing departments, informing them on what parts are to be produced or purchased.

In conclusion I should just like to refer briefly to several observations that we have made in examining the data processing systems from the point of view of the decision-making as opposed to the actual processing of data itself. Today, it seems that most managers consider that they have two alternatives: "We continue as we have been with some improved data processing accomplished perhaps through systems and procedures analysis, or we get automatic data processing equipment." It is hardly an exaggeration to say that some companies have become excited and, before thoroughly studying the situation, have gone out and bought a Univac or one of the IBM 700 series. After they finished clapping their hands and jumping with joy, they must decide what to do with it. This represents one attitude. The other is that "The damn thing is too expensive. It's only a fad. Let's stick to our hand methods."

There is a third alternative that has all too frequently been overlooked. If there is a large amount of data to be handled, there are two ways of accelerating its processing. One is by doing it faster, and this is what the computing machine will do for you. The second way is by handling only a selected portion of the data. But, you say, "If we handle fewer data, we cannot get the desired accuracy." Well, if I may use an esoteric term, that is sheer *bunk*! We have a tool called "probability sampling," which in many instances can introduce economies in the processing of data by reducing its volume and can yield all the accuracy required and frequently more accuracy than that obtained by handling every piece of data. This may sound incredible. I should like to cite some examples.

As you may know, every ten years a census of the United States is taken in which presumably certain characteristics of every person are determined. The Census Bureau's current policy is to estimate the accuracy of this "complete count," of population characteristics. This sounds interesting, doesn't it? How does one check a complete count? One obvious way is by repeating it. But the Bureau of Census has a much more efficient way. In 1950 it conducted a sample census called "a post-enumeration survey," which consisted of a sample of approximately one out of every two thousand people. This sample census was used to estimate the error of the complete census.

You may say, then, "This may be true for the Census Bureau, but what about industry?" Several years ago we worked with the

Chesapeake and Ohio railroad on the development of a method for dividing revenues between railroads for less-than-carload shipments carried by more than one railroad. A sampling plan was developed that involved examining an eight to ten per cent sample of the waybills. There was no doubt that a considerable amount of money and clerical work was saved by this process, but some railroad accounting departments said, "We cannot as a matter of principle, accept any solution that gives inaccurate results, no matter how small the errors involved." They felt that this was in some sense a degradation of their art. It became necessary to conduct an experiment in order to convince them to the contrary. The experiment, which was conducted, went as follows:

Their normal procedure of taking each waybill into account by the use of an automatic data processing equipment was run separately by three different computing agencies. Each yielded a different division of revenue. At the same time, at considerably less time and cost, estimates of the settlement were made on the basis of an eight per cent sample done by the sampling procedure that was developed. Finally, the control group separately went through the process at a considerable cost to come out with what was known or believed to be a very high degree of certainty, the correct answer. The results of this experiment show that the error in an eight per cent sample was only a fraction of that of a complete count made with the help of automatic data processing equipment. Why? The reason is not that the machine made mistakes but that people who were performing input operations were making mistakes in such things as card punching despite an editing procedure. We simply confuse and delude ourselves if we think that a complete count or the treatment of every piece of data necessarily yields completely accurate information.

You are likely to get the impression when listening to stories of successes with data processing equipment that success is easy to obtain. It is not. I do not know of a single successful computer installation that has not required considerable analysis of the decision process and decision rules. None of these things are obvious. There was a college professor of mathematics whose office was immediately behind his classroom. There was a door to his office beside the podium and blackboard. He was lecturing one day on the subject of analytical geometry and was going through a proof of a theorem. He would write down a step and say, "This is so because of Definition I and Axiom 2." He came to one step and said that the reason for this was obvious. He went on to the next step and was halfway through when he stopped. He looked at the board, reflected, turned to the class and said, "Excuse me." He walked back into his office. He came back several moments later, turned to the class and said, "I was right, that step was obvious."

CHAPTER 12

What to Expect From Operations Research

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WHILE we were waiting for this meeting to start, Dr. Ackoff and I were having a little side conversation as to the fact, as he said, that he was going to give an introduction to my talk. I think the actual situation is in the reverse in that this would be an introduction to his as it turns out, and so without further ado I shall now get to the introduction to Dr. Ackoff's talk.

The principal purpose of this talk is to discuss relationships between this kind of work and the accounting and financial work in particular, and to try to illustrate what some of the kinship between the two is and how the one is an aid to the other. I think this is pertinent, as many deep-thinking controllers and financial men today are giving basic thought to the evolution and development of Operations Research & Synthesis. It is evident from reading the professional literature in the financial and accounting fields that attention is being given by these thoughtful people to (1) the nature of such work and its place in a business organization structure and (2) its relationship with the fundamental work of the financial, treasury, and accounting function in a business.

The opportunity to speak to you today about a basis for organizing and managing Operations Research & Synthesis work is confirmation of this interest. In order to discuss the organizing and managing of Operations Research & Synthesis work, it seems essential first to "Net" down, in part at least, what it does and what its relations with other functional components in a business organization are likely to be. In other words, it is essential to describe the uniqueness of its contribution to the whole business and how this contribution ties in with those of other areas in the business.

Since you gentlemen are either financial and accounting executives or professional people, it seems appropriate to discuss the contribution and relationship of Operations Research & Synthesis to the accounting function.

Accounting people have normally been considered the custodians of, and experts in, the generation of information pertinent to business operations. For this reason the contributions and relationship of Operations Research & Synthesis to other areas of business can perhaps best be described for our purposes by considering its information characteristics rather than by attempting to establish bond with any of the specific functional activities of a business.

There is a basic understanding of information which motivates the Operations Research & Synthesis Worker and also the forward-thinking financial and accounting man when he addresses himself to accounting information, which is parallel, if not indeed the same. This understanding stems from the knowledge derived from data properly set in order and classified in accordance with some accepted and understood structure or model of, or hypothesis about, the real situation. For example, the accounting structure is superior in its information content to unorganized aggregates of data, incompletely defined lore, or vague verbal generalizations.

Perhaps there is at least one more area of understanding. This second area of understanding, while not basic to how pertinent information is developed, is nevertheless fundamental in respect to the operation of a business.

It is the realization *out of experience* perhaps that because of the intrinsically dynamic nature of business, it requires constant attention. As the nature of business problems, the technology applied within a business, and the organization structure of a business change, there is a concomitant need to modify, to change, and even to augment factual information so as to keep it in most useful form for both managers and specialists.

The Basis for Developing Orderly Information

In spite of this knowledge, the accountant may frequently be unable to provide maximum help in supplying information required, simply because he has not been adequately informed as to the exact nature of the problems on which a manager may feel a need for better information, on the one hand, or of the units or standards against which measurements should be made, on the other hand. This kind of situation may be particularly likely to arise where the measuring might best be done in physical rather than in dollar units.

In other words, getting appropriate information is a two-way proposition. The expected recipient must be able to describe or visualize his situation in as much detail and with as much precision as he expects from the information to be received. To form a basis for information, difficulty is likely to be encountered in those areas where there is no organized structure, model, or hypothesis concerning the situation comparable, let us say, to the widely accepted accounting structure in its field. If the visualization of the problem or situations is not sufficiently complete to describe the kind of information or the kind of measurements required to give a consistent and continuing picture of the whole situation and what may be going on within it, then it is not possible to organize for, and provide, appropriate information.

To men such as yourselves, this may sound like a truism. If it does, there undoubtedly exists a corresponding realization that its implementation in a modern business is at least a difficult and time-consuming job; more often than not, it is one that goes beyond the skills and methods usually available to us.

As responsible managers within a business, all of us are confronted with the continuing problem of spelling out the exact nature of a situation in which we need information in terms of (1) the objectives to be accomplished; (2) the assumptions underlying and forming the basis of the objectives; and (3) the system, plan, or organization in use to meet these objectives, i.e., the model of a situation; (4) the basic interactions within the system that govern its operations and their expected behavior; and (5) the channels of communication within the system through which those persons who operate the system are informed.

In addition, to complete this visualization, it is also desirable to have ideas about how the system is supposed to perform, how it might best perform under stated circumstances or ideal circumstances. This is the kind of visualization that provides a basis for establishing units or standards of measurement.

If I may inject a point here, I think this was the point that Dr. Ackoff was making when he tried to draw the distinction between procedures work, if you will, and Operations Research work, in answer to your question from the floor. Yet, such definition describes only the situation as it exists and, as such, can provide only a basis for information within the system. As responsible business managers, we know only too well that business conditions change and with them the objectives and means by which such objectives are realized. As a consequence, the visualization should, in addition, contain ideas concerning the soundness of the assumptions themselves upon which the system is founded so that a basis will be available for determining the adequacy of the system itself as business conditions shift or change.

Without this visualization we are literally caught in our effort to move up, not only on the problem of adequate and appropriate information, but on the more general problem of managing with continued crispness and assurance.

Illustrative Examples

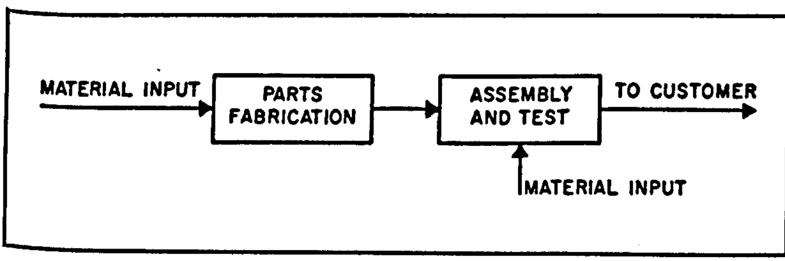
It might be well to pause for a moment and, in part, illustrate these observations with some examples.

Relation of Objective and System to the Character of Information

Mention has been made of the relationship existing between objectives, the plan "in place" for meeting objectives, as for example, the arrangement, organization, and the flow of materials through a manufacturing facility and pertinent information.

The case in point concerns such a manufacturing facility for large custom-built apparatus. It will be considered here only in the barest outline. For good and sufficient reasons this facility was organized into two components—(1) parts fabrication and (2) assembly and test, each with its own subfunctional manager. As is illustrated in Exhibit 1, the basic flow of materials was from parts

EXHIBIT 1. BASIC FLOW OF MATERIALS



fabrication to assembly and test with some flow direct from vendors and suppliers into the assembly and test component.

In order that this illustration will not appear too simple, stripped to the bare outline, it is only fair to observe that in each component, parts fabrication and assembly and test, there existed subcomponents feeding, in some instances, into each other and in other instances into main components.

The basic problem was to supply information that would permit the managers to keep these two main components in synchronism with each other. They had available to them the traditional measures of performance, such as, realization of direct labor budget, realization of manufacturing cost budget, — valuable for other purposes but little help in matching the flow of work through the two components.

They had available other information that was thought at one time or another to be the key to this situation, ranging from the pounds of chips generated per each square foot of floor space to individual machine-utilization figures; it was felt that this information might be a key to this situation. Needless to say, this growing volume of data was generated at considerable expense and effort by the accounting function in this business at the request of these managers. Yet none of these data gave a unified picture of the operation that could be used to take action for the purpose of matching and synchronizing operations.

The solution to this problem came only after a total objective for both components was defined. This objective, in respect to synchronizing, was simply that both components had as their purpose getting completed apparatus to the customers in accordance with the assembly schedule.

This objective made clear then that, for the purpose of synchronizing, all measurements and all information must be geared to the assembly schedule and the supporting parts and subassembly schedules.

This led to the next step of determining rational criteria for measurement in respect to this objective. Since this was a problem of interrelation of subschedules, time cycles, and similar characteristics, it was essential also to define the system in place and its inner workings.

A group of rather knotty problems in logic developed as a consequence. For example, being a custom building operation, there were at any one time three complete schedules in the shop, namely, (1) a current schedule, (2) the accumulated misses from previous schedules, (3) a future schedule against which materials were being marshaled. Since the time cycle for manufacturing the product was of the order of three months, the situation was further complicated by the fact that a current assembly schedule might well be for parts made three months before. This situation illustrates at least several interesting points.

(1) The need to establish priorities with respect to these time schedules, or better, a basis for establishing priorities, for example: Should the schedule of misses be completed first? Should this have the highest priority? Should work on a current schedule be first regardless of previous misses? Let us take another aspect of this. If a given schedule, let us say, consists of 10 jobs of difference in value, is 90% realization obtained when 9 jobs have been completed on time, or when 90% of all 10 jobs are completed? These are real problems, but they have to be solved and are solved. If they are not solved by or for the management of the business from its point of view, they are solved individually by each foreman or production clerk from his own view according to the extent of his experience and influence. The aggregate of such divergent and limited solutions may well be the reason for large in-process inventory accumulation, as well as inadequate production performance. There is always a price to be paid for the inadequacy of the solution to the total problem. This is the price the manager pays for either ignoring the problem or letting someone else with a more limited visualization of the problem solve it for his own purposes and from his own viewpoint.

What is instructive here is the need, then, for cooperative work by managers and, in this case, Operations Research & Synthesis Workers, in establishing a set of values that would make such priorities possible. In organizing for Operations Research & Synthesis work, an understanding — of this need for cooperative effort between responsible managers and Operations Research & Synthesis Professional Workers for the purpose of establishing value judgments or determining risks that can be taken — is always present.

(2) The second point is the need to understand the system — in this case as I have shown in a simplified diagram here (Exhibit 1) its time cycles and time spans, the degree of independence

of the various sub-functional areas, that is, in order to know in detail which items and which operations were critical to synchronizing. (3) Third, there is the fact that many conventional measures are inadequate. For example, 100% realization on direct labor is possible without realizing any of the three schedules mentioned earlier. It is possible to pick selectively from all three and meet the labor requirement, but not the schedule requirement as any of you know who have had experience with foremen. In other words, for the objective on hand, namely, getting goods out the back door on time, measurement of direct labor is not a primary indicator of performance.

This example could be carried forward into substantial details of high technical content, for there is much basis for this. But since its purpose is only to illustrate the need to relate information to objectives and the system "in place" and to understand both in quantitative detail, it will be terminated at this point.

What Is Meant by a Visualization of a Situation: The Accounting Model

The second example is concerned with what is meant by the visualization of a situation – how detailed it needs to be – how well it needs to be understood and how close to reality it should be. For this purpose, it seems that the general accounting system, or hypothesis of a business, is an excellent and well-known example, even though it is sometimes mistaken for the real situation itself. It illustrates in terms we all know from experience the degree of detail, exactness, and understanding that may be required of a visualization of a situation and the kind and accuracy of information that can be obtained through such visualization – in this case, an entire business operation.

The accounting model is designed to demonstrate the performance of an operation in place in terms of money. It assumes that the prime objective of the operation is not in satisfying customers, not in meeting production schedules, not in stabilizing wages, but in making a profit now. On the basis of certain assumptions, it establishes categories of outputs also measurable. In its way it demonstrates periodically the flow of the process through the operation in terms of dollars by stating values of inventory, receivables, accumulative costs, sales, and other related factors. It is based on certain assumptions, namely: (1) that the dollar is a natural and stable unit of measure of business operation; (2) that matching current billing against current cost gives a reasonable measure of the profitability and soundness of an operation for most current purposes; (3) that monthly and yearly measurement periods are the natural cyclic intervals in which to measure performance; (4) that this type of general model applies to practically all types of businesses with relatively little modification; (5) that this model should be suitable for all situations with little or no modification and (6) that the model will be suitable for all times. It is a model from which alternative decisions may be derived, and of this there are abundant examples. It is also a model on which limited prediction can be based, particularly if the periodic readings from the model are adapted purposefully to establishing trends. All in all, it is an excellent, rational model of a business operation, sufficiently valid to meet the test of practicality for a wide range of managerial and financial situations for which it is designed. It is excellent in the respect that it also encompasses a view of the whole operation as well.

Despite its excellences, this accounting method is limited too since it does not describe, for example, the principles of flow or process applying to the manufacturing operation in such a manner that they can be used to govern that flow process. This is true because of its intended orientation toward financial objectives and because it is by design a system of measurement based upon units of money and arbitrarily selected periods of time.

This model is an example of a well thought-out visualization of a business operation or problem. We all know too the excellent basis it establishes for the accumulation of some kinds of information, and also how badly it fails us when it is used as a basis for information outside its intended scope and purpose.

What is needed then to simplify the work of preparing appropriate information is comparable visualizations, different in form and content, of the operations or problems of a business as a whole.

Relation of Operations Research & Synthesis Work to the Requirement for Orderly Information.

I believe it can be seen from a reading of the literature on Operation Research & Synthesis and also from the remarks that have just been made by Dr. Ackoff that the concept of the work and contribution of Operation Research & Synthesis has, as one of its aims, such visualization of the basic problems of a business, a functional component within a business or a multifunctional area within a business. A further aim of such work, moreover, is to develop visualization with at least the same completeness as does the accounting model of the business for the purpose for which it was devised or evolved. To move beyond this where possible through the use, for example, of mathematical methods to appraising performance under predetermined or ideal conditions so that standards of measurement and information for comparison may be established with (1) the best possible, or (2) what had been expected.

The question may naturally arise as to how it is possible to do such purposeful work. Its origins go back perhaps as far as Frederick W. Taylor's disclosure of some seventy years ago that it was possible to apply the methods of empirical science to work situations within a business. The results of this long history of contribution by many people is summed up in three important developments. These three developments are:

Managing: A Result of Rational Action

The first is a seemingly simple insight that managing a business is not just the result of feel, intuition, or experience that results in inspired decisions that the executive himself cannot explain but that it is, to a very significant extent, the result of rational action. In other words, even though the business executive may view a market or any other situation as uncertain or fleeting or not completely known, when he decides to take action for whatever cause, he proceeds on a rational basis.

By this is meant that the manager focuses on specific objectives—be they the reducing of price levels, changing of production schedules, or expanding facilities. He bases his thinking on assumptions regarding the environment and the resources available. He appraises risks and weighs them against obtainable benefits. He attempts to identify alternative courses of action and selects one of them that to him seems to offer the most favorable balance among effort, risk, and likely result. He has expectations regarding the outcome of the course of action chosen, and these expectations establish a basis for measuring results, for revising, and for changing the revision made if circumstances change or if the results prove the decisions inappropriate.

A manager may know how to guess or play hunches with respect to every one of these elements. In fact, there may always be a degree of uncertainty or irreducible ignorance in making decisions. Nevertheless, if he reasons in this manner and is not acting on inspiration it should be feasible to bring to the notions about the nature of the business, the market resources, and the effect of action, more precision and significant detail through systematic study of each – not merely when decision is to be reached, but on a continuing basis.

The Patterns of Order in Business

The second development is that systematic study of these elements in a number of business situations has already brought to light a basic and significant orderliness in an increasing and expanding range of business phenomena. In other words, business and economic life are not entirely haphazard, as many of us would like to believe. On the contrary, basic patterns of order underlie many business phenomena.

It must be admitted that we are not dealing with immutable patterns of order, such as are disclosed by scientific research in the physical world, but with dynamic and shifting patterns. It is significant to note, however, that these patterns do have reasonable life span and hence may be utilized for the attainment of economic or social purposes.

Although the idea of rational action may come readily to the experienced business executive, the notion of a basic orderliness of some life span for business phenomena may be more difficult to accept. Yet we admit this orderliness, even though we may not describe it. When we build a new plant, we expect the basic requirements will remain sufficiently unchanged to permit payoff in from five to twenty years. We redesign our products, and we retool with the same expectancy of a basic orderliness of sufficient duration to assume payoff. We expect the ultimate in this respect when we go to automation. Similarly, we promote people on the basis of past experience and performance, presuming in this instance too that what has happened in the past has significant validity for the future. Perhaps we do instinctively recognize these patterns of order without being too aware of them. What is important is that we not only develop awareness but also give them definition both with respect to their content and with respect to how dynamic or how shifting they are in terms of the basic processes of our particular business. With such knowledge, we can plan and decide with greater assurance for both present and future.

The discovery of patterns and relationships already covers a great range of situations for a particular business. An examination of the literature will disclose an investigation of such things as the relation of cost and volume, volume and price, machine failure and volume, profitability and product mix, to mention a few. Here again, the objective is crisp and understandable description that can be communicated – not just a feel or a sense for a situation resting on the judgment of a single individual.

One senses a close kinship between these kinds of relationships and the characteristics and properties of materials and mechanisms familiar to the physical scientist and the engineer. They should permit the executive and his organization to understand the situation more clearly and from a common point of view so that they may maximize or balance among elements for optimal performance as situations arise.

The Applicability of Scientific Method

The third development is, of course, the growing recognition of the applicability of methods of investigation taken from the physical sciences, from mathematics, and logic. This makes it possible to define and describe business phenomena and managerial problems in simple and often in quantitative form. This latter development, in turn, makes possible systematic analysis of situations, intelligent anticipation of consequences through the synthesis of hypotheses or models of situations, a high degree of measurability and also of communicability.

It is these three developments that are of significance and must be grasped by the business executive who wishes to understand or apply Operations Research & Synthesis. Operations Research & Synthesis is founded on them and is informed by them. It is not a fire-fighting procedure, a means for solving spot problems or a collection of canned methods. It is analogous in an important sense to physical research, as conducted in industrial laboratories, in its processes, methods, and outlook. Without the increase in evidence and recognition of these three developments Operations Research & Synthesis would not be possible at all.

The Intent of Operations Research & Synthesis Work

On the basis of these developments it is the intent of Operations Research & Synthesis work to develop knowledge that makes it possible to visualize more definitely problems or situations within a business. This fundamental approach, resting on the understanding of the importance of patterns and structure for purposes of visualization, is applicable in all functions of the business. As was mentioned earlier, this understanding has been used, for example, in the accounting function historically. One of the types of models or hypotheses of the business for planning and measuring which is both commonly available and useful for a wide range of purposes besides sheer corporate recording, is often in the accounting structure itself. Consequently, as work of Operations Research & Synthesis develops so that better visualization is available of a business, of its products, and of the standards by which it may be planned, organized, integrated, and measured, the fundamental basis for more constructive, useful, productive, and less frustrating work in all of the other functions will be set up for the men in all of the present primary functional areas of work and very particularly for the forward-looking people in accounting and financial work.

The gist of it is, therefore, that Operations Research & Synthesis work properly conceived has the positive objective of filling a gap in the present work structure of most businesses, as Dr. Ackoff was pointing out earlier with his chart. It aims at doing work for the complex businesses of the future, with their technology becoming more intricate in all functions on a definite, systematic, and organized basis. This work will be done by personnel work which has heretofore either not been done at all or done only on a somewhat instinctive and usually unsystematic basis by occasionally gifted individuals and managers of the business.

On the one hand, providing for and performing such new kind of work will therefore be a primary step to urgently needed work simplification for the general and functional managers of a business. On the other hand, Operations Research & Synthesis can make available a more solid conceptual base for managing and conducting the work in all of the present primary functional components — especially so in the financial and accounting field.

The importance, therefore, of early and full understanding of the objectives and beneficial contributions made feasible by establishing from adequately conceived and competently staffed Operations Research & Synthesis components in place is doubly great, I feel, for men in financial work. As indicated above, Operations Research & Synthesis can provide the key both to removing many frustrations that — by either failing to face problems before them at all or by not stating them adequately or accurately enough to make helpful reactions possible — are limiting the opportunity and effectiveness of accountants today. The work of Operations Research may also be the key to open the door for an enlarged and more comprehensive scope of work in the financial function.

And incidentally, since accounting people have normally been the historic custodians and experts in the use of needed pooled office and accounting data and of statistical processing equipment, it would logically result that their work in these fields would be similarly enlarged and expanded.

As many informed people think — for example, Dr. Cuthbert Hurd of IBM as he stated in his recent article on computing and management science in the January 1955 issue of *Management Science*, the computers of the future will tend to blend many of the separate characteristics of the analogue and digital computers of today. It may become necessary to view such equipment as more than large-scale, pre-program desk calculators to which today's business procedures of an arithmetic nature may be applied. Certainly, to utilize the analogue characteristics at least to the fullest extent, we require the same visualization of problems or situations that has already been mentioned. It will be necessary to come to view the problem or situation to be so handled as models or systems representing reality, and these are the analogues to which he refers.

The result could be the broadening and extension of the use of such equipment through better visualization of the business operation. The consequent need to keep abreast of such equipment development from the standpoint of application, installation, and operation will itself be a growing and significant area of new work, provided that there are developed the parallel insights and knowledge for making such equipment helpful.

To recapitulate, the general manager, and the functional manager of business in the future, clearly must find ways to cope with certain fundamental problems of a business – such as defining its goals, anticipating the trends and climate that will affect them, knowing more about how the business really works, and stating their plans more rigorously as an indispensable requisite to the simplifying of their own work – to make it do-able. Such a program, in turn, calls for the performance of functional work that has not been done – at least on an organized basis at all before. And hence it will require (when this realization comes) for each particular business understanding of the concepts of Operations Research & Synthesis work and putting components and personnel in place to perform such work as a new primary function parallel to those of research and engineering, manufacturing, marketing, finance, and accounting, employee and public relations, and legal and corporate work.

The availability of these new "partners" to do such work heretofore not performed will eliminate those consequent gaps that caused frustration in the older functional areas and will facilitate new advances and new scope of activities and productivity in these older functional work fields. These trends and developments will perhaps have even more beneficial and far-reaching impact for the people in the financial function than for any other people in the older functions. Correspondingly clear is the consequent need, on the part of persons in both financial and Operations Research fields, for early and sympathetic understanding of the future potentials and requirements for operating businesses in these directions.

Organizing for Operations Research & Synthesis Work

The foregoing remarks have described many of the criteria that must be considered in respect to organization of Operations Research & Synthesis work and organizational placement of such work. A summary is somewhat as follows:

(1) The objectives of Operations Research & Synthesis work are the disclosure of knowledge about the business, of which visualization as previously described is an important part, for the benefit of others who are concerned with the operations or the managing of the operations.

(2) Operations Research & Synthesis work accomplishes this

purpose of increasing knowledge through an understanding: (a) that managing is rational; (b) that research in business as a phenomenon is feasible; and (c) that rational methods not now usually in the kit of tools available to a business can be used.

(3) The attitude toward the work is one of research, reflection, testing, and disclosure. The tempo of the work and the environment in which it must be done must correspond.

(4) As illustrated in the example of information needed to synchronize the activities of two functional subcomponents, it requires contact and work with responsible managers.

(5) As illustrated by the problem of visualization, the work can well range across an entire business or several functional areas if done completely and effectively.

(6) Operations Research & Synthesis is a continuous activity, as was pointed out in connection with the work of visualization; the need is not only to see the situation as it is in place but also to view the circumstances beyond it so as to provide means for gauging the need for change. Moreover, there is a need for continually refining the visualization itself with respect both to what is in place and to the circumstances beyond the specific situation that affect it. As an example, the accounting model mentioned earlier was not brought to its present state of development in one single effort.

Operations Research & Synthesis workers stand in distinct relation to the business and to its functions. They do not manage; they do not make decisions; they do not control. Their work supplies a finished product to managers and specialists in all other functions and on all levels — the basis for organized knowledge and information needed by all persons to make their own decisions with respect to their respective managerial positions in their jobs. These criteria suggest that we have here the evolution of a new kind of functional work. It must have a manager.

This kind of work, which heretofore has been done at best on a kind of instinctive, usually unorganized basis by occasionally gifted individuals within a business, is and will be of increasing importance, if we are to take optimum advantage of the rapid technological developments available to business and also sharpen your operation in the face of the progressively increasing expectations from workers, share owners, and the community.

The electronic computer in its full implications, automation with its inherent inflexibilities, the proposal of supplementary unemployment pay of even a guaranteed annual wage are all signs that we now need clearer understanding of how a business operation works, how it might work better and that the time already is late to begin to develop this further understanding.

The criteria also suggest that it should be a separate component, that it be so placed organizationally as to be able to work across the entire business operation at that level where the need is foreseen. This new component has a distinct product, knowledge, or information for appropriate managers and specialists. It has distinct methods of discerning such knowledge, as again can be seen by a reading of the literature and also in part at least by what Dr. Ackoff had time to disclose today; it has a definite and unique approach of its own, grounded in the scientific method of inquiry. Perhaps this latter can be summed up by saying that it has or must have the attitude of systematic research, not the attitude of getting something done somehow today — more important as that attitude is for many purposes.

The criteria also suggest that in organizing for such work there is an important managerial decision with respect to the level at which such work should be done. For example, the approach and methods are just as applicable for the most efficient loading of a single machine as they are for the efficient loading of an entire shop. At which level should the work be done? Shall it be from the viewpoint of the foreman? Or from the viewpoint of the entire business? The examples of visualization used earlier and the implications of benefits to be drawn from them with respect to (1) better understanding of the business operations and (2) simplification of the work of managers are assuredly based upon doing such work at the level of the business as a whole.

Operations Research & Synthesis and Personnel

Yet the establishment of a component and its placement at a level within the business for highest impact are by no means the end of organizing for such work. There is a question of people: (1) people to do the work, (2) people in place in the business to understand and use the work. Without understanding of what has been done and without its use in the operations by and through the managers the results are of little, if any, value.

The earlier example of synchronizing the activities of two manufacturing components pointed out that the judgment of responsible managers was required to aid in the establishment of the priorities of the schedules. Although this is quite a simple example, this type of situation where priorities must be established or risks evaluated as a result of the information disclosed is typical of the process. It requires a close and continuing relationship with responsible operating managers. It is also by this route that what is done becomes understandable bit by bit, and hence, usable. This way the results are not lost in a fine, leather-bound report at which nobody looks.

The other aspect of organization relates to those who do the work. In view of the body of methods now known to be useful in this kind of work, people with some degree of training are required. Since this is a fairly new kind of work on an organized and systematic basis, it is not going to be possible to go out and hire all the trained and experienced people that may be required. Time to learn is therefore an important factor in organizing for this work.

Nor is the problem strictly one of learning specific methods that seem important. There must be also time to learn about the business itself, its problems, its language, and its folklore.

The period for planning for such work, the time before results can be expected, will then be important factors for managerial decision on when to organize.

This indicates that where possible, it is desirable in the interest of time to organize the component with two kinds of people — (1) those who have knowledge of the business and its ways and who have demonstrated, for example, some insight into its visualization — and (2) those who have knowledge of what we are coming to call Operations Research & Synthesis methods.

Lastly, there is a consideration of how long it may take to get results, even with an experienced group of people. There is a point of reference. It has been observed that it took approximately seventeen years to bring silicones from the first test tube experiments to the point of commercial manufacture. Somehow we have learned to expect these things, these kinds of things, in physical research even though we may not like it. Yet we are here discussing an equally complex subject, a going business, and proposing to study it and the outside environment and climate in which it exists.

If the results were not to be forthcoming for seventeen years, there would be considerable question about the desirability of starting now, or any time for that matter. The point is that the results should not be expected overnight. There is, instead, the expectation of a gradually increasing body of knowledge about the business, a gradually increasing body of methods and a gradually increasing skill on the part of people – both Operations Research & Synthesis workers to do the work and managers to understand and use it. This is not work for "hot-shot" specialists who come in with foreknowledge of what to do, but rather a gradual accumulation of knowledge through systematic application of these skills to a business and its operations. It results in a gradual increase in the knowledge of the business and what to do about it.

What gives this matter urgency now is the fact that enough has already been found in areas where Operations Research & Synthesis has been applied to suggest that as managers, we are on the threshold of a whole new area of knowledge that will aid in simplifying the work of managing in these times when the responsibilities of managers are increasing so rapidly.

Those who proceed now, not in the expectation of magic, but in the expectation of the typical and the very human process of learning through organized effort, which builds up knowledge surely but slowly, will be the ones who will obtain the advantages for the future.

Discussion: Part Five

QUESTION: Wasn't a standard systems and procedures job undertaken on the application to which you referred in your second illustration?

DR. ACKOFF: I can answer this in two ways. I might point out that such a study had been made – about a year before we came in. The difficulty was that they had no standard that would represent an acceptable kind of procedure and no criteria that told them what the necessary information was and where it had to be, because they were studying a procedure in the abstract. They did not know what decision rule was required to control this process. They knew what decisions were currently being made, but they did not know how the decisions *ought* to be made. Consequently they set up a good procedure for the existing decision process. It was perfectly adequate if one accepted the current control system. But the moment the control system changed, it imposed new organizational and data processing requirements that could not have been anticipated unless one knew how the decision itself ought to be made. I do not know whether this answers your question or not, but I might say that the systems people were involved in both studies to which I referred.

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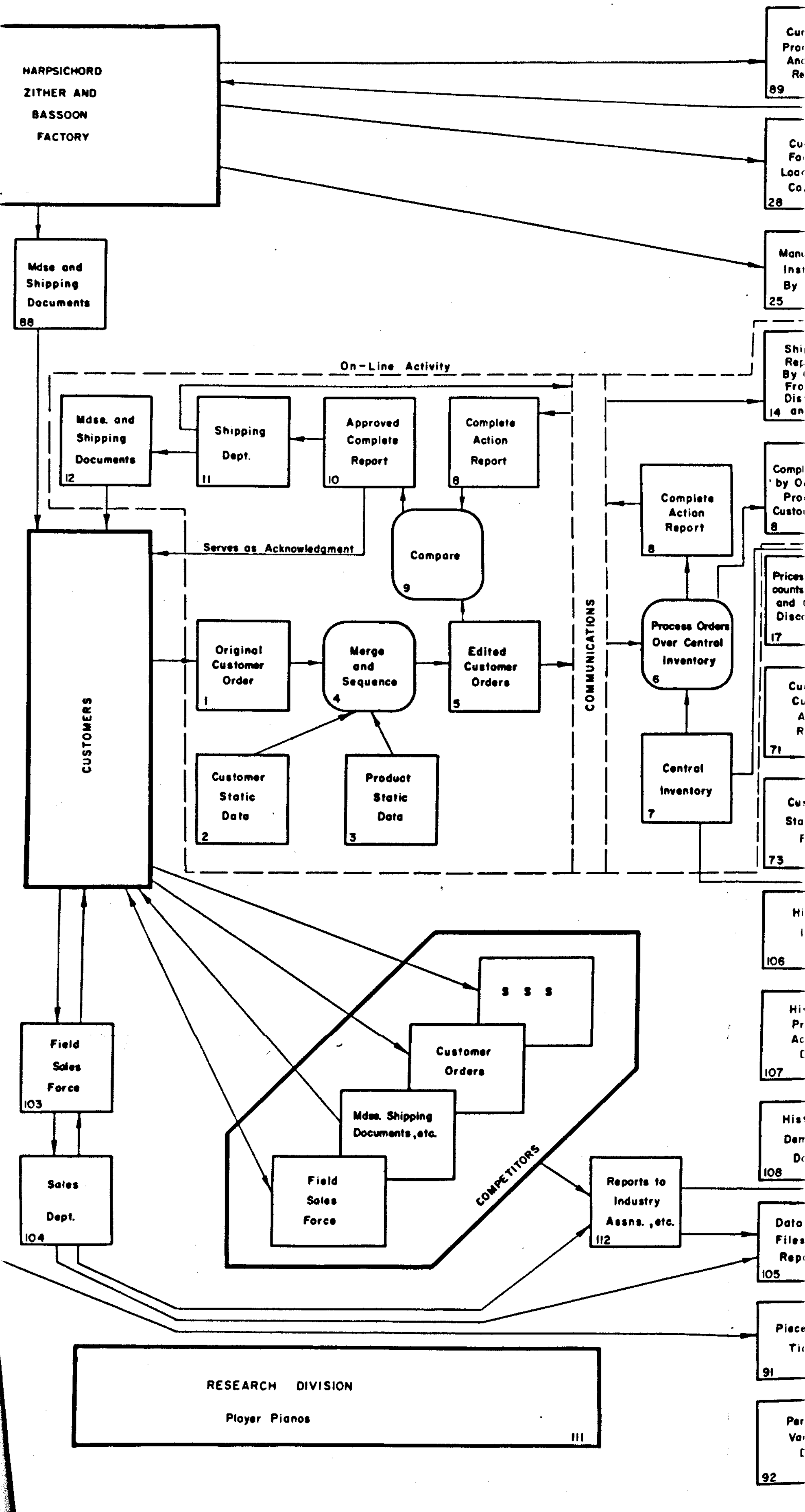
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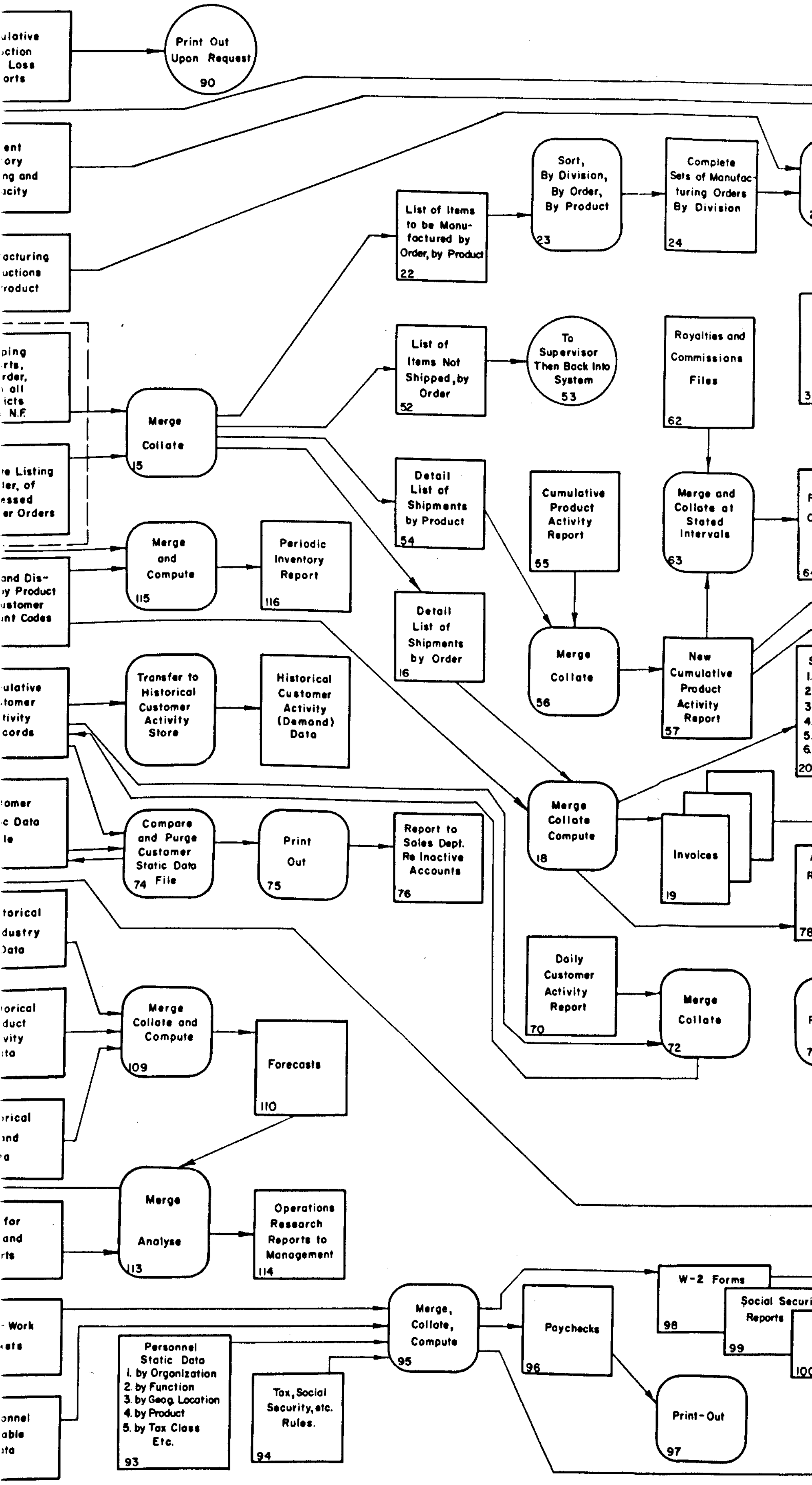
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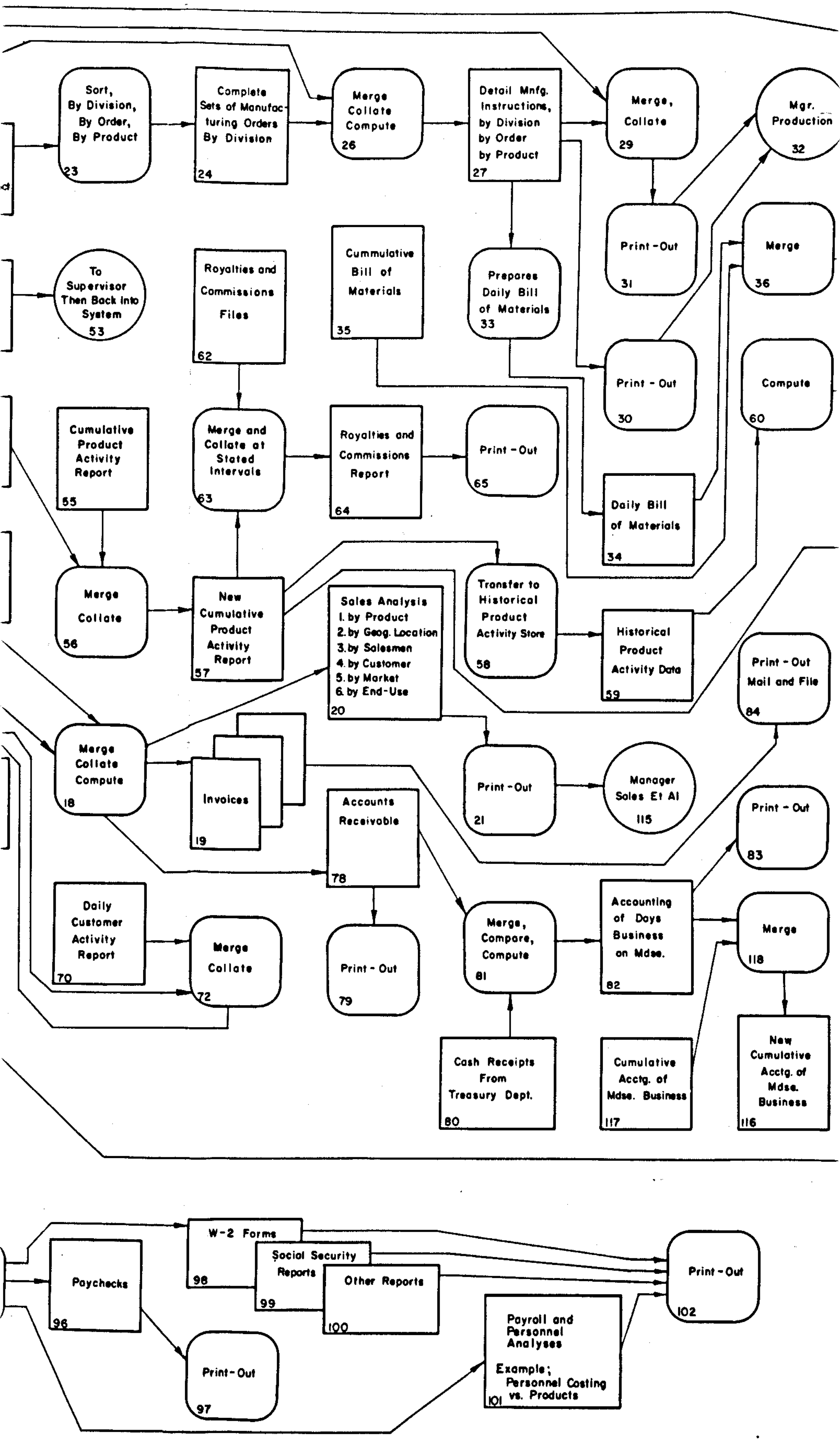
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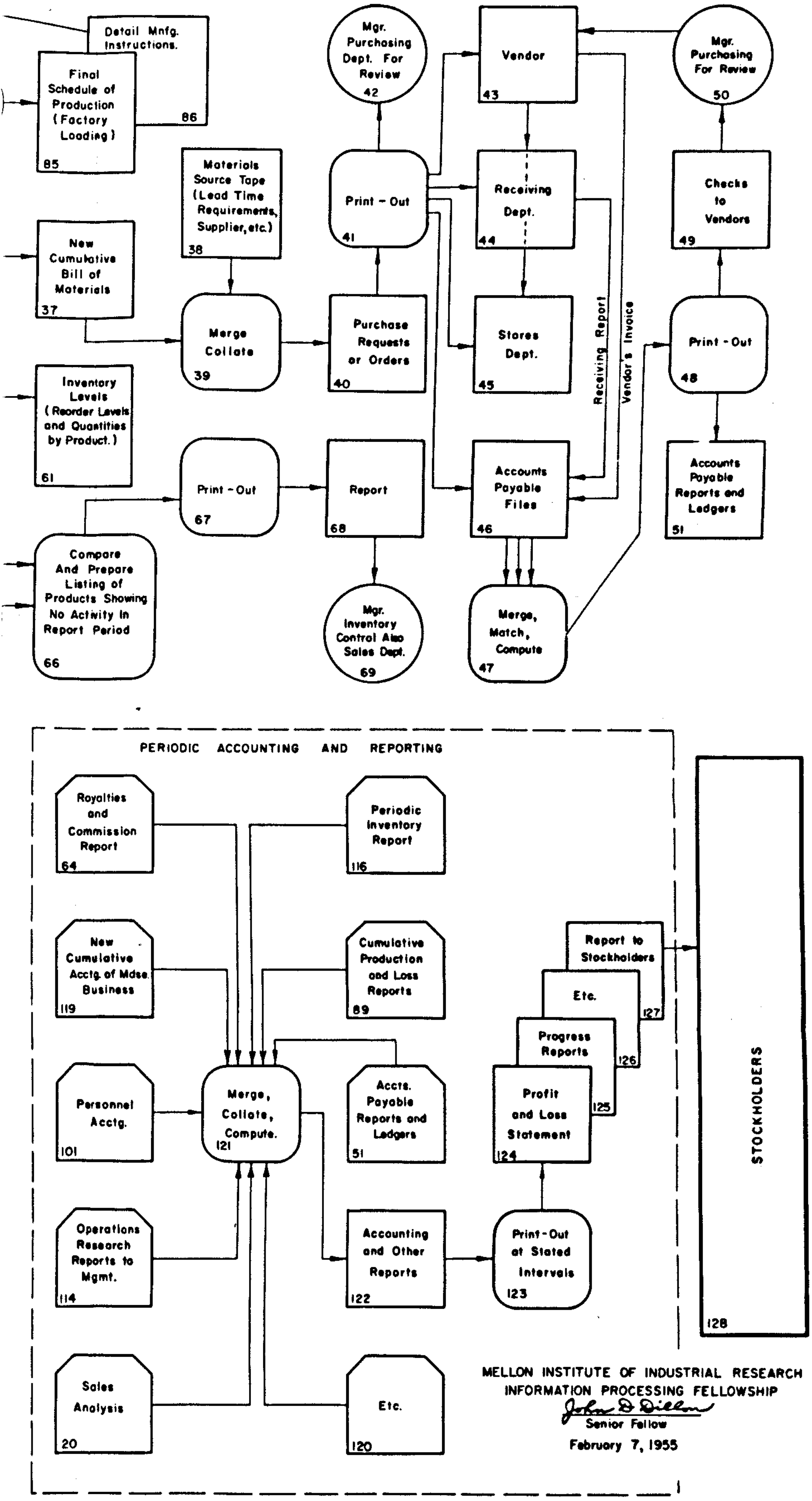

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