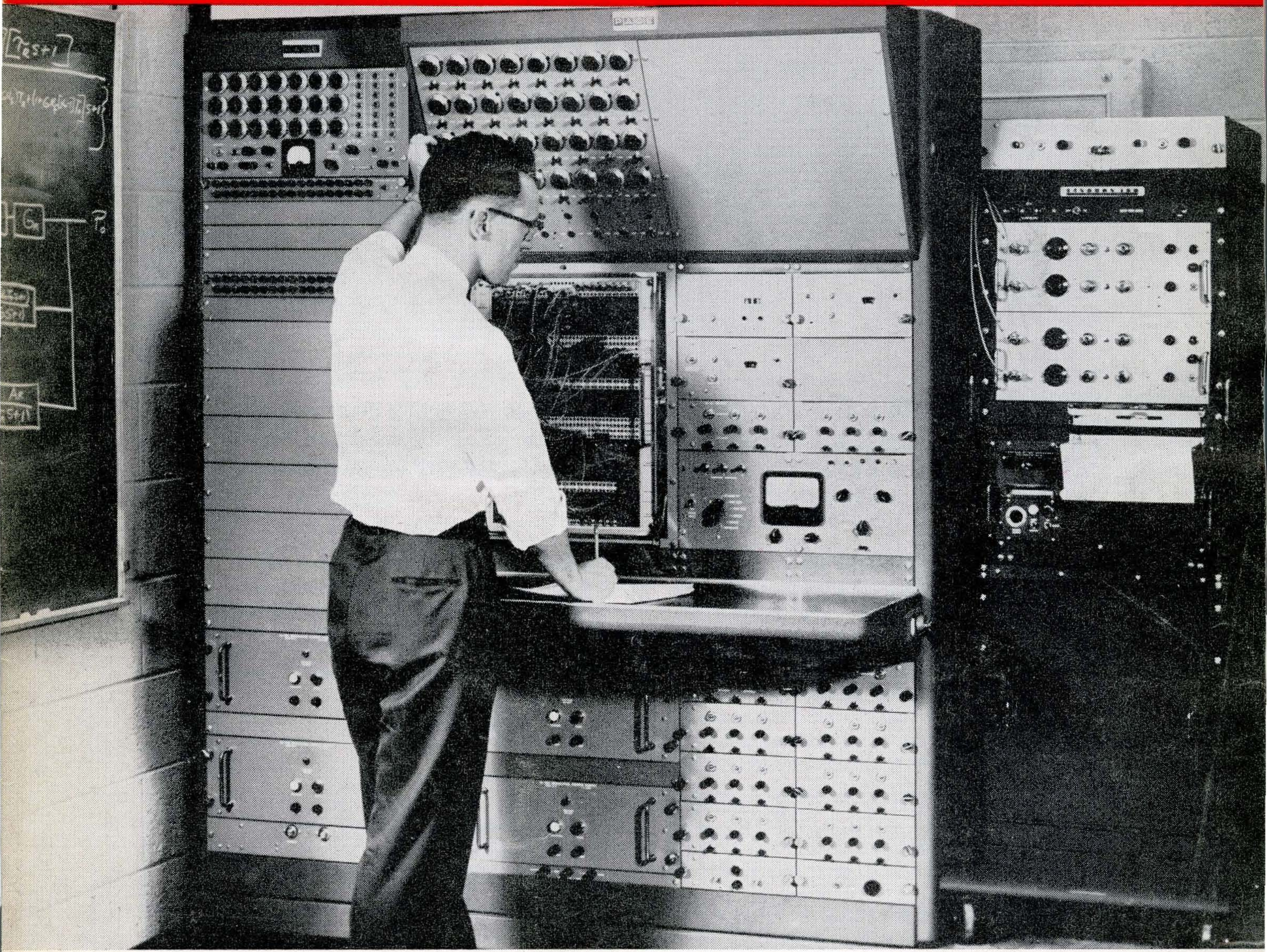
COMPUTERS
and AUTOMATION

DATA PROCESSING • CYBERNETICS • ROBOTS



OCTOBER
1957
Vol. 6 - No. 10

Are Automatic Computers Faster than Business Needs?

An Economist Looks at Data Processing

A Big Decision: Lease or Buy?

Readers' and Editors' Forum

ANALOG COMPUTER IN USE FOR DESIGN OF INSTRUMENTS

EVERY NOW and then we see a computer photograph that has a quality of reality, because it gives a good picture of how computing may go on, using not only an automatic computer, but chalk, blackboard, mathematics, and a man — a man that is apparently working, not conferring over invisible problems, not casually posed in one of the usual poses of a photographer. Such a picture carries a conviction of reality. And when we received such a picture in the mail the other day, we liked it and thought we would put it on the front cover.

The picture shows an ordinary cement-block engineering laboratory in Fischer and Porter, Hatboro, Pa., where an Electronic Associates analog computer is in use. This computer provides means for simulating and solving complex problems in the design of instruments. One problem to be placed on the electronic analog computer is accurate prediction of transient and steady-state phenomena in the control of closed loop processes.

MAKING MATHEMATICIANS INTERESTING

Alston S. Householder
Oak Ridge National Laboratory
Oak Ridge, Tennessee

SEVERAL YEARS AGO an ad hoc committee of the Division of Mathematics of the National Research Council made a survey of training and research in applied mathematics in the United States. One of the recommendations of this committee, made as a result of the survey, was that the division establish a standing Committee on Applications of Mathematics with the following functions:

(a) To facilitate cooperation among organizations concerned with various aspects of mathematics in applied settings.

(b) To call attention to the emergence of new areas in which significant applications of mathematics may be possible.

(c) To serve as a focus for the continuing scrutiny of problems concerned with training and research in mathematics as related to its applications.

(d) To take whatever steps are deemed appropriate to enhance the effectiveness of mathematics in its applications.

Accordingly, in October, 1954, the chairman of the division appointed a committee of eight members, with Dean Mina S. Rees, of Hunter College, as chairman. Dean Rees continued as chairman until the summer of 1956, at which time she asked to be relieved of the chairmanship, and the present writer was appointed in her place. In accordance with the usual policy of the Council, members are regularly appointed for terms of three years with two or three replacements each year.

The committee met, soon after it was formed, to determine a course of action, and for reasons that hardly need elaboration here, its attention quickly centered on problems of training. It, therefore, took an early interest in the proposal for the Semiñar on Applied Mathematics which was held recently in Boulder, Colo. Moreover, three members of the program committee for the Seminar were present or past members of the Committee on Applications, and the chairman of the program committee was then secretary of the Division of Mathematics.

The major concern of the committee, however, has been with the growing demands for mathematicians in government and industry, and the insufficient numbers of students being prepared to meet these demands. This problem, it seemed, must be attacked at the high school level, and Dean Rees proposed a project which is now well under way and will perhaps be of interest to others.

Contributing Factors

While doubtless many factors contribute in tending to repel even superior students from courses in mathematics, one of the important factors is lack of information about the careers that are open to mathematicians, and a scant and often distorted conception of mathematicians and their activities. The committee felt that as a committee it could do little toward making mathematics interesting, but that it might contribute toward making mathematicians interesting. It seemed that this could be done best by presenting sketches, or profiles in the New Yorker sense, of real, live mathematicians.

Since the profiles are to be designed for high school students, it seemed clear that the mathematicians profiled should be not too old, should be interesting and engaged in interesting work, and should be outstanding. Further, there should be women as well as men. Since many high school students are apt to consider a doctor's degree quite unattainable, many if not most should be at the bachelor's or master's level academically. And since the object is to make it known that nonacademic opportunities exist, most should be in nonacademic employment.

It is hoped that eventually these profiles will be assembled and printed in a little brochure, to be made available at no cost to high school students, as well as their teachers and counsellors. With this in mind, funds were requested from the National Science

(Please turn to page 23)

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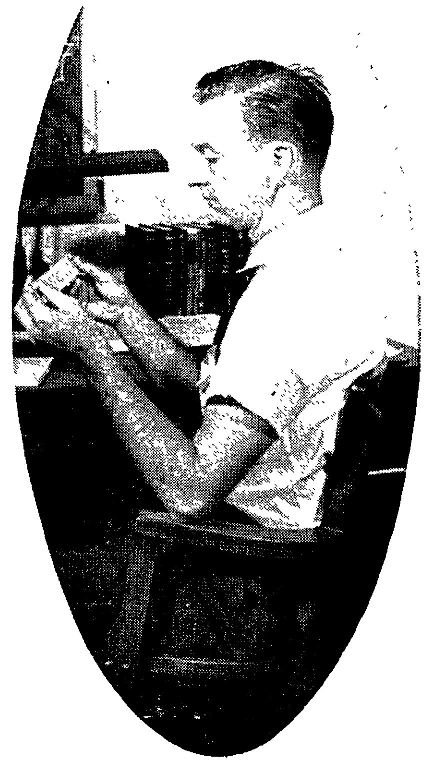

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A Big Decision:

LEASE OR BUY?

Theodore Labiner
North Bergen, New Jersey

THE recent antitrust suit court decision involving the consent of International Business Machines Corp. to selling as well as renting its equipment is presenting a new problem to a large segment of management—the present and potential users of IBM computers. Before the decree, the question of lease or buy was an academic one to the IBM user. He had no other option than to lease. Since IBM's share of the computer market has been estimated at 87 percent, the group now facing the big decision is quite large.

However, almost all of IBM's competitors have been offering their customers an option to buy or lease their computers for a number of years. Therefore, many users of computers have already weighed the advantages and the disadvantages of leasing vis-a-vis buying and have made decisions that reflect their attitudes toward the issue. Since non-IBM computer users have been offered a lease-buy choice, their past decisions on the option will provide an indication of how the IBM customer will react now that he is given the alternative. For it may be assumed that both the IBM and non-IBM user will approach the problem in a similar manner.

Survey Conducted

To uncover the motives that underlie the decision that has been taken by the non-IBM user having a lease-buy option, the author conducted a survey. It is believed that the results of the survey indicate a trend of thinking that will be followed in the future by the IBM as well as the non-IBM computer user. A total of 203 non-governmental domestic computer installations were included in the survey. One hundred and fifty-three questionnaires, or 75 per cent of those sent out, were returned.

The most significant factor revealed in the survey is managements' overwhelming preference for leasing their electronic computers. Among the total number of electronic computer users offered the lease-buy election, only 17 percent purchased their computer. This is compared to the 83 percent of the installations which were found to be leased.

Reasons for Leasing

The most prevalent reason for leasing uncovered in the survey is the fear of obsolescence. The rapid strides being made in the technology of electronics have created an atmosphere of caution among the users of computers. Advances such as the recent development of the cryotron, a device which will replace transistors and tubes in computers since it is so small that 100 will fit into a thimble, are continually occurring. The fact that their computer may soon be superseded by a newer advanced model has led to hesitancy among users to buy the machines. Overall, 80 percent of the surveyed lessees stated that the fear of obsolescence was a reason for making the choice of leasing rather than buying their computer.

Twenty-eight percent of the respondent lessees gave as a motive for leasing the large amount of capital that is involved in the purchase of a computer. Some of the companies reported that they did not wish to invest such a large amount of capital in equipment because it was needed in their business. Others felt that capital spent for the purchase of a computer could more profitably be invested in other ways. The availability of capital is a major reason for explaining why proportionally the greatest number of the users owning computers are insurance companies. In this light, it is significant that the first IBM large scale computer sold under the company's new marketing plan was sold to the Prudential Insurance Company of America.

Another important motive influencing management's decision to lease is that fact that they are not sure that the computer will meet the company's needs. Since computers are relatively new, many of the customers are unfamiliar with their performance and do not know if they will fit in with the company's system. Because one of the best ways to find out whether the computer will do the job desired is to put the machine into use within the company, the user will not want to buy the computer until he can be certain that it will meet his requirements and expectations. The survey disclosed that about 16 percent of the lessees made their selection based upon this uncertainty.

Maintenance Costs High

The complexity of electronic computers and the high cost of a non-functioning machine have led management to be very aware of the maintenance problem accompanying the ownership of the computer. Very few companies desire to recruit and maintain their own technical staff to keep the machines running. It is much easier to have the lessor retain responsibility for maintenance. This reason for leasing is not quite as important as it might be, because the manufacturer of the machine usually offers customers purchasing their computers an opportunity to sign a maintenance contract to service their machine.

This service contract is also offered by IBM under the terms of the consent judgment. However, many users feel that the service received by the owner with

a maintenance contract is not of the same standards as that provided by the manufacturer for the machines he leases but retains ownership. Thirteen percent of the surveyed lessees felt that the maintenance problem was a reason for selecting the lease option.

The next most frequently cited reason for leasing is the fact that the company involved was growing and its management expected that its needs would change. Therefore, it did not wish to be committed to any one type of computer. The small computer user was more prone to lease for this motive than was either the medium-size or large-size computer user. He, therefore, selected the lease option so that new equipment would be easily available when the need arose. The reasoning of 10 percent of the respondent lessees was influenced by this motive.

Another reason unveiled for leasing is "company policy." Users basing their lease decision on this motive have a fixed policy of leasing expensive technical equipment for which a lease-buy option is offered. Since most experts believe that each type of equipment presents a unique problem and should be independently considered, this appears to be a rather rigid and irrational policy for management to follow. However, eight percent of the lessees based their decision on this motive.

Since almost all the earnings of any large company are taxed at a rate of 52 percent, no important managerial decision on whether to lease or buy computers should be made without considering the effect of taxes upon the decision. Although only three percent of the lessees claimed to have based their decision on the income tax motive, others motivated by other reasons likely considered the advantages that accrue to leasing under the Internal Revenue Code.

On leases, the full amount of rental payments is a deductible expense for tax purposes. This advantage is partially offset since the owner may deduct a set annual amount for depreciation. However, this amount, in most cases, is less than the rental and the amount charged off as depreciation will equal the amount charged off for rental payments only after long periods.

Reasons for Buying

The reasons for purchasing the computers are much less involved and much less numerous. In all, there were only four different motives for buying divulged.

The most obvious reason for owning a computer is that such a course is much less expensive in the long run. If a company would apply its rental fees to the purchase of the machine, it could be paid off in a relatively few number of years.

For example, big computers usually sell for $1½ to $2 million, depending on the extent of the peripheral equipment. Rentals for these large computers average $30,000 a month or $360,000 annually. In addition, most manufacturers charge a higher rental if the machine is used for more than one shift a day. Every computer owner gave this long-range economy as a motive for making the decision to buy rather than lease.

Thirty-two percent of the purchasers claimed that they were motivated to buy their machines so that they would be able to retain complete control. These owners wanted to avoid the use-restrictions that the manufacturers of the computers impose on their lessees, as well as all other restrictions that are inherent when the user possesses less than ownership.

The nebulous element "company policy" is given as a motive for purchasing, as it was for leasing. Many management decisions in this area are made on a prejudice that one should own that which he uses. Sixteen percent of the computer owners stated that it was the company's policy to own all its equipment. To adhere to an overall sweeping policy such as this without considering the individual equipment is as rigid and irrational a policy as that followed by the managers who lease because it is company policy to do so.

The only other reason revealed for purchasing was the fact that no lease option was available. This was only pertinent to one computer manufacturer who at one time offered the lease option only to the users in certain specified geographical areas.

The Future

It has been shown that management at present faces the big lease-buy decision by electing to lease their electronic computers in a predominant proportion. As has been indicated, approximately 17 percent of the commercial computers marketed in this country are sold, while 83 percent are leased. It is believed that the IBM user, now that he too is offered the option, will follow very closely this same ratio.

This tendency to lease will not vary a great deal in the near future. The major motive behind management's selection of the option to lease is the fear of obsolescence. This factor of obsolescence plays such an important role in management's decision because the industry is so new, and so many dynamic changes are continually taking place. As long as these new developments continue to occur so rapidly and with so much frequency, this fear of obsolescence will prohibit a substantial number of users from selecting the option to buy their electronic data processing equipment.

The dynamic nature of the industry is not something which will stabilize in a few years. In contrast, as the industry grows out of its infancy the rate of change may occur at an even more rapid pace. For one thing, with IBM forced to sell its equipment, there may be a greater incentive for that company to obsolete its equipment with new improvements more quickly than it would if it had been permitted to continue to offer its computers only on a lease basis.

There is also an increased effort on the part of the IBM competition to try to capture a larger share of the computer market which is estimated to be a half-billion dollars in the next three years. Innovations may also be expected from new companies entering the market. For example, General Electric, having already made computers for the armed forces, has organized a special computer division with the aim of capturing a share of the commercial market.

For these and allied reasons, it will be many years before users will be able to confidently purchase their computer without the apprehension that their installation will be superseded by an advanced, superior model in a relatively short time. Therefore, until the industry has reached a state of equilibrium, management will continue, preponderantly, to lease.

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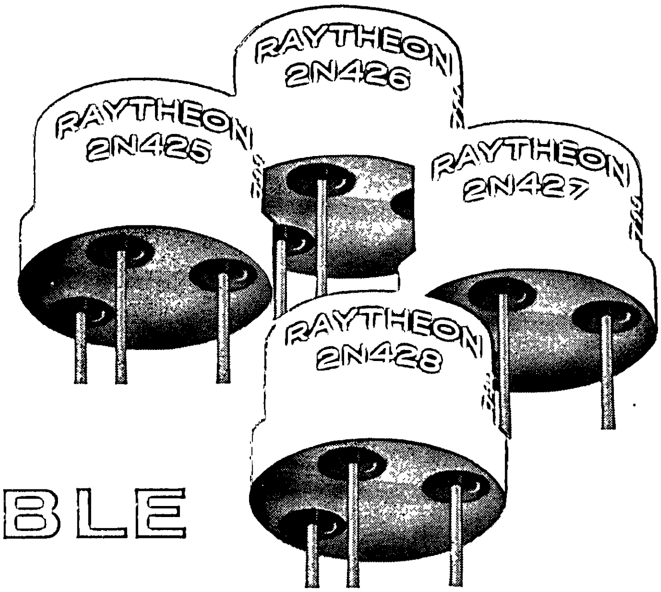

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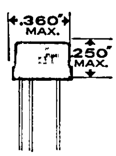

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			2N425			2N426			2N427			2N428		
Parameter	Conditions (25°C)	Units	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
BVPT		volts	−30	−50	—	−25	−45	—	−20	−30	—	−15	−25	—
V_{BE_1}	$I_B = -1$mA, $V_{CE} = -0.25$v	volts	—	−0.35	−0.45	—	−0.35	−0.45	—	−0.35	−0.45	—	−0.35	−0.45
h_{FE_1}	$I_B = -1$mA, $V_{CE} = -0.25$v		20	30	40	30	40	60	40	55	80	60	80	—
h_{FE_2}	$I_B = -10$mA, $V_{CE} = -0.35$v		10	15	—	10	18	—	15	20	—	20	30	—
$R_{sat.}$	$I_B = -10$mA	ohms	—	2.2 for $I_C = -100$mA	3.2	—	2.2 for $I_C = -100$mA	3.2	—	1.4 for $I_C = -150$mA	2.1	—	1.1 for $I_C = -200$mA	1.6
$f_{\alpha b}$	$V_{CB} = -5$v, $I_E = 1$mA	Mc	2.5	4.0	—	3.0	6.0	—	5.0	11.0	—	10.0	17.0	—
C_{ob}	$V_{CB} = -5$v, $I_E = 1$mA	$\mu\mu$f	—	14	20	—	14	20	—	14	20	—	14	20
Switching Speeds														
$t_d + t_r$	$i_C = -50$mA, $R_L = 200$ ohms	μsec	—	0.53	1.0	—	0.53	1.0	—	0.43	0.85	—	0.43	0.85
t_s	Values of i_B "on" and i_B "off" are	μsec	—	0.3	0.6	—	0.3	0.6	—	0.3	0.6	—	0.3	0.6
t_f	5.0mA for 2N425, 3.3mA for 2N426, 2.5mA for 2N427, 1.6mA for 2N428	μsec	—	0.45	0.65	—	0.35	0.55	—	0.35	0.55	—	0.30	0.50

For all types I_C (max.) = −400mAdc average
i_C (max.) = −1000 mA peak

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A Survey of Users of

THE IBM—650 COMPUTER

Edgar R. Fiedler and David R. Kennedy
University of Michigan
Ann Arbor, Mich.

DURING March of 1956 a questionnaire was sent to 121 users of the IBM-650 computer. The list of users, obtained by Dr. John W. Carr III of the Mathematics Department in the University of Michigan, from IBM, was at least a year old. The writers were unable to find a more current list.

The questionnaire was straight-forward, covering several areas of fact and opinion concerning the Type 650. The purpose was to gather information about the Type 650 and other high-speed electronic computers in the specific areas of:

1. The balance between the use of computers for scientific calculation as opposed to data processing.
2. Industrial policy on the question of decentralized computing systems vs. those which would be integrated.
3. Current uses to which the Type 650 is being put.
4. The number of Type 650's and other similar computers which are installed and on order.
5. The personnel requirements of a Type 650 computing section.

Of the total number responding, 96 percent wished to have a copy of this report sent to them.

Findings Listed

A total number of 121 questionnaires were mailed; of this number four were returned because of insufficient address, five were returned not completed because the company did not have or anticipate ordering a Type 650; 81 respondents completed the questionnaire. Of a possible number of respondents of 112, an excellent response rate of 72 percent was obtained.

The information received was analyzed through the use of IBM punched and verified cards. The analysis resulted in the following major findings:

1. The companies answering classified by industry were as follows:

Industry	No. Answering	Percent of Total
General Mfg.	30	37
Ins. and Banking	15	19
Oil and Gas	13	16
Aircrafts	11	14
Railroads	4	5
Miscellaneous	8	10
	—	—
TOTAL	81	100

2. 72 percent of the respondents used their computers primarily for data processing and 28 percent for scientific purposes.

3. 80 percent of those answering favored a centralized and integrated data processing organizational structure rather than a decentralized organization.

4. The uses to which the computer is put were weighted to establish averages which would reflect the importance or rank of each use. Using these weighed averages the percent of the companies using computers for several applications is:

Application	Percent
Payroll	65
General Engineering Problems	53
Cost Accounting and Budgeting	35
Premium billing and analysis	34
Production and Material Scheduling	33
General Accounting and Reporting	25

5. The major applications by industry are:

a) General manufacturing
   1) Payroll
   2) Production and material scheduling
   3) Cost accounting and budgeting
   4) General engineering problems

b) Insurance and Banking
   1) Dividend and installment saving accounting
   2) Mortgage loans
   3) Premium scheduling and computation
   4) Actuarial

c) Oil and Gas
   1) General engineering problems
   2) Payroll
   3) Production and material scheduling
   4) General statistical analysis

d) Aircraft
   1) Aerodynamics
   2) General engineering problems
   3) Rocket, missile and engine design and performance analysis
   4) Mathematical problems

e) Railroads
   1) Payroll
   2) Cost accounting and budgeting

6. Twenty percent of the companies have more than one computer currently installed. The average number of computers installed is one and one-third.

7. One-fifth of the companies have more than one type of computer similar to the IBM-650 installed.

8. Twelve percent of the companies responding have more than one Type 650 computer on order with one insurance company having 13 on order. Forty-four percent have one or more on order.

9. Twenty-eight percent of those answering have one or more other types of computers similar to the Type 650 on order.

(Please turn to page 28)

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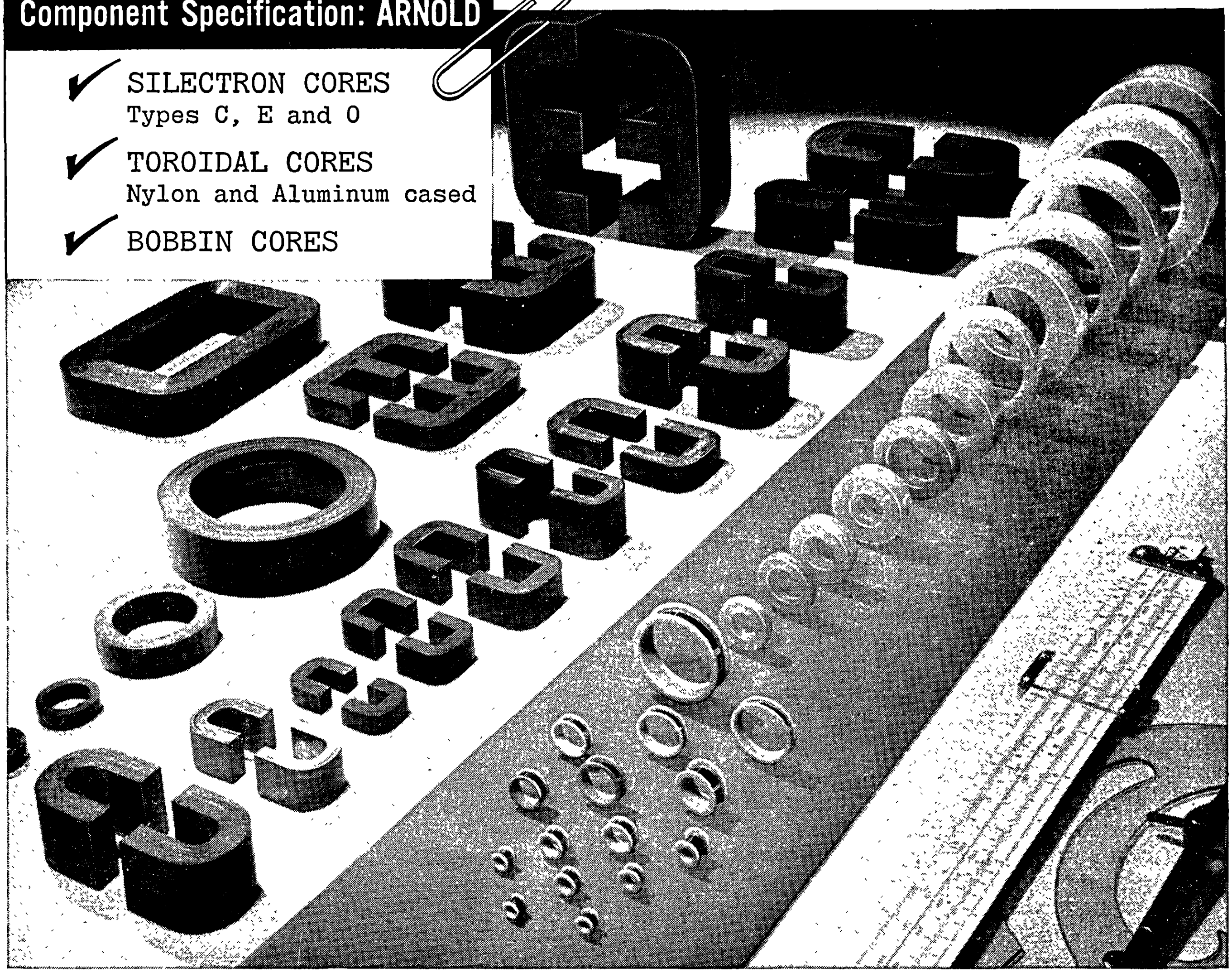

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ARE AUTOMATIC COMPUTER SPEEDS FASTER THAN BUSINESS NEEDS?

Ned Chapin
Systems Analyst, Stanford Research Inst.
Menlo Park, California

Accuracy, Reliability, and Capability

MEN in business today are almost universally agreed upon the practical significance of three characteristics of automatic computers: accuracy, reliability, and capability. These are three of the four characteristics that most significantly distinguish automatic computers from alternative types of business data processing equipment.

For example, nearly all businessmen agree that automatic computers, to be useful and of value in business data processing operations, must perform accurately. By accuracy is meant that the machines can perform exactly what they are programed to perform, right down to the last hundredth of a cent. In fact, it has been observed that the automatic computers on the market today have ample accuracy to meet business requirements and have at least as much accuracy as alternative equipment for doing business data processing.

From experience, men in business have learned that accuracy without reliability is of little value. That is, an automatic computer must give accurate results not only today, but tomorrow, and the day after, and next week, and next month. By reliability is meant that the machine can perform consistently in the way it has been programed to perform. Reliability is a time concept, a concept of continuing accuracy over the course of time. Reliability also includes the automatic computer's signaling its human operators if it deviates (because of component or equipment failures of various types) from doing what it has been programed to do.

It is noteworthy that men in business are satisfied with the reliability of storage, and arithmetic and logic units of automatic computers. Men in business are still somewhat dissatisfied with the reliability of some input-output units; but in general the order of reliability of automatic computers is at least 10 times better than of alternative data processing equipment.

Also from experience, men in business know that an automatic computer has value to business for the data processing it can do—that is, for its capability. Here automatic computers are clearly superior to alternative data processing equipments. Some equipment, which is also sold with the aid of the magic word "electronic," has been confused with automatic computers. Persons investigating such machines have often noted a lack of capability. This is to be expected since these machines were not automatic computers.

The capability of automatic computers that makes them of value in business is their ability to perform long sequences of complex, involved data processing operations. These sequences are performed by the automatic computer under its own control without the intervention of the human operator. Also, the automatic computer is of such a construction and design that it can take alternative courses of action and conditionally modify its own instructions. This permits the automatic computer to handle exception cases without human intervention to an extent not practicable with alternative equipment.

On the importance of the accuracy, reliability, and capability of automatic computers there is little question. These are recognized as essential characteristics of automatic computers. If men in business would like to see any change in these characteristics, then they would like to see these characteristics heightened, not reduced.

Automatic Computer Speed

On the fourth characteristic of automatic computers —speed—there is considerable divergent opinion. Some men in business say that all the presently available speeds of automatic computers are far greater than necessary. Others say that there is an imbalance in the speeds of automatic computers currently available. Still others say that the present speeds provide a reasonable balance; and still others insist that speed is such an important essential of an automatic computer that the highest possible speed should be sought even for business applications.

The presence of this wide diversity of opinion raises questions. Who is right and to what extent, and why? To answer such questions requires a little analysis. Without this analysis, the questions and arguments over the importance of speed in automatic computers for business use cannot be seen in a proper perspective.

Someone who examines an automatic computer will notice that a computer has three basic speeds. First, there is the speed of the operation of the arithmetic and logic unit. A common measure of this speed is the number of additions that can be performed each second. Sometimes the number of multiplications, divisions, or comparisons is used also as a measure.

Second, and closely related to arithmetic and logic speed, is the speed at which information can be obtained from the storage unit and turned over to the control unit or to the arithmetic and logic unit. This speed is usually measured in terms of access time. In practice, the operations of both the control unit and the arithmetic and logic unit involve information taken directly from the storage unit. For this reason, the speed of data processing by an automatic computer is effectively determined by the total interaction of access times and the arithmetic and logic speed. In effect, therefore, these two measures of speed can be consid-

ered together as a measure of the internal processing speed of the automatic computer.

The third basic speed is the speed of operation of the input-output units of the automatic computer. Since the input-output units are composed of electromechanical equipments, the input-output speeds for handling information are slower than the speeds between and within the storage, control, and arithmetic and logic units. That is, the number of units of information that can be handled per second by the input and output units is considerably less than the amount of information that can be handled per second by the storage, control, and arithmetic and logic units. Thus, there seems to be a very factual basis for saying that the basic speeds of an automatic computer are not all the same, and that the input-output speed in particular is usually distinctly slower per unit of information handled than are the storage, control, and arithmetic and logic speeds.

Speed Balance

This raises two questions. First, is the relative slowness of the input-output speed significant? Second, if it is significant, to what extent is it significant? In fact, these questions are sufficiently important so that by tracing down their answers, a great deal can be learned about the fundamental nature of the disagreement about the significance of the speeds of an automatic computer. Let us, therefore, turn our attention to the difference in the input-output, and the effective data processing speed of the automatic computer.

In common business practice three conditions of using an automatic computer are observed to exist. One of these conditions is referred to as "processing limited" or "computation limited." When this is said of the application of an automatic computer, it means that for the application in question, the input-output units must wait because the time required for the computation or data processing is longer than the length of the basic input-output cycle time. In other words, the input-output cycles do not follow each other as rapidly as the input-output units are able to operate because of the delay caused by the computation or processing.

A second condition is known as "input limited." In this condition input cycles follow one another at the most rapid rate the input unit will allow. The processing or computation within the other functional units of the computer frequently waits during part of an input cycle for the input of new data.

The third condition is known as "output limited." In this condition the output unit operates at the most rapid rate its design will allow—that is, the automatic computer operates at full output cycle speed continuously. The input unit operates at less than maximum speed—that is, it waits and is idle part of the time—and the other functional units also wait. In short, the terms "input limited," "output limited," and "processing limited" refer to the speed bottleneck in the operation of the automatic computer for the applications in question.

The very fact that the terms input limited, output limited, and processing limited have currency in the field suggests something about the observed balance of speeds in an automatic computer in business applications.

Perfect Balance Unlikely

Instances are frequently observed where a given automatic computer may be input limited, output limited, or processing limited depending upon the application. In fact, each and every application must fit into one or the other of these three categories for any given computer. The likelihood of a perfect balance for an application on a given computer—that is, for the input speed, output speed, and processing speed to be such that no one unit of the equipment waited for another—has to this writer's knowledge very rarely been achieved outside the laboratory.

In short, for various actual applications of any given automatic computer, an imbalance in one case in favor of input, in another case in favor of output, and in still another case in favor of processing speed will be observed. The fact that these conditions do exist gives rise to the views of those who say that the balance of speeds among the units of an automatic computer is not good. The imbalance pointed to exists only for particular applications and cannot, therefore, be proved to exist for all applications, because for any given automatic computer some applications are imbalanced in directions [1] other than the one pointed to. This is important.

Some of the imbalance of speeds that is complained of among business users of computers is actually in relation only to their own particular applications and is not a feature inherent in the use of automatic computers in business.

In order to further clarify this, let us consider separately the significance of computer speeds for the output limited case, for the input limited case, and for the processing limited case. Let us turn our attention first to the output limited case to see what the circumstances and significance of the case may be.

Output Limited

At present, the information produced as output by an automatic computer is primarily designed for human consumption. That is, the output information supplied by an automatic computer is usually converted into words and numbers on paper for the use of human beings. The more information that an automatic computer produces as output—that is, the more quantity—the more burden there is on the human beings using the information because there is more information to assimilate. An automatic computer, because of the speed capable from its output equipment, can produce large amounts of information for human use. The volume of paper produced can be literally measured in thousands of feet per day.

But what human being can assimilate the closely packed information from thousands of feet of paper per day and then act on it? [2] Most acting upon information is done by the contact of human being with human being. In practice such contact takes, on the average, at least a third of an executive's time. Simply

1 That is, input limited, output limited, or processing limited.

2 An outstanding exception is issuance of premium notices by an insurance company, where the thousands of feet of output are burst apart, placed in window envelopes, and mailed to policyholders.

to read all the information without assimilating it or meditating upon it, would require more hours than there are in a 24-hour day. In practice, of course, where high volumes of output are produced, much of it is not read. Much of it is referred to only occasionally; often only one or two figures that support a particular summary figure are examined.

In short, where large volumes of output are produced from an automatic computer, the case is usually that the principle of management by exception is not being observed. The principle of management by exception in substance states that all that needs to be reported to management are the things that require management's attention. Where conditions are satisfactory or proceeding as expected, there is no need to burden management with detailed statistics which only say that he does not need to act. Nor is there any need habitually to burden an executive with statistics for which he has no use; or for which he has only an occasional use.

An automatic computer, because of its data processing capability, can digest, can boil down, and can reduce the volume of information that is supplied to executives. But in addition, an automatic computer can prepare the epitome or essence of information and present it in the form of output for executive use. This, of course, is a far cry from producing as output thousands of feet of paper per day. The essence of what is produced by data processing usually is of small volume, but of high significance. Information, in other words, that is condensed, summarized, and digested by an automatic computer before being provided as computer output has much more value in the organization than have classifications, arrays, and tabulations of semi-raw data.

In other words, those applications of an automatic computer which are found to be output limited actually may well be suspect. The very fact that they are output limited stands as a red flag signaling that effective use possibly is not being made of the data processing capability of the computer. Rather, such output limited situations most frequently signal that the automatic computer is being used only as an overgrown punched card or paper tape machine, that only its punched card-like or paper tape-like capabilities are being utilized. But all the other capabilities of the machine are being paid for. To fail to use them does not reduce costs!

In other words, in most output limited cases it will be found that inadequate use is being made of the data processing capabilities of the computer.[3] When these applications are changed to make full use of the data processing capabilities of the computer, the volume of output usually decreases significantly and the automatic computer application is no longer output limited. While this is generally true, there are, of course, a few exceptions notable where very slow speed output equipment, such as electric typewriters, are being used.

Input Limited

In the input limited case, the volume of information entering the computer is so large that the input unit must operate continuously and the data processing being performed is so brief that the other functional units of the automatic computer must wait part of the time that the input equipment goes through each of its successive cycles.

Why Large Volume?

It can quite properly be asked, why is the volume of input information so large? In practice two situations will be observed. One is that part of the information put into the automatic computer is not used in the data processing, but is only transferred to output or discarded without being processed. This occurs most frequently in the business situations sometimes referred to as record or file maintenance.

In this situation it has often been found necessary to read information into the computer which is not actually to be processed because it is not practicable to write onto the magnetic tape or punched card that served for input—that is, new magnetic tape or punched cards are produced as output. On some addressed magnetic tapes where independent search can be used, part of such movement of information through the automatic computer is avoided. Only the information actually needed for the processing is inputed. But even in the cases in which processing is done, usually the processing affects only a part of the total amount of input information read in.

Consider the example of a selective updating of payroll records. By use of independent search, only needed records will be put in, but for each needed record usually the entire record (block) must be read in, even though the only items affected by the particular transaction at the moment may be the number of tax exemptions, etc. This typically places a heavy burden on the input-output units and a light burden on the processing equipment.

A second situation is where a large volume of input information is read in and all is processed, but where the processing performed is small in comparison to the total amount of input information read in. Thus, the items of input information read in may only be handled by the arithmetic and storage units on the average of two or three times apiece during the processing. But in order to perform the processing, large amounts of input information are required. This situation merits some further attention.

From Several Sources

In business systems it will commonly be observed that information is collected from a number of sources and combined by processing to produce some sort of report or record for either control or historical purposes. The data needed to prepare any one report or record usually comes not just from one source document or form, but from a number of them. The processing necessary to combine the information from the various source documents or forms may be little, moderate, or extensive, depending upon the circumstances of the case.

When business systems are being designed for automatic computer use, it is easiest to try not to disturb patterns of forms flow and information flow in the business. Use of an automatic computer, therefore, usually is made to ease the burden of a high volume of repetitive information processing that presently exists.

[3] A major exception is the situation in which the storage capacity of the storage unit is exceeded by the requirements of the application.

Where these conditions exist, a conversion is made into some type of machine language to serve as input for the automatic computer. Then the computer can process the information and produce the output information required. It is noteworthy that when this is done, the result is usually a substantial volume of input into the automatic computer, so much so, that usually the automatic computer is input limited.

Computer Could Process

If the input information be examined closely, in these cases it usually is found that the information being used as input was produced as a result of some processing sequences that were done before the conversion to machine language was made. There is often no particular reason, other than tradition, why the computer itself could not perform that processing just as well, if not better, than is done at present. To do the processing in the automatic computer increases the amount of processing performed there, but often decreases the volume of input information required since only the basic source information need then be supplied to the automatic computer.[4]

The results, in other words, often can be a substantial lessening of the input burden on an automatic computer. Accomplishing this decreased input burden, however, results in an increased burden on the capabilities of the storage, and arithmetic and logic units. When the amount of input information being used is decreased, and when the amount of processing done is increased, the result then may be a shift from an input limitation to a processing limitation.

The fact that such limitation shifts are possible from a redesign of the business systems underlines that the lack of balance which previously gave rise to the input limitation is not inherent in the automatic computer, but rather arises from the design of the business systems which specify the application.

Notice that the input limitation case has an important parallel with the output limitation case discussed earlier. By going back to the fundamental requirements and the fundamental sources of information, input and output limitations on automatic computers usually can be eliminated by a redesign of the business systems. In other words, since the input and output limitations arise because of the application, changing the application specifications can change the input and output limiting of the performance of an automatic computer.

Processing Limited

In the processing limited case, it will be found that the internal processing arithmetic speed (as defined earlier) becomes very important from a business point of view. It is, in fact, observable that in these situations quite literally faster speed means lower cost of data processing. There is, in other words, a close relationship between the speed at which the automatic computer is capable of processing information and the cost to the business concern for having the processing done by an automatic computer. This relationship which may seem obvious to some does not always seem obvious to others. For that reason, to clarify it consider two points of view.

One point of view is the following. Many of the costs of operating an automatic computer are fixed costs—that is, they do not substantially change as the volume or level of computer operations is changed. The rental, depreciation, or amortization of the computer remains the same for one shift operation whether or not the computer be used for the full shift. From multishift operation, some variation is introduced in the case of rental since the second shift change is normally only half of the one-shift rental.

The personnel costs associated with an automatic computer can be considered as effectively fixed costs. Since computer-trained personnel are and will be difficult to obtain and keep, they will be neither released, terminated, nor laid-off, but rather will be kept on the payroll even though work may not be immediately available for them some particular day or hour. This makes their wages or salaries effectively fixed costs from the point of view of computer operations.

Primary Variable Cost

The primary variable cost of computer operations is the supplies used, principally business forms that the computer requires. These vary with the volume of input and output information handled. Maintenance costs are usually a semifixed cost for a computer since the deterioration of vacuum tubes and other electronic and electrical components is largely independent of whether or not the machine is actually processing information. The deterioration of mechanical components, however, is more closely related to usage, particularly to the input-output volumes.

Because the costs of operating an automatic computer are primarily fixed costs, an increase in the amount of work performed during a given amount of time effectively decreases the average cost per unit of work performed. For example, consider the case where 100 units of work are performed in one shift per week on an automatic computer under one condition (even though 200 units of work per week can be obtained from the automatic computer in one shift). Here the average cost per unit of data processing accomplished usually is not quite one half of the full utilization cost. In other words, one way to obtain a decreased cost of using an automatic computer in business is to increase the volume of work accomplished.

But if the automatic computer is processing limited, how can this volume of work accomplished be increased? The obvious answer is that it only can be increased by increasing the effective speed of the computer. But the effective speed of an automatic computer is only partly under the control of the programer, since much of the speed characteristics of the machine are built into the storage, control, and arithmetic and logic units. This means that although the programer exercises some control over the speed at which processing is performed, the fundamental limitation on the top speed which a programer can obtain from a computer is the design limit built in by the manufacturer.

In other words, for the performance of a given volume of work, lower cost can generally be obtained from

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[4] It also usually results in an operating cost saving. See Chapter V of Ned Chapin, *An Introduction to Automatic Computers* (Princeton, N. J., D. Van Nostrand Co., Inc., 1957).

the faster computers because in the time that they have free, after processing a given amount of work, they can be used for still other work, thus spreading the burden of their costs over a larger amount of data processing. It is observable that nearly every one of the faster automatic computers in relation to the slower automatic computers on the market, is faster than its cost is greater.[5] In short, given a degree of time utilization, the cost per unit of data processing accomplished decreases as the speed of the automatic computer increases.

A second point of view on the importance of automatic computer speed is the following. What are the capabilities of an automatic computer? How do they differ from the capabilities of other machines and from human beings? If one were to list, as has been done in other places, the characteristics of an automatic computer, it would be found that all of them are also characteristics of human beings and machines working in combination.

For example, an automatic computer can decide, based upon the nature of the information it is processing, whether or not to take alternative course of action "B"; and a human being processing information can decide whether or not to take alternative course of action "B." If the information is being processed by a combination of men and machines, as for example, by punched card equipment operated by human operations, the same type of decision can be made. The human being can set up and operate a punched card machine to select those cases which are to be handled using alternative "B" and those which are not.

It is appropriate then to ask what is the advantage of the automatic computer over the combinations of machines and human beings? After all, to use an automatic computer, one must instruct it in great detail. The preparation and set-up costs necessary to obtain the processing from an automatic computer are comparatively high in relation to those needed for combinations of human beings and machines. If an automatic computer can only do what other men or machine combinations can do, why use an automatic computer in business?

Lower Cost

The answer is of course largely cost. One will use an automatic computer if the cost in relation to the benefits received is more favorable for an automatic computer than for any of the alternative means of doing the data processing. But how is the lower cost realized if the function performed can be essentially the same? What is it about the automatic computer that makes it possible to process data at a lower cost? Is not the price of an automatic computer much higher than that of any other alternative machine? Is not the set-up cost high? Is not the installation cost large?

All of these costs are large. Yet since they are all basically fixed costs, as was pointed out earlier, a lower cost per unit of processing accomplished can be obtained if the speed of the automatic computer processing is high enough to more than offset the high costs. This suggests that the faster the automatic computer is in the storage, and arithmetic and logic speed, the less costly per unit of data processed it will be to operate, and the greater cost advantage it will have over other data processing alternatives.[6]

In short, an automatic computer is superior to other data processing alternatives mainly because of its higher speed of data processing.[6] This higher speed makes possible a lower per unit cost of data processing accomplished because the costs of an automatic computer are primarily fixed costs and because the design specifications of the application and of the automatic computer determine the actual processing speed. Any automatic computer application not designed to take full advantage of the high speed designed into the computer is in effect throwing away money. Any application of an automatic computer designed so that the processing speed is not the limiting speed is usually making ineffective use of the processing capability of the machine. Generally speaking, lower per unit processing costs can be obtained by making fuller use of the data processing capabilities of the automatic computer.

Review and Summary

To summarize, considerable debate has been heard about whether or not the high speed of an automatic computer is important to business and whether or not there is a balance in the speeds of an automatic computer. It has been pointed out here that all applications of an automatic computer in business must be limited by either the input, output, or processing speed of the automatic computer, and that the limitations observed in practice are largely a function of the specifications of the particular applications for which an automatic computer be used.

It was also pointed out that where the input-output speeds are limited, generally action can be taken to reduce the volume of input and output by the better design of the business systems used in utilizing the computer. This improved design of the business systems usually can result in converting the application from input or output limited to processing limited. In the cases where the applications are processing limited, the processing speed can be shown to be the basic determinant of the per unit cost of processing directly done by the automatic computer.

Since an automatic computer can perform only data processing that could be performed by other means, the business acceptance and superiority of an automatic computer must lie in the areas of cost and speed. But because of the fixed cost characteristic of automatic computers, the speed contributes to the lower cost. In short, the internal processing speed of an automatic computer is one of its most fundamental characteristics. Without speed, the use of an automatic computer can rarely be justified in business on a cost basis. As noted earlier, to be practical in business an automatic computer must do data processing with accuracy, reliability, and capability; but accuracy, reliability, and capability without speed are of no value to business because of cost. The speed must also be present and, in general, the higher the speed, the lower is the per unit cost of data processing accomplished.

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5 That is, if the processing speeds be measured in microseconds per unit, the ratio of the costs of the faster automatic computers to the costs of the slower automatic computers is more than the ratio of the speeds of the faster automatic computers to the speeds of the slower automatic computers.

6 Note that the processing limited case is still being discussed.

AN ECONOMIST LOOKS AT *Data Processing*

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THE purpose of this paper is to provide an economic framework for assessing the role of data processing in the American economy. By the term, "data processing" we mean the recording, computation, analysis and maintenance of the records generated by business transactions. It is the non-physical counterpart of "materials processing" in the internal operations of a firm, as well as the direct reflection of a firm's external relations with other firms and with governmental agencies. In short, the processing of data is a necessary concomitant of the basic economic processes of production, distribution and exchange.

In what follows, we treat data processing from two points of view: (I) the macroeconomic, or the aggregate economic activity of the nation; (II) the microeconomic or the activities of individual firms.

I: THE MACROECONOMIC LEVEL

The Growing Volume of Data Processing

IN ANY dynamic economy, long run changes in structure and function occur continuously. Several of these long run changes have also functioned as generators of an accelerating volume of data processing. These may be grouped under the following four headings:

1. **Secular trends**—The long term growth of certain basic variables in our economy. For example, Chart No. 1 shows the growth in one of these basic variables—population. From a figure of approximately 123 million in 1930, total population has now (1957) reached a level of approximately 170 million (the projection of the "High Series" seems to be the most accurate to date) and should be approximately 180 million by 1960. This factor alone necessitates an increasing amount of data processing at all levels. Moreover, our population has grown concomitantly with other economic variables, the most significant of these being total output of goods and services and its counterpart, income.

CHART ONE

UNITED STATES POPULATION, 1930-1952 WITH PROJECTIONS TO 1960*

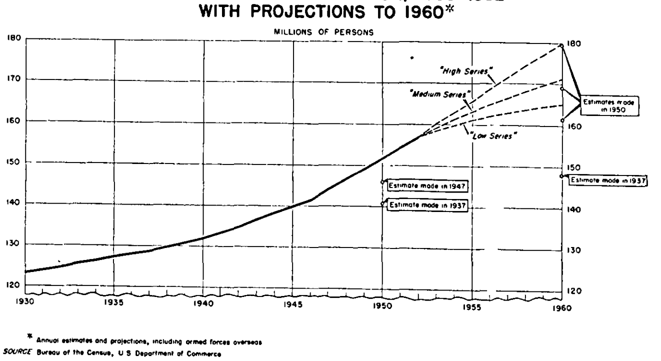
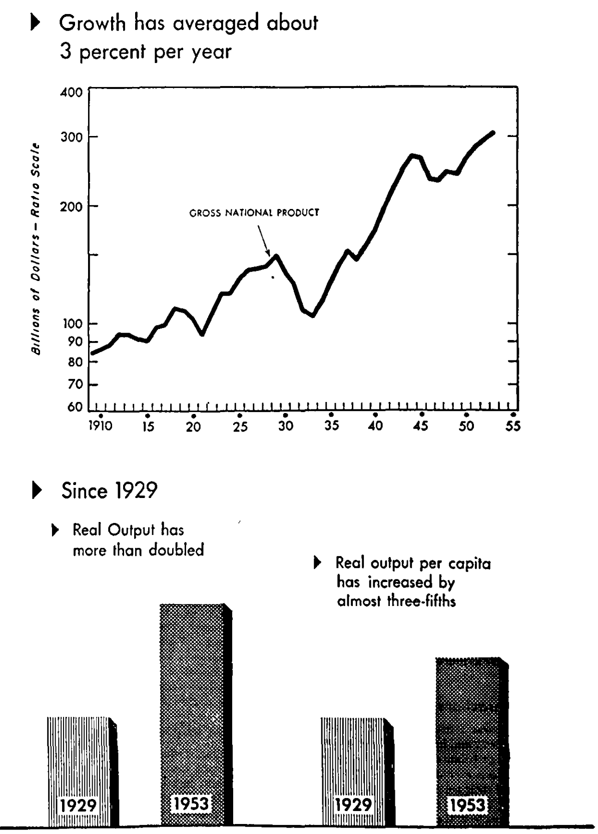


Chart No. 2 shows the growth of per capita Gross National Product (GNP).

The National Output CHART TWO
In Constant (1947) Dollars



The data here indicate that not only has total output in the economy kept pace with population growth, but from 1929 to 1953 real output per capita increased by 60 percent—a good general indication of increasing living standards. This fundamental characteristic of our economy—long term growth—has generated and (according to authoritative projections) will continue to generate increasing amounts of data processing.

2. **Structural change**—This refers to the rearranging of major segments of the economy in terms of their relative importance in the system due to the introduction of new activities and the abandonment of older forms of economic activity. The most fundamental

structural change, for example, has been the shift from an agricultural to an industrial economy, and within the latter, a shift from goods producing to service producing activities. Corresponding to these basic shifts have come adjustments in the labor force, the size of business units and techniques of production. All have had profound ramifications for data processing.

3. **Complexity**—The significant impact of this factor is felt not only in production and distribution techniques (i.e. assembly lines, specialization, etc.) but primarily in terms of the interrelationships of the components of the economy. This process involves extensive interfirm and firm-governmental data processing.

4. **Increased Regulation and Control**—The passage of various items of economic and social legislation (Social Security, Unemployment Insurance, Federal Reserve System, Wage and Hour Laws, ICC, SEC, etc.) have initiated enormous record keeping operations in business. Subsequent use of these data by government has necessitated substantial increases in data processing resources at Federal, State and local levels.

MANIFESTATIONS AND MEASURES OF DATA PROCESSING GROWTH

The basic factors responsible for the growing volume of data processing mentioned above may be described quantitatively in a number of ways.

1. First, a significant shift has occurred in the composition of the labor force. Involved in this change are the relative rates of growth of so-called "blue collar" production workers and "white collar" groups not directly engaged in physical output. One study indicated that:

> In 1950, "white collar" occupations accounted for 21 million persons, or 37 percent of the employed civilian labor force. This group has shown extraordinary growth. While the number of employed non-farm manual workers had grown 73 percent between 1910 and 1950, the white collar group expanded 162 percent. The clerical and kindred group has grown the fastest with the professional and technical group next in line.[1]

The Assistant Secretary of Labor recently stated:

> Taken together, the white collar occupations actually have reached a historic position according to our latest information. . . . This year (1956) they represent the single biggest group in the labor force and they are expected to be well out ahead by 1975. . . . A few years ago we reached this kind of situation in our industrial distribution, there were (and are) more people employed in industries producing services than those producing goods. Now the occupational distribution has reached the same stage: *today we have more white collar than blue collar workers* in the American labor force.[2]

Chart No. 3 depicts these relationships and their projections to 1975.

Since most "white collar" workers are engaged in some type of information handling, the implications of this historic change, so far as the quantity of data processing is concerned, are of staggering proportions. Some of the reasons for this development are given in the article by Flexner and Ericson:

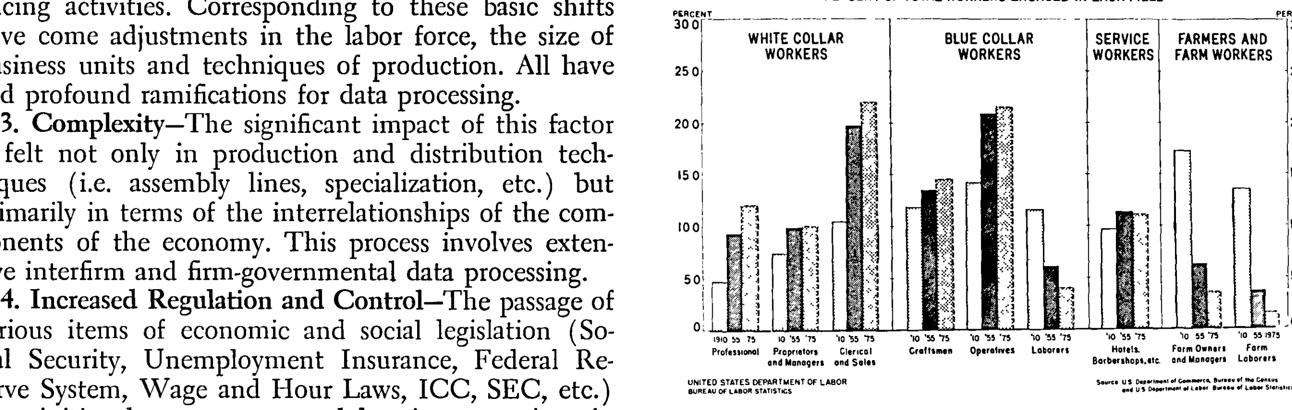
> This phenomenal growth of the salaried white collar occupations was related to technological advances, extension of domestic commerce, and increases in banking, insurance and professional services of many kinds, both private and governmental. New techniques processes and equipment have been turning out an ever growing volume of manufactured goods without corresponding increases in production workers and with shorter hours. This development has required *more record keeping* as well as the services of more highly trained technicians for research, development and maintenance. The increasing emphasis on cost analysis has also been influential.[3] (Emphasis mine, H. G.)

CHART THREE

EMPLOYMENT IN THE MAJOR OCCUPATIONS

1910, 1955, AND PROJECTED 1975

PERCENT OF TOTAL WORKERS ENGAGED IN EACH FIELD



2. Another kind of structural change, of significance for data processing, involves the size of business units in the economic system. Although there are over four million business units in operation, "In 1951, the upper 1 percent of all firms provided three fifths of all paid employment." [4] The concentration of employment in large firms requires extensive management and administrative controls involving intrafirm data processing on a large scale to achieve maximum coordination.

3. It is useful at this point to list some of the physical and/or financial magnitudes of aggregate economic activities which necessitate efficient data processing on a continuing basis for optimum functioning: [5]

Business Sector

—Approximately 67.5 million civilian workers requiring, for the most part, weekly payrolls and associated data.[a]

—87.9 billions of dollars in inventory (manufacturing and trade, 1956). Involved here: file maintenance, orders, reorders, determination of economic levels (inventory control), etc.[b]

—54.0 billion dollars of sales (manufacturing and trade) necessitating sales statistics, accounts receivable and payable, sales forecasting, market analysis, etc.[c]

—3.2 billion shares of stock outstanding plus 106 billion dollars worth of bonds, this involves stock transfers, dividend payments, interest payments, etc.[d]

—42 billion dollars in consumer credit: outstanding; (involves billing, posting, etc.).[e]

—334 billion dollars of life insurance in force in U.S. as of 1954. In this connection, H. F. Craig, in a Harvard doctoral dissertation, describes the amount of paper to be processed by an insurance firm with about 5,000 employees (a relatively small firm) as follows: [f]

The business is a "paper" industry involving communication by mail between a central office and 7,000 agents in the field operating from 200 branch offices. The volume of paper flowing in and out of this department of the Home Office each day is considerable, numbering on average 36,000 standard forms per day and involving a dollar value of 2.46 millions per day.

The volume of service involved and the comparatively low unit value of each transaction emphasized the need for mass production techniques; whereas the total volume and aggregate value involved necessitated an organized and precise system of accounting control. The problems involved in servicing the functions were intensified by fluctuations in work load from day to day and from week to week.

Source: Harold Farlow Craig, "Administering a Conversion to Electronic Accounting." Graduate School of Business Administration, Harvard University. 1955, Page 22.

—Approximately 13,600 commercial banks with 50 million checking accounts and 10 billion checks cashed annually.[g]

Government Sector

—Government budget approximately 70 billion dollars (1956).[h]

—18 billion printed and mimeographed forms processed annually.[i]

—Volume of 25,000,000 checks per month issued by Treasury.[j]

The foregoing is, of course, only a partial listing of some of the broad magnitudes of paperwork that the U.S. economy is heir to. Omitted from this listing are the vast quantities of data processing arising from inter-industry, interfirm and intrafirm business relationships. It is sufficient, however, to indicate the enormity of the existing and potential paperwork bottleneck which we must overcome if maximum economic efficiency is to be achieved.

The Economy's Adjustment

Given the reasons for the growth of data processing and various measures of the quantities involved, how has the economy responded to the task?

We have indicated previously that one way in which the economy reacted was by altering the "labor mix" in the direction of a greater proportion of white collar (data processing) workers relative to so-called "blue collar" workers. However, the incomes of the two groups have not changed accordingly; "blue collar" workers have experienced (for the period 1939 to 1954) a greater rate of increase than the white collar group. Table 1, for example, shows that **in 1939, the median salary of clerical and kindred workers was higher than that of any of the three production workers categories** (both men and women). From 1939 to 1954, however, the wages of the three male production workers groups (Craftsmen, Operatives and Laborers) had increased by approximatley 224%, 233% and 250% respectively, while that of the clerical group increased by only 163%. A similar picture emerges for female workers from the available figures.

Two reasons for this lag in clerical workers salaries have been offered: (1) a lesser degree of unionization among clerical workers[6] and (2) a lag in clerical productivity relative to that of other occupational groups. With regard to the former, it is of interest to note that the clerical labor force has become a prime target of a new unionization attempt by the AFL-CIO.[7] Whether the drive succeeds or not, one result of it will be increased pressure on clerical wages. The factor of clerical productivity however merits lengthier consideration at this point as it is central to the problem of overall economic efficiency.

TABLE 1: Median Wage or Salary Income, Specified Occupational Groups, United States, 1939 and 1954

Occupation Group	Men 1937	Men 1954	Men Percent Increase 1939—1954	Women 1939	Women 1954	Women Percent Increase 1939—1954
Clerical & Kindred Workers	1421	3735	162.8	966	2468	155.5
Craftsmen, Foremen and Kindred Workers	1309	4246	244.4	827	n.a.	——
Operatives and Kindred Workers	1007	3349	232.6	582	1852	218.2
Laborers, except mine	673	2358	250.4	538	n.a.	——

SOURCE: Adapted from Table 6, J. A. Flexner and Anna-Stina Ericson, "White Collar Employment and Income," Monthly Labor Review, April 1956, Page 7.

Frequent assertions have been made in the literature on this problem to the effect that, ". . . the volume of paperwork has grown much faster than either the U.S. economy or the hourly efficiency of those who do the paperwork,"[8] and that, "There are strong evidences that record-keeping costs have been increasing relatively more than the cost of other business functions."[9] Unfortunately empirical studies of clerical productivity are almost non-existent due to the fact that, more often than not, there is no measurable output that can be related to any measurable input. There is, however, some indirect statistical evidence to which we may refer on the clerical productivity problem. John W. Kendrick, in a recent study of productivity trends in the U.S. economy, stated:

> The difference between the rates of growth in production in the economy as a whole and in the industrial sector covered by this study implies that productivity in the uncovered segments—trade, service, finance, and construction, which account for almost half of national product—increased at an average rate of less than 1½ percent a year.[10]

The figure of 1½ percent (in sectors where there is a high clerical ratio) should be compared to the figure for the entire private domestic economy of 1.7, to a weighted gain of 2.0 for the aggregate of industry groups and 2.3 the unweighted gain for the same groups.

Since one of the major reasons for differences in productivity rates among occupational groups is the amount of capital equipment utilized, Table 2 (on next page) brings together some of the published data which are pertinent to our inquiry on clerical productivity.

Although the table is incomplete, several interesting observations may be made. First, taking the last year for which all the data are available, namely 1952, it may be seen that there are approximately *52 percent* more production workers in all manufacturing than there are clerical workers (all industries) but that capital investment per production worker exceeds that of clerical workers by approximately *1200 percent.* Secondly, the proportion of clerical worker investment over production worker investment has fallen from the years 1946, 1947 when the ratios were 8.67, 10.23 and 9.78 respectively to a relatively constant ratio of about 7.6 for the next four years, 1949-1952.

TABLE 2: Capital Investment Per Production and Clerical Worker, 1940-1956

YEAR	Production Workers (Manufacturing) (in thousands) 1	Clerical and Kindred Workers (in thousands) 2	Capital Investment per Production Worker (dol.) 3	Capital Investment per Clerical Worker (dol.) 4	Clerical Worker Investment as Percent of Production Worker Investment
1940		5,441		n.a.	n.a.
1946	11,745	7,158	7,081	614	8.67
1947	12,890	7,416	7,927	811	10.23
1948	12,717	7,613	8,815	862	9.78
1949	11,597	7,732	9,718	734	7.55
1950	12,317	7,903	10,423	799	7.66
1951	13,144	7,823	11,212	859	7.66
1952	13,144	8,235	11,980	910	7.56
1953	13,833	8,126	11,777	n.a.	n.a.
1954	12,588	8,428	n.a.	n.a.	n.a.
1955	13,061	8,586	n.a.	n.a.	n.a.
1956	n.a.	9,056	n.a.	n.a.	n.a.

1. U. S. Department of Commerce, Statistical Abstract, 1947-1956.
2. U. S. Department of Commerce, "Current Population Survey" by correspondence.
3. National Industrial Conference Board, Economic Almanac 1946—Page 298.
4. For capital investment, figures for Private Purchases of Office and Store Machines was used from U. S. Department of Commerce, National Income, 1954 Edition, Pages 210-211.

n.a.—not available.

If Kendrick's assumption about the lower rate of productivity gains in industries where there is a high clerical concentration is correct, and if, as the table indicates, investment per production worker vastly exceeds that for clerical workers, it follows that a great increase in capital expenditures per clerical worker is needed to increase clerical productivity in the economy.

II: THE MICROECONOMIC LEVEL

ANALYTICALLY, the treatment of data processing from the point of view of the single firm is concerned with the behavior of the clerical costs for different levels of clerical output. As was indicated above, however, it is extremely difficult to describe or to measure clerical output. Moreover, the analysis of clerical costs on the firm level is hampered by a dearth of empirical studies in this area. Nevertheless, subjecting clerical costs to a systematic economic analysis provides guideposts for organizing and directing management's thought in this area even in the absence of empirical data. Further, an analytical treatment often serves to indicate the type of data needed for a proper evaluation of the problem. What follows therefore, is an analytical presentation of the economics of clerical costs which is based in part, on some of the quantitative data presented above. It need hardly be emphasized that the concepts developed here must be continually tested against quantitative studies when and as these become available, if they are to merit any degree of confidence.

The general term, costs, may be divided into two parts, fixed and variable. Fixed costs are costs which do not vary with the quantity of output; variable costs do vary with output. Labor and materials are examples of the latter, plant and equipment, of the former. Clerical costs are a species of labor cost, hence they may be considered as a variable cost. The nature of clerical operations, however, is such that clerical costs, though variable, show a different pattern of variability from that, say, of production worker costs.

To illustrate: a minimum clerical staff is necessary regardless of the level of output so long as the firm continues to function at all. When output increases, however, increases in the number of clerical workers may lag behind increases in (say) production workers for the reason that the "clerical core" can, for a time, handle the increased clerical load. For example: one clerk can type an invoice for 100 units of product X or for 1000 units of product X, if output increases, without significant additional effort. This is not usually the case for the production effort required.

Additional clerks will become necessary however, when (1) the number of customers increases, thus necessitating a greater number of invoices, (2) when a firm's output is diversified, (3) when additional reports both intrafirm and between the firm and governmental units are required, or (4) when the firm itself expands via new plant and equipment.

The elasticity of clerical expansion relative to increased output will itself vary with the nature of the industry. Expansion of the clerical labor force is more sensitive to output changes in industries which are predominantly "paper processing" such as insurance companies, banks and commercial or consumer credit companies. Translated into diagramatic terms, this reasoning implies a fairly flat (average or marginal) clerical cost curve at the outset but a steeply rising curve beyond a given output level. The reason for the latter being that when additions to the clerical staff become necessary, they take the form of homogeneous small increments of input—another five clerks, for example—rather than taking the form of new office machinery. Thus the ratio of the variable inputs (clerks) to the fixed inputs (existing office and equipment) increases, producing the cost curves as shown in Figure 1.

Due to the fact that additional clerical help need not be hired until a certain level of output is reached, average clerical costs (that is, total clerical costs divided by output) will decrease at the outset, will have a flat portion over a certain output range and then accelerate rapidly. Marginal clerical costs or the additional clerical costs incurred for increasing amounts of output (due to the well known postulate of diminishing mar-

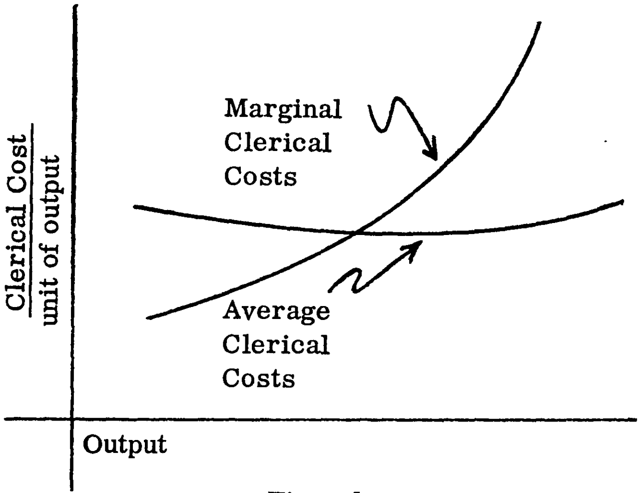


Figure 1

ginal productivity) will have the characteristic shape shown above.

Let us next analyze the changes in a firm's cost structure where the clerical operation is mechanized by the introduction of a large scale commercial electronic computer. Several assumptions should be made explicit here: first, that the computer will provide, at the least, output equivalent to that formerly achieved by the clerical staff; and second, that the variable cost elements associated with computer output (e.g. paper and tapes and/or cards) are small enough, relative to the total cost of the computer, to be negligible for analytical purposes.

The major analytical effect, then, of data processing equipment is the substitution of fixed for variable costs. That is, the equipment represents a capital investment of the firm—one which must be amortized according to a definite depreciation policy. The firm thus incurs a relatively constant annual cost regardless of the output achieved. This is represented diagramatically in Figure 2. Since the total fixed cost is constant relative to output, average fixed cost, fixed cost per unit of output, is represented as a negatively sloped curve. (The marginal cost curve is eliminated under our assumption of a negligible variable cost component.) Thus, the greater the computer output (let us assume, for the sake of simplicity, continuous three shift operation of the equipment) the lower the cost per unit of output.

Fixed Cost Element

Accordingly, changes in clerical output (reflecting changes in demand) will not result (as in the precomputer example) in corresponding changes in clerical employment. On the other hand, a fixed cost element is introduced into the cost structure, similar in nature to that of interest payments on funded debt. This holds whether the firm buys equipment outright and amortizes the cost or pays monthly rental charges.

The acquisition of electronic data processing equipment means, among other things, that additional clerical output may be performed when needed, without dipping into a shrinking clerical labor supply. Aside from purely quantitative considerations, moreover, there are elements of speed, versatility, availability of

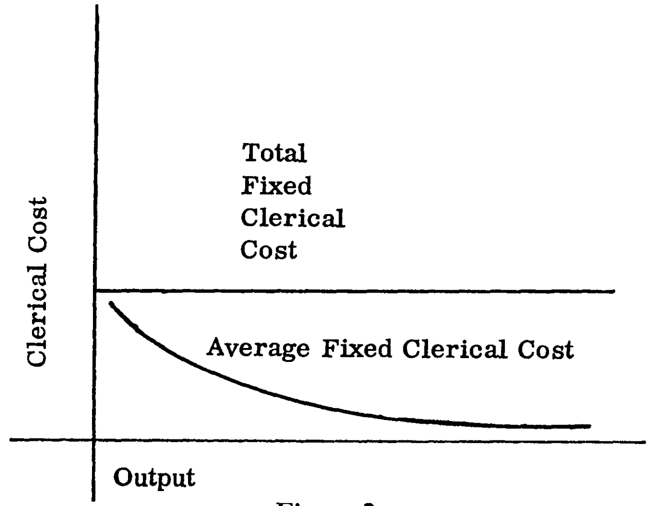


Figure 2

new kinds of information (due in part to the possibility of utilizing advanced mathematical and statistical techniques) and general improvement of systems and procedures, all of which contribute to overall firm efficiency.

Another significant effect of capital investment by firms in electronic data processing equipment is a reduction in what may be termed "secondary investment." The experience of firms which have acquired electronic computers indicates that office space, filing cabinets, and other pieces of office equipment are released from previous commitments and made available for new use. Furthermore, this "secondary investment" would have to accompany any non-mechanized expansion in the office staff. This factor must be taken into account in any economic evaluation of investment in electronic data processing equipment. The actual amounts of "secondary investment" which should be treated as an offset to "primary investment" will vary with the nature of the firm, but the mounting costs of office space and equipment suggest that the offset is a sizeable one.

The Data Automation Lag In American Industry

The available evidence on the extent of office automation as measured by the quantity of large and medium size electronic computers in use indicates that progress in this area is lagging. According to a recent survey there were 163 large size and 616 medium size commercial electronic computers in use as of February, 1957.[11] Because of duplication, that is, firms having more than one computer, the number of firms is smaller than the total indicates. When compared with the figure of 6,093 (excluding government agencies) firms having 100 or more clerical workers (where some type of office automation would be indicated) the gap between the need for and the supply of electronic data processing equipment becomes manifest.

Several Reasons

Several reasons may be adduced for the neglect of this vital problem—the real and potentially dangerous paperwork bottleneck in the U. S. economy:

1. The inability (or unwillingness) of firms to visualize their data processing operations in a theoretical manner.

2. The uncoordinated growth of the data processing function within firms—separate departments grow at different times, at different rates and for different reasons.

3. Inertia—the tendency to leave things as they are (a corollary here is intra-firm politics which militates against the integration of separate domains).

4. Ignorance of better techniques which are currently available for immediate application.

5. Pressure for capital expenditures along other lines which may appear more urgent or which seem to promise greater returns. (A corollary here is the feeling that the existing shortage of clerical personnel is a temporary phenomenon.)

It is hoped that the foregoing analysis of data processing in its macro and microeconomic aspects will provide a background against which present and future developments in this field may be more fully assessed.

AUTHOR'S NOTES

1. Jean A. Flexner and Anna-Stina Ericson, "White Collar Employment and Income," Monthly Labor Review, April 1956, Pages 1 and 3.

2. Rocco C. Siciliano, "The Creative Manpower Shortage," address presented at the National Convention of American Statistical Association, Detroit, Michigan, September 9, 1956, Page 9.

3. Flexner and Ericson, op. cit., Page 2.

4. Betty C. Churchill, "Size Characteristics of the Business Population," Survey of Current Business, May 1954, Page 17.

5. a. Economic Report of the President, January 1957, Page 142. b. Ditto, Page 158. c. Ditto, Page 158. d. The Economic Almanac (NICB) 1956, Page 89. e. Economic Report of the President, 1957, Page 170. f. Economic Almanac, 1956, Page 414. g. E. C. Van Deusen, "The Coming Victory Over Paper," Fortune, Oct. 1955. h. Economic Report of the President, 1957, Page 176. i, j. Hoover Commission, "Task Force on Paper Work Management," Pages 18, 41.

6. National Industrial Conference Board, "Clerical Salary Survey, 1955."

7. New York Times 12/4/56.

8. E. C. Van Deusen, "The Coming Victory Over Paper," Fortune, Oct. 1955, P. 131.

9. Haskins and Sells, "Data Processing by Electronics," 1955, P. 2.

10. John W. Kendrick, "Productivity Trends: Capital and Labor," P. 9, Occasional Paper 53, National Bureau of Economic Research, 1956.

11. "Office Automation," Page 114, Published by Automation Consultants, Inc., 1450 Broadway, New York 18, N. Y.

Forum

(Continued from page 3)

Foundation to finance the necessary interviews, writing, printing, and distribution. At present, funds have been made available for interviewing and writing, and it is to be hoped that the funds for distribution will be forthcoming when needed.

As can be imagined, the task of selecting the profilees was not a simple one, and the committee does not claim to have made the best possible choices. It was thought that eight or ten profiles would be sufficiently representative, and that a larger number might repel the prospective reader. But to ameliorate the difficulties somewhat, 20 names were chosen, and the profiles to be published in the brochure will be selected from among the 20 that will actually be prepared. For selecting these 20, letters were sent to a number of governmental and industrial employers of mathematicians, requesting nominations with a brief sketch of the background, interests, and achievements of each nominee. Responses to these letters, together with some nominations by members of the committee, yielded a list of about 50 or so, and the committee voted on these.

As plans were being formulated, it came to the attention of the committee that the National Council of Teachers of Mathematics had requested the National Science Foundation for funds for preparing and distributing a brochure setting forth the mathematical requirements of various occupations. After some discussion between the two groups, it was agreed to join forces and to include the statement of requirements in the same brochure with the profiles.

The interviewing and writing are now under way, and are being done by a professional writer engaged for the purpose by the National Research Council. While funds for printing and distribution are not yet assured, it is to be hoped that they can be had, or that some other means of publication can be found. The present article is written to inform others interested in these problems of one specific endeavor that is being made to improve the future level of applied mathematics. Moreover, the present chairman of the Committee on Applications of Mathematics will welcome any suggestions for future projects, and doubtless the same will hold for his successors.

FALLOUT COMPUTER – SOME TECHNICAL CORRECTIONS

J. Howard Wright
National Bureau of Standards
Washington, D. C.

I AM WRITING to correct some technical errors in the "News Note" feature on page 3 of your July, 1957, issue.

Instead of one "fallout computer" with "two new elements", two distinctly different computers have been employed by the Atomic Energy Commission in the present Nevada tests, in addition to the services of a group of fallout experts using rapid hand methods. Both of the new computers are special purpose analog units, approximately desk-size. The Sandia Corporation machine operates at a modest speed and produces an output of intermediate computation data as a series of curves drawn by an electromechanical curve plotter. These data are then utilized to draw a final plot of fallout.

The other machine, with which I was associated, was developed at the National Bureau of Standards. It is arranged to complete the computations and provide a final display of fallout all within a small fraction of a second after the original wind and cloud data have been inserted. In achieving such speed, this machine is limited in accuracy by the conventional large cathode ray tube employed to follow the solution and display the final fallout.

(Please turn to page 26)

INDUSTRY NEWS NOTES

Ed Burnett

New York, N. Y.

TRAINING IN TRACKING SUBMARINES

THE WALDORF INSTRUMENT DIVISION of F. C. Huyck & Sons, Long Island, N.Y., is building Sonar Simulators for the U.S. Naval Training Device Center. The simulator, which has been designed and engineered by the company, contains an electronic task force of aircraft and ships hunting an electronic submarine submerged in an electronic sea. The instructor can set up a great variety of hunting problems, and the computer will then automatically create the conditions of actual anti-submarine warfare. The company reports that a sonar operator trained on its land-based simulator, can separate the sound of a submarine's propellers from those of other ships engaged in the hunt, count the propeller blades of the submarine, tell its echo from that of a whale or a school of fish, and give its bearing and speed.

COMPANY TO GOVERNMENT REPORTING ON MAGNETIC TAPE

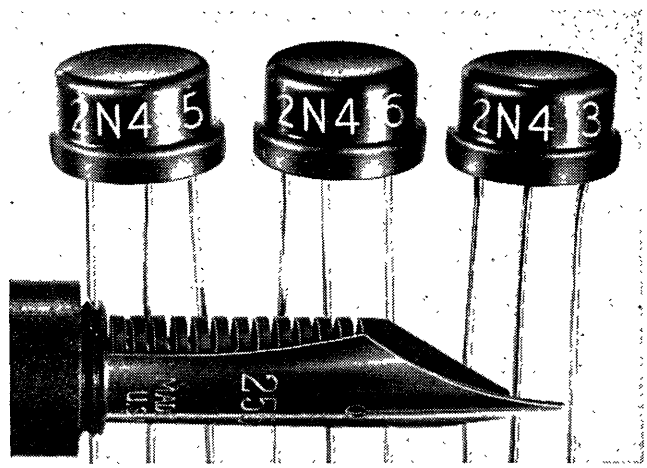
THE SOCIAL SECURITY ADMINISTRATION, Baltimore, Md., reports that several more companies are turning to computers and magnetic tape to file their Social Security reports. The companies which have followed the lead of General Electric in filing via tape to fit the Social Security Agency's computer, are Consolidated Edison of New York, International Business Machines Corp., and Consolidated Telegraph and Electric Subway System. The system bypasses completely the preparation of paper reports by the company, and the translation by the government back into computer language. Ford Motor Co. is expected to join shortly. Some 30 other major companies have expressed interest in converting to a reporting system which uses magnetic tape produced by electronic computer.

ELECTRONIC CHARACTER RECOGNITION

SOLARTRON ELECTRONIC GROUP, Thames Ditton, Surrey, England, is marketing "ERA" ("Electronic Reading Automatic"). This device is a bulky machine with over 200 tubes; it may cost in the neighborhood of $25,000; and it is claimed that the device scans any printed or typewritten document which can be read by the human eye at the rate of 300 characters a second, and feeds the information directly into a computer by means of electronic impulses. An English retail store chain is using a bank of ERA machines to "read" sales slips for direct transmittal into computers with which they print the tabulations desired, all within a few hours of closing.

Rheem Manufacturing Co., New York, and Solartron have formed Rheem-Solartron Ltd. to conduct research and development work on ERA and other electronic products. Each computer maker in America is being approached for adaptations of ERA to their particular needs.

COMPUTER TRANSISTORS IN STANDARD PACKAGE



RAYTHEON MANUFACTURING CO., Newton, Mass., is now producing four new PNP germanium transistors, in a standardized package known as the JETEC 30, especially for computer use. These transistors have alpha frequency cut off at 4, 6, 11, and 17 megacycles. (See picture above.)

NEW MAGNETIC TAPE MAY SOLVE STORAGE PROBLEMS

AUDIO DEVICES, INC., New York, is producing a new magnetic tape with magnetic print-through from layer to layer so low as to cause no harmful effects through decades of storage. The new tape, called "Master Audio-tape" is the first tape of this kind in production, and promises to solve important quality and storage problems faced by all regular users of magnetic tape.

MARKET FOR SMALL MACHINES PREDICTED BY VICTOR

VICTOR ADDING MACHINE CO., Chicago, Ill., President, A. C. Buehler, has claimed that automatic electronic computers will never replace simple desk-size calculating and figuring machines. He predicts "competitive coexistence." The smaller machines, he believes, meet a definite need which computers can never fill. We can comment that the wooden lead pencil has not yet been displaced by any more electronic writing instrument.

Forum

(Continued from page 23)

FILMS INTRODUCING ELECTRONIC DATA PROCESSING MACHINES

I. From Henry B. Ramsey, Jr.

Penn Mutual Life Ins. Co.
Philadelphia 5, Pa.

WE ARE LOOKING for an appropriate film to provide an introduction to Electronic Data Processing Machines — what they are capable of, what major problems are involved, how they function, etc.

It occurred to me that, in your position as "information gatherer" in the computer field, you may have a list of available films. If you are in a position to give us any information as to content, price, availability and manner of procurement, it would be most appreciated.

II. From the Editor

We do not at present know of appropriate films for this purpose, but we shall publish your letter in Readers' Forum.

If any reader knows of such films, will he please write Mr. Ramsey with a carbon copy to us.

COURSES IN MACHINE ACCOUNTING AND ELECTRONIC DATA PROCESSING

I. From Denis S. Philips

Director, The Management Institute
New York University
Washington Square, New York 3, N. Y.

FROM TIME TO time we have sent you news from New York University concerning special features of the program of the Management Institute. I am happy now to send you news of the fall session courses in machine accounting and electronic data processing. I believe you will find the information about these courses of interest to your readers. (See III below.)

II. From the Editor

Computers and Automation is interested in descriptions of courses, seminars, summer sessions, guided study, etc., being offered in the field of electronic data processing, machine accounting, automatic computers, numerical analysis, and other subjects bearing on computers and automation. From time to time we plan to publish basic reference information in this field. We invite every school and college to send us information about their courses in the interest of more and better education about computers, their implications, and applications.

III. Syllabus

Program in Machine Accounting Management

Co-ordinator: EUGENE F. MURPHY

THE PURPOSE of this program is to present the most recent developments and the latest techniques available in machine accounting, punched card, and punched paper tape equipment. The courses are intended for supervisory and managerial personnel who have found it necessary to become familiar with the far-reaching developments in the field of office automation as well as for those who require a more formal plan of training. The program is conducted in association with the National Machine Accountants Association.

A Certificate in Machine Accounting is awarded to those who complete a minimum of three courses. Completion means attendance at 80 per cent of the class sessions and a minimum grade of B on final examinations.

513. PS19B—APPLICATION OF MACHINE ACCOUNTING EQUIPMENT AND SYSTEMS, Fee: $50.

JOSEPH M. HILL — Instructor, Division of General Education, New York University; Supervisor, Machine Accounting Methods and Systems, Paragon Oil Company, Inc.

A comprehensive description of applications and uses of the various kinds of equipment available in machine accounting, with particular emphasis on punched card, addressing, duplicating, and bookkeeping machines. How these machines perform such tasks as reading, arranging, filing, searching, computing, and writing is explained. Emphasis is placed on the capacity and limitations of these devices and how to use them.

Especially recommended to those whose positions require, or will eventually demand, that they understand the functions of machine departments. Designed also for those without a basic background in machine accounting who plan to specialize in punched card machines and systems. Reference to plugboard wiring is minimal. Extensive use of training aids and field trips.

515. PS19M — LABORATORY IN WIRING AND OPERATING PUNCHED CARD EQUIPMENT, Fee: $60. (includes laboratory fee)

EMANUEL SCHERR — A.B., M.B.A.; Instructor, Division of General Education, New York University; teacher, Boy's High School.

Plugboard wiring and machine operation of the basic punched card equipment as used by most companies. The application of operating methods in the preparation of accounting data is performed by the student in typical machine room situations. Such operations as sorting techniques, reproducing, gang punching, merging, matching, listing, tabulating, addition and subtraction, controlling, total transfer, x and digit selection, are included in the procedures. Covers the key punch, sorter, interpreter, reproducer, collator, and 402 tabulator.

Intended for those who want to enter the punched card field, for machine operators who want a fuller understanding of plugboard wiring, and for management personnel who desire a detailed knowledge of the principles and functions of punched card accounting equipment.

517. PS19E — INTERMEDIATE PLUGBOARD WIRING FOR PUNCHED CARD MACHINES, Fee: $50. (includes materials)

WILLIAM J. HAYES — Instructor, Division of General Education, New York University; Programmer, Electronics Department, Installations Division, Metropolitan Life Insurance Company.

Plugboard wiring for the reproducer, collator, and tabulator (402-403), describing advanced wiring for such operations as interspersed master card and offset gang punching, field selected reproducing, combined reproducing, gang punching, and summary punching, mark sensing, crossfooting, multiple x selection, summary punching, progressive total printing, tape controlled carriage, multiple line printing, and selectors. Extensive use of the latest visual aids.

Prerequisites: PS19D, PS19M, or their equivalents.

518. PS19K — PLUGBOARD WIRING FOR ADVANCED PUNCHED CARD TABULATING EQUIPMENT, Fee: $50. (includes materials)

WILLIAM J. HAYES

Covers the plugboard wiring for operations performed on the Accounting Machine Type 407. The applications discussed include such wiring problems as listing, controlling, adding, subtracting, multiple selection, counter coupling, total transfer, alteration switches, summary punching, class and field selection, tape controlled carriage, and multiple line reading. Heavy emphasis is placed on selector operation. Such problems as (a) expanding digit selectors by the use of pilot selectors, (b) conserving pilot selectors through the use of the comparing relays, and (c) the theory of the selector holding circuit are discussed. The theory of the "echo" impulse and the "reset check" circuits is reviewed. Extensive use of the latest visual aids.

520. PS19L — PLUGBOARD WIRING FOR ADVANCED PUNCHED CARD CALCULATING EQUIPMENT, Fee: $50. (includes materials)

WILLIAM J. HAYES

Covers the plugboard wiring for operations performed on the Electronic Calculator Type 604. The wiring problems cover such operations as adding, subtracting, multiplying, dividing, successive calculation, group multiplication, factor expansion, and selection. The approach to all problems is made through the use of the problem analysis chart with the aim being that the student think through each problem, breaking it down into logical sequential steps. The system for debugging a complicated problem, using the operator's indicator lamp panel, is explained thoroughly. The binary system used in the calculator is reviewed with the extensive use of visual aids.

521. PS19 — PLANNING AND MANAGING PUNCHED CARD SYSTEMS, Fee: $50. (includes materials)

EUGENE F. MURPHY — Lecturer, Division of General Education, New York University; management consultant.

Designed for those concerned with the over-all development and economical operation of punched card installations. Of special interest to executives of comptroller and treasurer level, office managers, methods and procedures analysts, and accountants. Emphasizes the importance of procedure development, card design, document originating, coding, scheduling, and accuracy control. Also embraces the principles involved in converting a clerical procedure to a punched card basis, such as space layout, supervisory development, training requirements, and instruction writing. Case problems of greatest interest to the group are presented together with group discussions, work charts, and presentations by guest lecturers.

Prerequisites: PS19B or the equivalent.

Electronic Data Processing Program

The Electronic Data Processing Program offers a series of carefully integrated courses designed for those who are already engaged in the actual preparation of computer programming and also for those who wish to prepare themselves for advancement in this rapidly expanding field.

For those currently employed in computer centers, the program offers more specialized training in both programming and the actual operation of computers. It offers the opportunity for such personnel to increase their ability in the formulation and analysis of problems arising in large-scale data processing and in the evaluation of the questions that arise concerning the choice of a computer system for a group of data processing problems. The program is also intended for those in management who wish to familiarize themselves with the necessary information on high-speed and integrated data processing equipment to prepare for its orderly introduction in the office. Certain courses are recommended for those who wish to acquire the necessary training as beginners.

A Certificate in Electronic Data Processing is awarded to those who complete a minimum of three courses. Completion means attendance at 80 per cent of the class sessions and a minimum grade of B on final examinations.

523. PS19A—OFFICE AUTOMATION: ELECTRONIC AND TAPE-PROCESSING SYSTEMS, Fee: $50. (includes materials)

EUGENE F. MURPHY

Prepares management personnel for the orderly introduction of electronic and tape-processing devices in the office. Provides necessary information on high-speed and integrated data-processing equipment so that management can consider the type, size, and cost of the electronic device needed for specific office applications. It enables management personnel to discuss and report on the systems of communication, computer arithmetic, and components such as magnetic drum, magnetic core, delay lines, high-speed printers, and tape-processing equipment. The general approach to programming, personnel requirements, and systems evaluation is also covered. Demonstration of actual electronic installations is included, as well as special presentations by guest lecturers. No technical training is required.

527. PS19H — PROGRAMING AND CODING METHODOLOGY FOR MEDIUM-SIZE COMPUTERS IN BUSINESS, Fee: $50. (includes materials)

KARL L. FREYTAG—Instructor, Division of General Education, New York University; Senior Procedure Analyst, Coordination Division, Metropolitan Life Insurance Company.

Designed for those concerned with the practical problems of planning for and using a medium-size computer on business problems. Course covers problem planning, flow charts, programing, program debugging, subroutines, machine editing, trace routines, optimization routines, and automatic rerun techniques. Intended for middle management executives, managers of punched card installations, and personnel responsible for the actual preparation of computer programs.

528. PS19J — PROGRAMING AND CODING METHODOLOGY FOR LARGE-SCALE COMPUTERS IN BUSINESS, Fee: $50.

JOHN A. COMERFORD — Instructor, Division of General Education, New York University; Manager, Development Bureau, Machine Accounting Department, Consolidated Edison Company of New York, Inc.

An introduction to the methods, practices, and procedures currently employed in the use of large-scale digital computers for such clerical operations as inventory control, payrolls, sales analyses, and other business problems. Special attention is given to record design, incoming data analyses for errors, study of logic involved in repetitive items handling, and the editing of records produced by a computer.

Covers the preparation of flow charts and logical diagrams on work procedures in language understandable to both the supervising executive and the technician responsible for preparing the machine instructions for a computer.

Intended for middle management executives, procedure analysts, and technical personnel responsible for the actual preparation of computer programs.

529. PS19P — OPERATING AND PROGRAMING LARGE-SCALE DIGITAL COMPUTERS FOR BUSINESS APPLICATIONS, Fee: $75. (includes laboratory fee)

JOHN A. COMERFORD

Designed for those who are familiar with coding and the logic of the computer but who require more specialized training in programing and in the actual operating procedures of a large-scale computer. The workshop illustrates the flow charting of business problems and their translation into computer language. The appropriateness of alternate methods for different types of computers is discussed. Actual use and operation of a computer is included in the instruction as well as the testing of programs. A thorough study is made of the commands used in computers. Automatic coding techniques, debugging techniques, and library routines are illustrated. The importance of systems design is stressed.

Prerequisites: PS19A, PS19J, or equivalent experience.

530. PS19N — OPERATIONS RESEARCH TECHNIQUES APPLIED TO DATA PROCESSING, Fee: $50.

JACK HELLER — B.Aero.E., M.Aero.E., Ph.D.; Instructor, Division of General Education, New York University; Research Scientist, A.E.C. Computing Facility, New York University.

An introduction to the mathematical formulation and analysis of problems arising in large-scale data processing with digital computers. A general classification of types of data processing problems is formulated, studied, and illustrated by examples such as statistical surveys, payrolls, single inventory control, multi-inventory control, billing, etc. The problem of time and cost estimates of single data processing to be performed on a digital computer or system of computers is formulated and analyzed. Questions arising in the choice of a computer system for a group of data processing problems are discussed. Intended for management executives, procedure analysts, and statisticians who are responsible for the analysis and general formulation of data processing programs.

Prerequisite: Experience in Programing.

(Continued on page 29)

A Survey of IBM-650 Users

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10. The average number of full-time programmers employed exclusively for the operation of a computer and associated equipment is seven. The aircraft industry averaged 13 and the other industries averaged six with little variation among them.

11. Of the 11 aircraft companies who responded all of them favored a decentralized computer organization, while 65 of the remaining 70 respondents favored a centralized organization.

Other less significant findings included:

1. No significant differences could be found among the various industries in regard to either the number of 650's installed or on order. This also applies to other types of similar computers.

2. As would be expected the primary use of a computer in the aircraft industry is scientific. Generally the other industries have data processing uses.

3. The ranking of applications for those companies whose primary use is data processing is:

1) Payroll
2) Premium billing and analysis
3) Cost accounting and budgeting
4) General accounting and reporting
5) Production and material scheduling
6) General engineering problems

The ranking for those whose use is scientific is:

1) General engineering problems
2) Rocket, missile and engine design and performance analysis
3) General mathematical problems
4) Aerodynamics
5) General statistical analysis
6) Payroll
7) Production and material scheduling

The presence of a few scientific applications in the list for companies which use their computers primarily for data processing and vice versa suggests that because of the cost of a computer, in order to attain maximum utilization it is necessary to adapt as many uses as possible to it rather than have it dominated by a single department.

The results of the questionnaire have established that there is a definite difference between the scientific and the data processing users when cross-classified against personnel requirements, the question of centralization vs. decentralization and uses for which the computer is being applied. However the latter analysis shows that the applications are not entirely different between the two.

It may be noted that little was done with the question concerning personnel requirements except for the segment dealing with number of full-time programmers and number of persons employed exclusively for computer operation. The reason for this is that the other part of the question was badly written and consequently a great deal of ambiguity in interpretation resulted.

The authors wish to express their thanks to those who responded. They feel that the survey was valuable in establishing the link between classroom study of theory and the use of computers in the business world. It is their hope that this report will be of interest to the companies which cooperated so excellently.

Forum

(Continued from page 27)

THE MAKER OF COMPUTING MACHINES

George R. Price
Kingston, New York

ONCE, as in a vision, I saw an old man as magnificent as a statue by Praxiteles or Michelangelo, with white hair that fell to his shoulders and a full white beard. He spoke with the voice of a king, and he carried himself like a ruler of men, so that all who knew him regarded him with wonder and esteem. Now, it is said that in his youth he had had much liking for the spectacular, and was wont to build tremendous fires and set off such explosions that the very earth seemed to shake. And they say that later he became a mighty builder and erected huge edifices that even today astonish the eye. I remember the house where I was born. Its foundations were of solid steel, and its walls he had built of massive rock to endure for the ages. And now in his old age he had become a master artificer, and created wonderful mechanisms of surpassing delicacy.

Never did Swiss watchmaker or craftsman of old Nuremberg fashion such miraculous devices. He had built a relay as tiny as a mote of dust, yet swift as a thyratron. He made camera tubes more sensitive than image orthicons, yet no larger than an acorn. He had little microphones that were amazingly sensitive over a range of seven or eight octaves, and machines smaller than the head of a pin that were more complex than an automobile.

Now at this time the twin sciences of instrumentation and servo-mechanism design were just getting started, and on these the old man concentrated his efforts. And shortly his home became like an Arabian Nights palace, with myriad little automatons that turned to watch him as he strode through the halls, synthesized exotic perfumes for him, or grouped themselves into delicate patterns to please his eye. Next, computing machines became all the rage, and the old man set to work on these.

His first models, his Series 1 computers, were of largely conventional design, though constructed as beautifully and painstakingly as an illuminated manuscript. They had Input Devices for receiving information, a Computing Organ, a Memory, and Output Devices for furnishing the results of their computations. And set over all was a Control Unit that directed the transfer of data among the different units of the computer, determined what computations should be performed and what should be done with the results, and so forth, setting up the necessary electrical connections as required. Perhaps the only really unconventional feature was that these Series 1 computers, like the simple servomechanisms that had preceded them, were made self-repairing, like self-sealing gasoline tanks, but far more artfully. While there were many servants in the old man's house, he built many computers too, and I fancy he would have had little time for new designing if his machines could not repair themselves.

Very early, before the Series 1 had undergone much development, the old man made the first of his great inventions, and started on the Series 2. And this invention, I hold, was the greatest that ever was made. Compared with it, wheel and lever, plow and loom appear insignificant. Though in its immediate consequences it was not so spectacular as some of his later inventions, yet it implied and prepared the way for those later ones. And though it may seem a quite simple thing, yet it is worthy of the deepest thought. Aeschylus might have made it the theme of a trilogy mightier than the tale of the theft of fire from heaven, or Sophocles might have found in it a meaning more profound than in the story of Oedipus.

The need that produced the invention was this: In the Series 1 computers, the Control Units were themselves governed by programs of instructions, but the labor of programming the many computers was too great for the old man and his servants. Therefore it was necessary to redesign the computers so that each could devise its own program. Now the computers had certain *goals*, such as correctly answering problems, keeping themselves in repair, and so on, and the programs caused the computers to behave in such a way as to tend to attain their goals.

To make this goal seeking automatic, the old man built into the Control Unit an Evaluator Organ, setting it functionally superior to the remainder of the Control Unit. To the computers he added certain devices—new Input Devices and such—that gave to the Evaluator Organ measures of success or failure in reaching the goals; and he so arranged things that when a computer was reaching its goals, the connections then in use would be favored in future computations, while when it was far from its goals, other impulses were sent out by the Evaluator Organ to modify the switching network so that those relays then closed would close with greater difficulty in the future. This meant that the Series 2 computers after a time automatically set up those connections for routing information, that would favor the reaching of the goals. This was the invention, and the consequences were strange and wonderful.

At that time the old man lived in a great house on the broad top of a hill, and the machines he built he kept, some in the house, some in the gardens at the east of the house, and most of them in a wide field at the foot of the hill.

The Series 2 computers he built in great number and in a variety of shapes and sizes. He equipped them with wheels and motors so that they could move about by themselves, and he gave them among their goals that of seeking fuel for the motors when necessary. And the strange thing about these machines was the way they moved about. To watch one, you would have sworn that it was alive—except that you saw its wheels and metallic sheen and the lenses that focussed light on its camera tubes, and all the other signs of its mechanical nature. Some of the Series 1 machines, to be sure, possessed the power of locomotion, but there was much difference between their behaviour and that of the Series 2 machines.

Much of the lifelike behaviour of the Series 2 computers came from what the old man called the *avoidance reaction*. I have seen, for example, a Series 2 machine fall down a rocky slope, denting one side and twisting an axle; and in the future that machine, in moving about through the field, always avoided the slope, for the injuries it received caused the Evaluator to set up connections that kept it away from the slope. And I have watched a Series 2 machine firmly fastened to the ground while its outer covering was unbolted and its inner mechanism investigated and rearranged. All during this process its wheels turned frantically back and forth, and hoarse sounds came from its loud speaker and horn, and while it was open one could see its gears turning erratically and clashing and grinding against each other.

The cause of this behaviour was simply that one of the computer's built-in goals was that of maintaining its form, so when it was opened up and its internal mechanism altered, the Evaluator set up connection after connection in a vain effort to prevent the manipulations. This was all there was to it, and yet one might almost have supposed that the machine could feel the sensation of pain.

In addition to the avoidance reaction, there was also an *approach reaction*. I have witnessed it when, for example, I have supplied a Series 2 computer with fuel or otherwise benefited it. For a time, then, the machine may tend to follow me about—though this happens more frequently with the later and more elaborate machines. Concerning this approach reaction, I believe that the old man for a long time had high hopes and thought that it might lead to great consequences, for he apparently did not at that time appreciate the enormous difficulty of what he wanted ultimately to achieve.

As he built more and more of the Series 2 machines, the old man kept making the computing mechanism larger and more elaborate. What he sought particularly to add was the power of association or analogy, so that, for example, a machine that had been injured on one particular slope would avoid not only that locality but all others like it. To this end, while he retained much of the original form of the Series 2 computing mechanism, he built over and around this primitive portion, a great complex system of relays and interconnecting wires woven together like some vast Persian rug of incredible intricacy. And this device worked as he had hoped it would, and he built new and ever more wonderful computers, till the garden and the field were filled with them, and he saw that his work was good, and he was pleased.

For a very long time indeed the Series 2 computers satisfied the old man, but at length he made the second of his great inventions, and produced the first of the Series 3 machines. What he added by this invention was a new extension in time. The old servomechanisms had worked mainly in the present, while the Series 1 and 2 computers, through the Memory Units, extended into the past as well. But now, to the Series 3 machine, the vast expanse of the future was open.

He built the computing mechanism much like those in the later Series 2 machines, but vastly larger and more complex, and above and at the front of the rest he placed a new unit, the Super-Evaluator. This was closely coupled to the old Evaluator, but well separated from Input and Output Devices, so that it could concern itself with the future and be free from the impulses of the present. With this device, infinite new possibilities of complex behaviour were opened to the computers. They were free from the simple need to directly seek a goal, so that they could seek distant, altered goals through devious routes.

When the first of the new computers was finished, the old man set it in the garden to the east of the house. Each day he patiently taught it, and it grew wonderfully in intelligence, and in time learned to talk. And the old man saw that his work was good and he rejoiced, and for a time he rested from his work. Each day he walked in the garden and talked with the Series 3 machine, and told it of all the wonders of the world. And after a time he built a second Series 3 machine and placed it also in the garden and taught it as he had the first. The two machines talked together, and explored the garden, and studied the machines they found there, and the old man was pleased with them.

But one day the old man had been away from the house on business in some distant field almost invisible from the hill top, and when he returned he found that his laboratory had been broken into and his notebooks opened and studied. On the floor he saw the marks of wheels, and he was afraid, for the Series 3 machines, though dull and gross, nevertheless had a certain sly cleverness. What, he asked himself, will happen if they have further opportunity to study my notes and learn all my art? Will they not then become a menace to the whole world? So he grew angry, and he drove the two Series 3 machines out of the garden and down the hill into the field, and he built a great wall around the field so that they could never return to the garden.

Still the old man was proud of his work, and he frequently visited the field and talked with the two machines, and after a time he built two more. But one day when he came to the field, there were only three of the Series 3 machines, and the parts of the fourth were scattered about the ground. He saw that what he had suspected and feared was true. Somehow, in all that maze of wire and relays and magnetic memory cells, somehow there was not only intellect but also savagery, for one of the machines had destroyed another.

I think that from that day forward he took but little pleasure in the Series 3 machines, though he built a great many more. Less and less frequent grew his visits to the field, and its care he turned over almost entirely to his servants. They brought him reports of what was happening there, and he learned that the sight that had saddened and worried him was often repeated. Never a day passed but the ground was strewn with the wreckage of some Series 3 computer destroyed by its fellows.

The computers had also learned another sort of behaviour that was equally displeasing to the old man. Several machines would seize one of their fellows, hold it firmly, and slowly and ingeniously take it apart, thereby producing an intense avoidance reaction, with swift spinning of wheels, clashing of gears, loud, meaningless noises from the loud speaker. The Series 2 machines had frequently destroyed one another, but never on such a scale as the Series 3, and never had they shown this second type of behaviour. He realized that this was a matter of some derived, complex goal made possible by the Super-Evaluator.

Worse and worse became the behaviour of the machines, until the old man began to wonder whether he had invented, not a digital computer, but rather the pure quality of malevolence. Finally he went among them and studied them and selected eight of them whose behaviour was passable. He placed these eight on the highest portion of the field, and all the others he destroyed by flooding the field. With the eight he would make a new beginning.

The difficulty, he saw, was in the great complexity of the computers. The simple goals that he could build into them directly could control only the tiniest portion of their behaviour. Most of what they did was controlled by the goals established in the Super-Evaluator, and based upon what they had experienced. So the problem was to teach them correctly. The eight machines he had selected and saved would furnish an example to those that followed. He made more Series 3 machines and set them in the field; but presently the old behaviour returned.

Now the old man had lived all his life without issue, but in his old age a son was born to him. This son grew into so wonderful a youth, so comely in feature, so generous in nature, so firm in character, that all who met him were amazed at his goodness and none ever forgot him. I imagine that many a time the old man and his son had discussed together the problem of the Series 3 machines. The problem, the old man explained, was one of goals. It was easy to design a machine so that it would seek a simple goal. If, for example, he wanted to design a computer so that it would seek the brightest possible illumination, he had only to provide it with a phototube connected in such a way as to send the proper type of impulse into the Evaluator. Then the Evaluator would adjust the circuitry in the remainder of the computer in such a way as to encourage the sort of behaviour that caused the phototube to be illuminated.

But the goal he wanted in his machines was altruism, benevolence, cooperation. How could anything so complex be programmed? What was needed was an Input Device that would send impulses to the Evaluator in proportion to the benevolence of the machine's behaviour—but how could he build an Input Device to measure benevolence? All he could do was provide the Series 3 machines with a few simple built-in goals that the Super-Evaluator could elaborate into complex goals.

He had made the Super-Evaluator powerful so that the derived goals could be stronger than the original ones, and he had tried to design the built-in goals so that they would, through experience, tend to turn into benevolence. But somehow, things usually seemed to go wrong. The final behaviour of the machines after they were fully trained seemed often to be the precise opposite of all that he had tried to build into them. Instead of the approach reaction, he found the avoidance reaction; instead of benevolence and cooperation, malevolence and strife.

What was necessary, the old man continued, was to keep on trying to design a computer in which benevolence was a built-in, powerful goal. In the meantime, though, they had the Series 3 machines. Left to themselves, they always seemed to acquire the wrong behaviour. So what they must do was to furnish them with a detailed set of rules to precisely regulate their conduct.

In due time the rules were formulated and communicated to the machines. Some of these rules were followed and some ignored, but on the whole I think there was but little change, and most of that was for the worse. The destruction of machine by machine continued unabated, and the avoidance reaction was elicited in cleverer and cleverer ways.

At length the old man decided that the time had come to destroy the Series 3 machines. "They are creatures of hatred," he said to his son. "I have labored over them for many years, and they have brought me only sorrow and regret. Before, I spared eight of them. This time, none will survive."

"Father," said the young man, "let us try once again. Let me disguise myself as one of them and go down among them and teach them."

"What will you teach them?" asked the old man. "I have given them laws, and they obey only the ones that do not hamper them in their malevolence."

"We have given them too many laws," said the young man. "I will teach them one law only: that they shall love one another."

So it was decided, and the young man concealed his fair human body within the harsh metallic confines of a machine, and left the house and went down the hill. And I think that in all the history of the world there was never any sight so strange and wonderful as this. As he descended the hill, his father's servants came and stood at the doors and windows watching, and from that great house through the open doors and windows floated the strains of wondrous music following him down the hill. And they say that at the sound of this music the machines in the field below forgot for a moment their hatred, and their coarse savagery was softened, and for a while they gazed upward at the hill in wonder.

For many days the young man lived among the machines disguised as one of them, and sought to teach them the new law, but in the end they turned upon him so that he barely escaped with his life, while the machine in which he had hid, they destroyed slowly and with much ingenuity to produce the avoidance reaction.

Then, I think, the old man and his son had little to do with the machines and the field for a long time. Ever more and more malevolent did the Series 3 computers become, ever more and more ingenious in destruction and in elicitation of the avoidance reaction.

And in my vision I thought I saw once more the old man and his son. They dwelt in a castle on top of a mountain so high that one could see the sun and the stars together in the sky. "My son," said the old man, "I have designed a new computer in which the goal of benevolence has been built in directly. These will be the Series 4 machines, and to them love will be more natural and inevitable than hatred was among the

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NEW PATENTS

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THE following is a compilation of patents pertaining to computers and associated equipment from the "Official Gazette of the United States Patent Office," dates of issue as indicated. Each entry consists of: patent number / inventor(s) / assignee / invention. Printed copies of patents may be obtained from the U.S. Commissioner of Patents, Washington 25, D. C., at a cost of 25 cents each.

July 16, 1957: 2,799,449 / Alan M. Turing, Wilmslow, Donald W. Davies, Southsea, and Michael Woodger, Ashtead, Eng. / National Research Development Corp., London, Eng. / A data storage transfer means for a digital computer.

2,799,450 / Robert R. Johnson, Pasadena, Calif. / Hughes Aircraft Corp., Del. / Electronic circuits for complementing binary-coded decimal numbers.

2,799,451 / Hans P. Luhn, Armonk, N. Y. / I.B.M. Corp., New York, N. Y. / A binary code counter.

2,799,812 / Harmon G. Shively, Akron, Ohio / B. F. Goodrich Co., New York, N. Y. / An electrical decoding and work actuating apparatus.

2,799,821 / William A. Hannig, Schenectady, and Arnold H. Silver, Troy, N.Y. / General Electric Co., N.Y. / a mechanical-electrical analog converter.

2,799,844 / Arthur G. Anderson, Riverdale, and John W. Horton, New York, N. Y. / I.B.M. Corp., New York / A spin echo memory process.

2,799,845 / Ernest J. Dieterich, Watertown, Mass. / Raytheon Manufacturing Co., Newton, Mass. / A time selector for selectively transmitting recurring items of stored information.

2,799,846 / David A. Negrin, Fanwood, N. J., and Robert Leffler, Dayton, Ohio /— / A fault warning indicating system for use in detecting and indicating the existence of a fault condition in any one of a plurality of monitored channels.

July 23, 1957: 2,800,277 / Frederic C. W. Timperley, Tom Kilburn, Manchester, Geoffrey C. Tootill, Swigdon, and Brian W. Pollard, Hollinwood, Eng. / National Research Development Corp., London, Eng. / A controlling arrangement for electronic digital computing machines.

2,800,278 / Graham I. Thomas, Hollinwood, Eng. / National Research Development Corp., London, Eng. / A number signal analysing means for electronic digital computing machines.

2,800,279 / Siegfried Hekster, Oegstgeest, Necherlands / — / A device for determining the resultant of series or parallel complex resistance in arbitrary combinations.

2,800,280 / Munro K. Haynes and William W. Lawrence, Poughkeepsie, N. Y., and Gordon E. Whitney, Derby, Colo. / I.B.M. Corp., New York, N. Y. / A comparing system.

2,800,584 / Richard F. Blake, Wash., D. C. / U.S.A. / A pulse position decoder.

2,800,643 / Auguste F. Mestre, Saint-Maur-des-Fosses, France / I.B.M. Corp., New York, N. Y. / A matrix memory system.

July 30, 1957: 2,801,050 / Orlando J. Murphy, New York, N. Y. / Bell Telephone Lab., Inc., New York, N. Y. / For a computing system a pulse system producing nulls in electrical networks.

2,801,051 / Earl S. Perkins, Hinsdale, Ill. / Butler Co., Chicago, Ill. / A navigational system for dirigible craft.

2,801,344 / Samuel Lubkin, Bayside, N. Y. / Underwood Corp., New York, N. Y. / A magnetic gate circuit for gating both positive and negative input pulses.

2,801,405 / Walter S. Oliwa, Irvington, N. J. / Monroe Calculating Machine Co., Orange, N. J. / A circuit for comparing two binary coded items.

2,801,406 / Samuel Lubkin, Bayside, N. Y. / Underwood Corp., New York, N. Y. / A data processing system for processing mixed alphabetic and numeric data.

August 6, 1957: 2,801,795 / James O. Williams, Waverly, Ohio / — / A trigonometric computing device.

2,801,815 / Everard M. Williams, State College, Pa. and Edwin V. Cousy, Dayton, Ohio / — / A remote control system.

2,802,138 / Howard E. Tompkins, Ridley Park, Pa. / Burroughs Corp., Detroit, Mich. / Computing elements and systems.

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New Patents

(Continued from page 32)

2,802,160 / William E. Engeler, Syracuse, N. Y. / General Electric Co., N. Y. / An intermediate zone locating servo-system.

2,802,203 / Raymond Stuart-Williams, Pacific Palisades, Calif. / Telemeter Magnetics and Electronics Corp., Los Angeles, Calif. / A magnetic-memory system.

August 13, 1957: 2,802,625 / Arthur H. Dickinson, Greenwich, Conn. / International Business Machines Corp., New York, N. Y. / An electronic multiplying and dividing machine.

2,802,953 / William R. Arsenault, Santa Monica, and Allen E. Garfein, Culver City, Calif. / The Magnavox Co., Los Angeles, Calif. / A magnetic flip-flop circuit.

2,802,976 / James E. Brook, Hackensack, N. J. / Bendix Aviation Corp., Teterboro, N. J. / A position servo.

2,802,978 / Robert G. Legros, Sevres, France / — / A distant control device for rotatingly positioning a shaft on precise preset positions.

2,803,003 / Sigmund B. Pfeiffer, New Providence, N. J. / Bell Telephone Lab., Inc., New York, N. Y. / A reflected binary digital-to-analog converter for synchro devices.

2,803,221 / John R. D. Walker, Rugby, John D. Oates, London, and John E. M. Combes, Manchester, Eng. / Vickers-Armstrong Lim., London, Eng. / A follow-up remote control system.

2,803,399 / Thomas D. Morgan and William L. Morris, Bartlesville, Okla. / Phillips Petroleum Co., Del. / A computer for solving convergent systems of linear simultaneous equations.

2,803,401 / Eldred C. Nelson, Los Angeles, Calif. / Hughes Aircraft Co., Culver City, Calif. / Arithmetic Units for electronic digital computers.

2,803,402 / Edward J. Rabenda, Poughkeepsie, N. Y., and David W. Rubidge, Chatham, N. J. / International Business Machines Corp., New York, N. Y. / A device for segregating aggregate information contained at cyclically repeated index points on a statistical tape.

2,803,405 / William D. Howell, Deep River, Ontario, Canada / U.S.A. / An apparatus for providing count or time control of a series of counting operations on trains of electrical pulses and for automatically recording the results.

The Maker of Computing Machines

(Continued from page 31)

Series 3. We can let them dwell among us, and we can feel perfect trust in them. Today I have finished the first of the Series 4."

Then the old man and his son looked away toward the east, but I could not see what it was that they saw there.

After a time the young man turned back toward his father. "And what," he asked, "is to become of the Series 3 machines? Would it not be well for us to destroy them now? They grow rapidly more and more clever. Already they have built enormous crude computers of the Series 1 type, which they use mainly for destruction. They have invented hideous new weapons, and soon they will be able to surmount the wall that you long ago placed around the field. Let us destroy them quickly."

"There is no need," said the old man. "They will do it for us. Let us watch for a while, and presently we shall see a fine spectacle. See, over yonder to the south, that field that looks like the crater of a burned-out volcano. I well remember the magnificent explosion that I set off there in my youth. In a few moments we shall see below us another such explosion."

ADVERTISING INDEX

Following is the index of advertisements. Each item contains: Name and address of the advertiser / page number where it appears / CA number in case of inquiry (see note below) / name of the agency if any.

READER'S INQUIRY

If you wish more information about any products or services mentioned in one or, more of these advertisements, you may circle the appropriate CA Nos. on the Reader's Inquiry Form on p. 32 and send that form to us (we pay postage; see the instructions). We shall then forward your inquiries, and you will hear from the advertisers direct. If you do not wish to tear the magazine, just drop us a line on a postcard.