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THE INTEGRATED ELECTRONIC DATA PROCESSING SYSTEM AS AN INTELLIGENCE CENTER

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CHAPTER I

INTRODUCTION

The purpose of this thesis is to investigate the development of electronic data processing equipment and its present applications in the manufacturing organization; to isolate the advantages and disadvantages accruing from the centralization of data processing in the organization; to search for evidence that the integrated systems now installed are being used as intelligence centers.

The approach used is a search of the literature, which is relatively limited not only because of the newness of the field, but also because manufacturers who have installed integrated systems are not overly interested in publicizing any applications which might hold competitive advantages for them. Because of these limitations, some judgment and intuition have been used to fill in missing links.

Several models are proposed to indicate as simply as possible the complexities of quantifying the many internal and external variables which compose the manufacturing company. In addition, several models have been developed to indicate specific applications of the integrated data processing system as an intelligence center.

On the pages immediately following, there is a short dictionary of computing language. Ordinarily, this would be placed at the end of the thesis. However, this glossary seemed so timely and useful that it has been promoted to the front of the thesis. Most previously available definitions were developed by computer manufacturers or by individuals whose experience is limited to working with the equipment of a single manufacturer.

However, the definitions which follow were developed by the Association for Computing Machinery's Standards Committee's Subcommittee on Programming Terminology. The result is a more universal and presumably more lasting set of definitions than any of those developed earlier. These definitions were approved at a meeting held on October 26, 1962, and the first publication of them was in the April, 1963, issue of *Communications of the ACM*. This issue carried only a selected list and not the entire series of definitions. The definitions on the following pages represent only a portion of those which have now been published and have been simplified in some cases. They were selected primarily to assist the reader in coping with some of the words in this thesis which might not be understandable solely from the context in which they are used. Secondarily, they were selected in the hope that they might be useful to the reader in coping with the almost daily break-throughs which are announced through the general news media.

A Brief Dictionary of Computing Language[1]

Algorithm - a process carried out a cording to a precise prescription leading from given, possibly variable, data to a proven definite result.

Artificial Intelligence - the study and science of the use of computers and related mechanisms for the solution of problems involving reasoning, usually with the additional requirement that performance improves with experience.

Bug - a mistake in a routine, or malfunction in a computer.

Calculator - a device for performing arithmetic on which the sequence of operation codes is either impressed manually, e.g. desk calculator, or introduced from a pin board or punch board, e.g. a card-programmed calculator. A calculator performs arithmetic and possibly logical operations upon data, but not upon its own program.

Computer - (1) any device capable of solving problems by accepting information, applying prescribed operations to the information, and supplying the results of these processes.

(2) more specifically, with regard to digital computers, a device for performing sequences of arithmetic and logical operations, not only on data but also on its own program.

(3) still more specifically, a stored program digital computer capable of performing sequences of internally-

stored instructions, as contrasted with a calculator on which the sequence is impressed manually, e.g. desk calculator, or on which the sequence of instructions is executed as obtained from tape or cards, e.g. card-programmed calculator.

Computer, Analog - a computer which operates on continuous electrical or mechanical phenomena. Problems are solved by the computer operating on physical analogs which have the same mathematical relationships as the problem variables. Briefly, an analog computer measures whereas a digital computer counts.

Computer, Digital - a computer utilizing discrete numbers to express all the variables and quantities of a problem. A digital computer counts while an analog computer measures. Problems are solved by arithmetically implementing the mathematical relationships.

Cybernetics - the comparative study of the control and intracommunication of information handling machines and the nervous system of animals and man, in order to understand and improve communication. Briefly, the science of control and communication in animals and machines.

Data - (1) a general term loosely used to denote any or all facts, numbers, letters, symbols, etc. which can be processed or produced by a computer.

(2) in a more restricted sense, data refers to numerical information as contrasted with non-numerical information.

(3) implying source data or raw data as contrasted with information which is then defined to mean the knowledge obtained by the processing of data.

Data Processing - (1) a general term usually applied only to so-called business applications of computers, such as merging, sorting, and updating of files.

(2) in a more general sense, the totality of operations performed by a computer.

Flow Chart - a diagram, using special symbols, illustrating a schematic representation of the flow of control in a computer program. The diagram may contain several types of elements; e.g., operation boxes, alternative boxes, connectors, along with directed lines showing the sequence in which these elements are encountered during the execution of the program. Synonym: flow diagram.

operation box - an element in a flow chart describing one or more operations to be carried out. There is one entry and one exit.

alternative box - an element in a flow chart where a decision is made. There is one entry and two or more exits. Synonyms: decision box, comparison box.

fixed connector - a symbol in a flow chart indicating that two or more points of the program are joined.

variable connector - a connector where the program may continue along one of several paths, depending on the setting of a coded switch.

Hardware - the physical equipment such as the mechanical, magnetic, electrical and electronic devices from which a computer is fabricated; the material forming a computer as distinct from the routines.

Heuristic - description of a procedure that may lead to a problem solution but one that cannot be guaranteed to lead to a solution.

Information - (1) in broad business and industrial applications of computers, the term information is used to denote a broader area than the somewhat restrictive numerical implications of the term data.

(2) knowledge obtained as a result of processing source data or raw data.

Information Processing - usually a less restrictive term than data processing, encompassing the totality of scientific and business operations performed by a computer.

Information Retrieval - the process or study of techniques employed in the storage of vast amounts of information and the extraction of any specified or particular information.

Learning - sometimes used to describe the ability of a computer program to improve its performance in solving a class of problems based on its own experience. This is achieved by means of a preplanned strategy where the program modifies itself based on results that have been obtained to this point in time.

Library - an organized collection of checked standardized routines and/or data usually assembled on a tape, disc or other bulk storage device for easy accessibility by the programmers of a particular installation or users' group.

Program - (1) the complete plan for the solution of a program.

(2) more particularly, the complete sequence of machine instructions and routines as organized to solve a particular problem.

(3) to plan the procedures for solving a problem. This may involve the analysis of the problem; preparation of a flow diagram; preparing, testing and developing subroutines; specification of input and output formats; and related phases of problem preparation.

Programming - the art and science of putting together a logical sequence of instructions to direct the actions of a computer system.

Random Access - (1) describing the process of obtaining information from or placing information into a storage system where the time required for such access is independent of the location of the information most recently obtained or placed in storage.

(2) describing a device in which random access, as defined in (1), can be achieved without effective penalty in time.

__Real-Time__ - the performance of a computation during the actual time that the related physical process transpires in order that results of the computations are useful in guiding the physical process.

__Routine__ - (1) a set of coded instructions arranged in proper sequence to direct the computer to perform a desired sequence of operations.

(2) a subdivision of a program consisting of two or more instructions that are functionally related.

(3) a __program (2)__.

__Simulation__ - the dynamic implementation of a model representing a physical or mathematical system and its phenomena by computers or other equipment imitating the behavior of the system in order to enable study of the system. The system simulated by a computer may be another computer.

__Simulator__ - (1) a system of computer routines which effectively converts an actual, physical computer into a different, perhaps hypothetical, computing device, thus providing a means of simulating the actions of the latter by means of routines written for the former.

(2) a system of routines to simulate some

physical complex such as a refinery, a network of factories and transportation links, maneuvers of armed forces and the like. This definition has to do with the application of computers and programming techniques rather than the programming systems, per se, as implied in the first definition.

Software - the totality of programs and routines used to extend the capabilities of computers, such as generators, compilers, assemblers and operating systems.

Storage - (1) any device into which data can be placed, which will hold this data, and from which the data can be copied at the later time. Synonym: store.

(2) in particular, the erasable or internal storage in a given computer.

Subroutine - the set of instructions necessary to direct the computer to carry out a well-defined mathematical or logical operation. A subroutine differs from a routine in that it contains at least one unset program parameter. Subroutines are usually considered to be of two types, open or closed. A subroutine not stored at the place at which it is to be used is a closed subroutine. A subroutine in the form that it can be inserted directly at the point in the main instruction sequence where it is to be executed is an open subroutine.

System - (1) a collection of parts united by some form of regulated interaction, an organized whole.

(2) a collection of service routines which sequences programs through a computer, provides conversion, input/output and debugging subroutines and makes helpful remarks to the operator is known as an operating system.

(3) as used in some computing installations, the system includes, and defines the interrelationship of, hardware, service routines, processing procedures and accounting methods.

CHAPTER II

HISTORY OF THE DEVELOPMENT OF COMPUTING DEVICES

9th Century B.C.	Place value concepts were developed (Hindu-Arabic origin).
542 B.C.	Bamboo rods were used in China for calculating.
300 B.C.	Euclid developed geometry as a logical subject (Greece).
650 A.D.	First example of Hindu numerals used outside of India was found in Mesopotamia.
12th Century	The Chinese developed an abacus made from beads and rods. One type of abacus is still being used today in Chinese banks and shops. Shortly after World War II, an American clerk was pitted against a Japanese bank clerk in Tokyo in an abacus-versus-desk calculator contest. The Japanese won every problem presented.
1614	Logarithms were invented by John Napier (Scotland). This was extremely important in helping astronomers chart the skies,

	aiding sailors to plot their locations, and enabling engineers to build cities, highways, and dams.
1617	John Napier developed numbering rods or "bones" that simplified the tiresome work of multiplication.
1620	Edmund Gunter built the first slide rule (England).
1622	William Oughtred, an English mathematician, used two sticks marked with logarithmic scales to make an improved slide rule for multiplication and division.
1624	The first comprehensive table of logarithms was published by Henry Briggs (England).
1643	19-year-old Blaise Pascal became so bored with adding figures in his father's office in Rouen, France, that he built a mechanical calculating machine based on gear wheels. Each wheel could be set at any one of ten positions 0 to 9, and each had a tooth for nudging the next counter when it passed from 9 to 0, so as to carry 1 into the next column. The results

of addition or subtraction were shown through small openings or windows.

1671 The first machine that could multiply automatically was built by Gottfried Wilhelm von Leibniz (1642-1716), the German mathematician who discovered the principles of calculus at about the same time as Sir Isaac Newton. A special device controlled automatically the amount of adding to be performed by a given digit, and in this way he invented the first multiplying machine. Leibniz also incorporated a stepped wheel or drum having on part of its outer surface nine teeth of increasing length, from one to nine, an idea which is still in use today.

1780 A Frenchman named Joseph Marie Jacquard developed an automatic weaving loom which operated from instructions punched into cards or paper tape. The machine was so radical that very few were sold. However, a working exhibit at the Paris World's Fair sold hundreds of looms. Some Jacquard looms, practically unmodified, are still in use today.

1786 J. H. Mueller read a paper in England entitled "Automatic Computing Machines." This paper contained almost all the basic principles that are applied in modern-day computers. Had the technology of the day been adequate, they actually could have built a computer in the late 1700's.

1812 An Englishman named Charles Babbage designed a steam-driven machine to compute and print mathematical tables. In 1822, the British government supplied funds for developing this machine which Babbage called a "difference engine". This was actually the world's first digital computer. It had a "memory" derived from the same sort of punched cards as those used in Jacquard's loom. Cards also would be used for input to the machine and control of successive operations. The machine was to have an arithmetic unit (a "mill") in which to store data and it was to print out the results, thus avoiding transcription errors.

Babbage completed a small working model but was unable to complete a full-sized version because he could find no manufacturer who was able to produce the needed parts. But, his concepts were perfect--complete and accurate.

One of Babbage's cohorts was Lady Lovelace, the daughter of the poet Lord Byron, who was a mathematical genius. She developed a form of binary arithmetic, and an "infallible" betting system through which she lost both her fortune and her husband. More important is the fact that she worked out some very complicated programs for the "difference engine" and might be considered the world's first programmer.

1820 The first successful calculating machine manufactured on a commercial scale was invented by Charles Thomas of Colmar in Alsace, France. This machine performed all four arithmetical operations through the use of three distinct sections which were concerned with setting, counting, and registering.

1850 The runner was first added to the slide rule by Taverier-Gravet, a French company.

1850 The first key-driven adding machine was

	patented in the United States by D. D. Parmalee. It could add only a single column of digits at a time.
1872	E. D. Barbour incorporated a printing device with an adding machine.
1872	In England, Lord Kelvin built a machine made up of pulleys, weights, and connecting rods that was used to predict the height of the tides.
1875	Frank Stephen and W. T. Odhner developed a calculator still being made in many countries. Marchant manufactures this calculator in the United States.
1876	The first tape adding machine was developed by E. D. Barbour of the United States.
1878	The modern German calculating-machine industry was founded in 1878 by Arthur Burkhardt, who manufactured a Thomas-type machine called the Arithometer. Others, including Allen in the United States in 1927, made this same basic machine.
1883	The first cash register was developed by Patterson Brothers in Dayton, Ohio.

1887 The Comptometer, developed in the United States, was the first successful key-driven calculating machine that could handle more than one column of digits at a time.

1889 The invention of the punched card by Herman Hollerith of the United States laid the foundation for automatic sorting and tabulating machines. He worked out a mechanical system for recording, compiling and tabulating census facts. Data was placed on cards the size of an old dollar bill in the form of holes made with a conductor's hand punch. The cards were then positioned, one by one, over cups filled with mercury. Rows of telescoping pins were dropped to the surface of the card and where there were holes, the pins went through to the mercury, made an electrical circuit, and caused a dial pointer to move one position. This system made possible the completion of the 1890 census of 62 million people in one-third the time required for the 1880 census of 50 million.

Prior to 1900, Hollerith set up similar installations to handle the New York Central's car accounting system, actuarial work for several insurance companies, and sales analyses for Marshall Field in Chicago.

1903 The "Duplex" model of the Comptometer was the first machine that could have simultaneous depression of keys in every column without interfering with the carrying of "tens".

1914 A company founded by Hollerith--which eventually changed its name to IBM--put four basic business machines on the market: a key punch for punching holes in cards; a hand-operated gang punch for coding repetitive data into several cards at the same time; a vertical sorter for arranging cards in selected groups; and a tabulating machine for adding the data punched into cards.

1915 The Ford Instrument Company produced large quantities of an analog computer which was used to find and keep the range for naval guns.

1919 The first electronic "flip-flop" circuit that pertained to digital computers was described by W. H. Eccles and F. W. Jordan in a 1919 issue of *Radio Review* (United States).

1931 Vannevar Bush of the Massachusetts Institute of Technology built the first "modern" large analog computer.

1931 C. E. Wynn-Williams published the first article about the use of thyratron tubes in counting circuits. It appeared in the *Proceedings of the Royal Society* (England).

1937 Professor Howard Aiken of Harvard University, working in conjunction with IBM, began putting together a "computer" made up of 78 adding machines and desk calculators controlled by a piano player type roll of perforated paper. This first computer was known best as the Automatic Sequence Controlled Calculator and as Mark I and was used extensively by the U. S. Navy during World War II. It depended on switches and relays for movement of internal data. Although it contains more than 750,000 parts and 500 miles of wire, it is only one-tenth the size of the machine proposed by Babbage. It is still in operation.

<u>1940</u> George Stibitz demonstrated at the Bell Telephone Laboratories an automatic digital computer for multiplying and dividing complex numbers used to analyze alternating electric circuits. Stibitz designed his Complex Computer by wiring together ordinary telephone relays. He represented each decimal digit by a code of 1's and 0's so that four relays by their patterns of being energized or not energized could express the code and designate each digit.

<u>1945</u> John von Neumann and a group at the Moore School of Electrical Engineering of the University of Pennsylvania began work on the Electronic Discrete Variable Automatic Computer, or EDVAC. Three major advances were incorporated: EDVAC used the binary number system by converting from decimal to binary language through internal circuits; ultrasonic delay lines increased memory storage capacity; a program of operating instructions was stored in the increased memory. EDVAC is still being

used at the Aberdeen Proving Grounds.

1945 The first electronic digital computer, which used electronic tubes rather than electrical relays, was the Electronic Numerical Integrator and Computer, ENIAC, which was developed at the Moore School of Engineering of the University of Pennsylvania, under the auspices of the Ordnance Department of the U. S. Army. This machine contained 18,800 vacuum tubes and it took Moore Professors J. Presper Eckert, Jr. and John W. Mauchly two-and-a-half years to solder the 500,000 connections for these tubes.

ENIAC could perform 5,000 additions and 500 multiplications per second. It was used for solving ballistics problems at the Aberdeen Proving Grounds for eight years, where it became known as the "Electronic Brain". It had no moving parts, and new electrical connections were required whenever a new problem was tackled.

1947 EDSAC, the Electronic Delay Storage Automatic Calculator was built at the Cambridge University Mathematical Laboratory by Dr. M. V. Wilkes. EDSAC also used the binary system of arithmetic and ultrasonic memory storage. But whereas earlier machines had to specify the location for each instruction, EDSAC contained an accumulator register and a program counter. Arithmetic operations were performed in the accumulator. The accumulator register simplified computer logic and enabled instructions to be read into the control unit automatically, in order, thus increasing operating speed substantially. It is still being used at Cambridge.

1948 IBM introduced the SSEC--Selective Sequence Electronic Calculator--which contained 21,400 electrical relays and 12,500 vacuum tubes. This was slower and smaller than ENIAC but it was the first electronic machine to employ a stored program. Now, with this internal storage system, the computer could modify its own instructions according to the data submitted for analysis.

1952 A highly-publicized installation of UNIVAC was made in the Bureau of the Census.

1953 More major improvements were introduced by MIT in the design of a computer known as Whirlwind I, including magnetic core storage and marginal checking. J. W. Forrester proposed the use of small ferrite cores for storing binary digits in order to achieve high operating speeds and fast memory access. The first core matrix had a capacity of 1,024 words, each word consisting of 16 binary digits. Random access to any number took only 1 microsecond. The system of marginal checking meant that weaknesses were discovered before they created failures during machine operation.

Whirlwind I was the forerunner to the SAGE (Semi-Automatic Ground Environment) computer system. This is the real-time data processing system which automates the air defense of North American and involves processing of large quantities of radar and other types of data. SAGE is considered to be the largest computer network in the world.

1953 Production of large-scale commercial computers started with IBM's 701 and Remington Rand's UNIVAC.

1956 Production of computers for business applications really started in earnest, following a 3-year gestation period during which only a few exploratory installations were made.

1963 Today's computers operate at speeds of as much as 100,000 additions per second and 10,000 multiplications per second. Whereas the storage capacity in the Harvard-IBM machine was limited to 72 storage registers, some of the current computers have access to literally millions of storage registers in less than a millionth of a second. The reliability of computers is at the point where one billion to ten billion operations take place between errors, and, in fact, automatic checking devices practically eliminate the chance that wrong results will be put out.

It is estimated that there are about 8,000 computer installations now in operation in the United States.

CHAPTER III

THE MECHANICAL AND FUNCTIONAL ASPECTS OF COMPUTERS

A. Mechanical Aspects

Two Types of Computers.--Modern electronic computers are classified as either analog or digital computers. A digital computer, such as the one designed by Babbage, carries out computations by counting or in some way working with the digits of the original problem. An analog computer measures one type of quantity, but gives a result in terms of some other quantity.

More specifically, the analog computer computes by making measurements on some parallel physical system. A slide rule is an analog computer. Automobile speedometers and thermometers are other well-known analog computers.

Digital computers deal solely with numbers that represent the characteristics of the problem. They may be special or general purpose. The computers used in numerical control of machine tools would be considered special purpose, while machines such as UNIVAC would be called general purpose.

Within the computer field, digital computers capture most of the publicity and most of the dollars. In 1962, around $1,300,000,000 was spent on purchases and rentals of digital computers, while the sales of analog devices totaled between $35,000,000 and $45,000,000. In this consideration of integrated data-processing, the word "computer" is meant to include only general purpose digital computers.

Elements in the Digital Computer.--The main task of a digital computer is to perform operations on numbers. It must be able to calculate and perform sequences of arithmetical and logical operations in accordance with programmed instructions, thus eliminating the need for human intervention at each step. Ordinarily, the computer is considered to consist of a combination of units for input, output, control, storage or memory, and processing.

Input.--The input to a computer is usually thought of as including the original recording of the data, the conversion to another medium if needed, and the actual transfer of the data into the processing unit. Ordinarily, numerical or alphabetical instructions are represented by a numerical code on punched cards or tape. More recently, the Stanford Research Institute developed the use of magnetic ink to code bank checks which can then be read directly by the computer. There is other equipment under development which can read symbols written in regular ink. Eventually, computers will be able to accept all data and instructions in ordinary, printed English. There is also research under way which is expected to result in a computer which can accept data verbally.

Punched cards are a common input medium, because they are a versatile means of storing information. Companies using punched-card equipment can continue to use it when they convert to faster electronic data processing systems. Although computers can read several hundred cards per minute, this is much too slow considering the speed at which the computer can perform calculations, and usually the information is transferred to paper or magnetic tape which can be processed more quickly.

Punched paper tape is not only a faster input medium than punched cards but can be produced as a by-product of the regular office typing. This eliminates duplication of effort, eliminates an opportunity for errors to creep in, and allows a very easy check on accuracy simply by proofreading the printed page. Another advantage is the fact that the equipment used to punch and read paper tape is less costly than that for handling cards or magnetic tape. Computers can process paper tape at speeds of from 150 to 500 characters per second.

Magnetic tape, on which data is indicated by the presence or absence of invisible spots, has a read rate of 50,000 and more characters per second. Thus, a single foot of magnetic tape, which can be read in a fraction of a second, contains as much information as fifty punched cards which take many seconds to be read into the computer.

Direct keyboard input of data through an electric typewriter can also be used, but this is a slow process and is used only for small quantities of data.

An important executive function is taking in information. This may be in many forms, including written and oral reports, and on-the-spot observations.

Storage or Memory.--Data might be considered as in storage as soon as it is in a form readable by the computer. Once it has been read into the computer, data moves into a storage area even if only for a millionth of a second. This storage area may take several forms which vary in cost and in "random-access" time, the time it takes for the computer to reach any item of information anywhere in the storage area. One common way in which information is stored in a computer is in the form of north-south or south-north polarization of small magnetic cores, about 8/100 of an inch in diameter. Each core stores a "1" or a "0", one bit of information, according to the direction of the polarization. Various combinations of these "1's" and "0's" are used to represent the letters A through Z, the numbers 0 through 9, and a few additional characters, such as $ and %.

The information in storage or memory may include instructions, data, reference tables, or the results of intermediate and final calculations. It can be referred to once or many times, and can be replaced whenever desired.

Executives maintain large stores

<u>of information such as that in the company files, that maintained by subordinates, and that retained in the individual executive's brain. The "random-access" time is extremely varied</u>.

<u>Processing</u>.--This unit ordinarily has a small storage capacity but can perform subtraction, multiplication, division, comparison, selection, and other mathematical and logical operations. It can distinguish positive, negative, and zero values. It can perform as many as fifty different operations and through combinations of the basic operations is able to handle more complicated operations.

Data is processed according to programmed instructions. These instructions are followed in sequence. The processing unit performs a logical decision when instructed to deviate from the sequence according to the results of a prescribed test. This "test" instruction is called a "conditional branching instruction" and can be considered similar to a branch or fork in the road.

<u>Every executive has some knowledge of and capacity for performing mathematical operations</u>. <u>However, his ability to make logical decisions is probably the most important talent</u>.

Output.--Computer output can take two basic forms. One form is suitable only for future processing in the system. The other produces printed records or reports for human use. The early computers used electronic typewriters for direct print-out. Some computers now use typical tabulating-card printers. Faster than these methods is magnetic tape output. But printed output is closing the time gap since electronic printers capable of a speed of 100,000 words, or 5,000 lines per minute are now available.

After information has passed through the executive "system", the resulting output may be filed for later use, may be discarded, or may be used as the basis for decisions and actions. The output can take several forms, such as writing and speech.

Control.--Every computer program follows a planned sequence of instructions which are kept in storage. These instructions are made available to the control unit as needed to direct the sequence of operations. Sometimes special instructions are supplied by the control unit so that the processing unit will make logical decisions according to the intermediate results calculated.

More specifically, the control unit tells the input devices when and what information is to go into memory. It tells memory where to place this information. It tells the processing unit what operations to perform, where in memory to find the information, and where to store the results. It locates file information and stores it in memory. And it controls output by specifying what information is to be sent out.

Among the "controls" which guide executives are job specifications, company policies, individual experience, and corporate records.

B. Functional Aspects

Computer versus Human Thinking.--Some psychologists regard thinking as a bipolar process. Reasoning is at one pole, imagination at the other. This is a useful approach in contrasting machines and humans.[2]

Reasoning is deductive thinking and is generally considered to be precise and logical. It's pretty easy to duplicate mechanically. On the other hand, imaginative thinking appears to be a comparatively random process. But a dividing line between the two ends of the pole is nonexistent. Deduction is accomplished by following specific steps in sequence. But, in moving toward the imaginative pole, more and more trial-and-error thinking, in conjunction with more and more feedback, is a necessity.

Thinking might be considered a process, although certain thoughts have no clear beginning and no conclusion. Problem-solving is usually considered to be a thought process, and it takes no imagination to see that for management problem-solving, both imagination and reasoning are required. Management seldom finds itself in the luxurious position of being able to solve one problem at a time. Furthermore, there are always many different kinds of thought processes occurring simultaneously. The computer, however, can and must finish one problem before going on to the next. It often outshines the manager in performing certain functions because of its amazing speed, perpetual accuracy, and constant attention to the problem at hand.

Pure deductive reasoning, if such a thing exists, is perhaps the only sort of human thinking which has no overtones of emotion. To date, no one has been able to emotionalize computer activities although attempts are being made.

Operations That Might Be Considered Thinking Operations.--Berkeley has cut through many of the semantic arguments about what is and is not thinking, and believes that there are no human thinking operations inherently beyond the capacity of computers.[3]

For example, reading and writing and arithmetic are clearly evident talents of humans and computers. This was pointed out earlier in this chapter. History, geography, literature, and social studies are learned by humans, and all the facts on these subjects can be stored in the memory of the computer. Foreign languages are learned by man and by machines, and both are able to translate from one language to another.

Man observes his environment; computers can recognize magnetic-ink characters and even some of the standard printed characters. Man recognizes speech sounds; this might be considered a computer weakness at present, but advances are being made. Man can put different speech sounds together to form words, combine words to express ideas; this ability can be programmed with ease for the computer.

Differences Between Man and Computer.--The human being is an on-going whole. He learns many "programs" as he matures. These programs are never really complete since they change continually as new experiences, new information, and new programs modify them. Furthermore, there is an unavoidable interrelationship and integration among all the programs.

In the case of the computer, there is no confusion among programs. The computer does one job at a time. Any program can be added in its entirety or removed completely whenever desired. The "personality" of the computer can be changed completely by injecting thousands of bits of information within a few seconds. Its memory is very large and easily controlled. It can be turned off temporarily or permanently.

What Can Computers Do?.--There are many spectacular achievements. Computers have been programmed to prove theorems in Euclidean plane geometry in a manner equivalent to that of a bright high-school student.[4] They have been programmed to play games such as checkers and chess and 3-dimensional tic-tac-toe.[5] It is simple for a computer to solve logical problems such as:

> "It is known that salesmen always tell the truth and engineers always tell lies. G and E are salesmen. G states that D is an engineer. A declares that B affirms that C asserts that D says that E insists that F denies that G is a salesman. If S is an engineer, how many engineers are there?"[6]

Computers are being used to diagnose heart defects and can do this as well as skilled cardiologists.[7] Workable translations of Chinese into English, probably the two most widely used languages on earth, have been demonstrated by IBM.[8] Programs are even available to convert a computer into a one-armed bandit.

These are all impressive demonstrations of the versatility of the modern computer. But, they are mere child's play when stacked up against the business problems currently being tackled.

Can Computers Learn?.--Pavlov's experiment was a demonstration of a change of behavior as a result of learning. Skinner showed that a rat could learn and could forget. Then, A. G. Oettinger of Cambridge University programmed the EDSAC computer to adjust its output in response to a conditioning-like stimulus.[9] However, this is still a relatively unexplored area.

Can Computers Think Creatively?.--Creative thinking basically involves taking existing information and reorganizing it in a unique way. The creative process does require some inspiration or insight and this part of the process cannot be programmed. But, the end result, the rearrangement of existing data in novel ways, is a very real possibility. Newell, Shaw, and Simon, among others, believe that creative thinking can be simulated on a computer, although they have come up with no convincing demonstrations.[10]

What Can't a Computer Do?.--There is some difficulty in trying to develop a list of things a computer can't do. Some have already been mentioned. Others, which once seemed unlikely, are advancing by leaps and bounds. For example, it appears probable that computers can be programmed to recognize individual faces and to explain the reasoning a lawyer goes through when he presents his case to the jury. It is even theoretically possible for a computer to reproduce itself.[11]

Borko covers this area rather well: " . . . computers do not think, nor do they solve mathematical problems whatever the type of problem employed. The computer can only perform prescribed physical operations . . .. Machines can manipulate symbols but not thoughts; thus the computer output is devoid of all intellectual content. This output, however, can be made meaningful and useful when it is interpreted by the human operator. The computer performs mechanical and electronic operations. It is the human interpreter that thinks."[12] This is a reassuring passage, but it may be overly optimistic.

What About Reproducing the Brain?.--Theoretically, it would be possible to reproduce the human brain by interconnecting neuronlike devices. But, it becomes extremely difficult to interconnect even the simplest devices when they number say 10^6 or 10^7 elements. Man's brain contains an estimated 10^{10} neurons, many of which are connected in very complicated ways to many other neurons. It is not really known whether the interconnections are ordered or random, but most likely there is at least some randomness. At present the odds on constructing a computer-device resembling the brain are something like one in 10^{12}; that means that even if 10^{10} devices could be physically arranged and interconnected, the chances are 999,999,999,999 to 1 that this monstrosity would not function in the same manner as the human brain. Much more knowledge of the basic mechanisms involved is needed before the odds will improve significantly.[13]

The Computer versus the Brain.--John von Neumann's remarkable but unfinished book, The Computer and the Brain, puts the entire brain-machine story into clear focus.[14]

The human brain is far ahead of its machine rivals in so far as energy consumption is concerned. The whole brain with its billions of cells functions on less than 100 watts.

The most efficient known substitute for a brain cell is the transistor. A machine containing a transistor to represent each cell in the brain would need more than 100 million watts.

In terms of speed, the human brain is far outclassed by the modern computer. While the discrepancy may not be as great as that for energy consumption, it is still impressive. Computers are ahead of the human brain by a factor of more than 10,000. On the other hand, the human brain is much more complex than the most complicated computer being used today.

The last two pages of this book bring forth the often over-looked fact that the language of the brain is not the language of mathematics. Languages such as Greek and English are historical accidents. "It is only reasonable to assume that logics and mathematics are similarly historical, accidental forms of expression."

The Computer as a Decision-Maker.--There are various criteria for making decisions, and for the executive these might be described in terms of a profit-and-loss situation. The executive may, for example, aim to maximize his profits or to minimize his losses, or to achieve some optimum combination of the two. Unfortunately, he must ordinarily make decisions based on incomplete evidence. As long as the evidence exists in the form of quantitative data, then the computer can be considered an effective decision-maker. But to some extent the world of business contains many chance elements which require special skills, including the ability to anticipate the moves of competitors, and it is here that the computer becomes less competent than the executive.

For computers as for businessmen, accurate information is of prime importance. If nonsensical or inaccurate information is used for input, then the output will probably not be usable.

CHAPTER IV

INFORMATION FOR PLANNING AND CONTROL

Information or Communication Theory.--The work done by Claude Shannon of Bell Telephone Laboratories and Norbert Wiener of M.I.T. has formed the basis of the new discipline known as information or communication theory.[15,16] They have distinguished three levels of communications problems:

1. Technical Level: how accurately can symbols be transmitted?
2. Semantics Level: how precisely can the symbols transmitted deliver the desired meaning?
3. Effectiveness Level: how well does the transmitted meaning affect conduct?

Of most interest to the manager may be the noise which occurs when messages are transmitted. The message received may be entirely different due to distortion in transmission. It should be noted that, in general, the shorter the message the greater the danger that its full value will not reach the receiver. Short reports are currently in vogue and this danger ought to be considered very carefully.

Evidence of noise showed up in a study of 100 companies done by the Savage-Lewis Corporation.[17] According to the report, vice-presidents understand only 67% of a message from the board of directors or top management. By the time the same information gets to the general manager level, only 56% survives. The level drops to 40% as it reaches the plant manager, to 30% in the case of foremen, and to 20% among workers.

Cybernetics is an important part of information theory. It relates the information and control patterns of organizations to that of the new automatic machines. In these machines, the patterns of performance are set by man but electronic controls keep the machines performing according to plan. Decision centers plan and establish tolerances within which machine performance is acceptable. The performers communicate their performance back to the decision centers but no action is taken unless corrections need to be made. This is the familiar exception principle of management theory. Only that data needed for a corrective decision is fed to the executive or manager.

Another contribution of cybernetics has to do with a biological analogy. The human brain is a planning and decision center which communicates through the nervous system to other parts of the body. These in turn communicate back their performance which leads to new messages from the brain to continue, adjust, or stop the initial action. This communication loop is called "feedback", which Wiener defines as " . . . a method of controlling a system by reinserting into it the results of its past performance."[18]

A computer is, of course, a cybernetic system. It handles information--it receives, stores, manipulates, and sends it out. Its control unit is the heart of the feedback system which makes it so versatile.

The Information Revolution.--In the long run, the new information technology may have an important effect on the structure of management. Leavitt and Whisler predict, "Information technology should move the boundary between planning and performance upward. Just as planning was taken from the hourly worker and given to the industrial engineer, we now expect it to be taken from a number of middle managers and given to as yet largely non-existent specialists."[19]

Data can be stored more efficiently, transmitted more efficiently to decision centers. The revolution has expanded the horizons of organizations. The headquarters of a corporation with many branch plants scattered around the country can have production and sales information for the previous day on executive desks each morning. These will not be raw facts; the information will have been analyzed by the computer and the pertinent points will have been marked for immediate attention. The only way that this analysis can be accomplished in such a brief time span is through an integrated data processing system, a subject that will be explored in later chapters.

Communication Through Channels.--Barnard points out that "The need of a definite system of communication creates the first task of the organizer and is the immediate origin of executive organization."[20] There is a clear directional flow of information in an organization. Decisional information flows to lower levels, and information about performance flows from lower levels. But the definite lines of communication established on the organizational charts are not always followed.

There are problems even when information flows through the proper channels. Boulding reports that there is a practice of filtering information as it travels through various hierarchical stages.[21] People on the lower echelons deliberately distort messages going up in order (1) to give the boss the information that will please him, and (2) to present their own performances in the best light. And, of course, messages going down are also subject to non-objective alterations.

Communication Media.--Managers seem to prefer the use of oral rather than written communication according to one poll.[22] But although they gather and disseminate information orally, they ask for and give written confirmation. Oral reports are seldom used when large quantities of data are involved, as in the case of production or finance reports. But, regardless of the size of the communication, the oral messages are much more likely to be improperly heard, and are less risky for the recipient to ignore, than written messages.

Much of the written information which flows through a corporation is composed of messages that are regularly distributed because of functional requirements. These standardized reports place a limitation on the content of the message but do promote uniform content and quality. But these reports should be sent only to those who actually need the information. It's not always easy to determine who needs what, nor is it easy to see that those who need and receive the information make proper use of it.

The accounting department in one Wall Street Firm used to send out a 37-page report every month to 37 executives. One day, the head of the accounting department asked each executive whether he really needed the report and received 37 "yes" answers. The next month, the accounting department again prepared the report but filed all the copies. Not one request or query was received. A few months later the report was dropped completely.[23] The chances are that much of the information was duplicated by other reports which were still being distributed.

Availability of Information.--Since the depression of the 1930's, more and more statistical data have been developed by the government. In addition, private industry has become increasingly willing to supply data on its operations to governmental and private research agencies. During World War II, economic data was collected on the largest scale yet and this data is still being calculated and disseminated. There is a steady flow of articles, reports, analyses, and forecasts from government bureaus, trade groups,consultants, banks, stock brokers, and research firms. The flow of scientific and industrial books and magazines grows larger every year. On top of this avalanche of information from outside the organization, additional data rises from inside the organization itself.

Information Retrieval.--Kemeny, in an article published in 1962, discussed the problems which will face libraries by 2000 A.D.[24] He estimates, for example, that Harvard will have more than ten million volumes by that date, and that it would be most difficult for researchers to use the facilities if the present library procedures are still in use, assuming that Harvard could afford to maintain its present system.

Present library procedures can be both discouraging and time-wasting. Half of the material desired for this thesis, for instance, was not listed in the general catalog. Half of what was listed was either on reserve, or removed from the library. "Removed from the library" includes student borrowings for two weeks, faculty borrowings without time limits, and permanent borrowings by subsidiary libraries. One general management magazine subscribed to by the University is ostensibly sent to a subsidiary technical library. However, the subsidiary library has its own subsidiary library where this particular publication is kept. It happens that the sub-sub-library is located in a separate building, in what is really an office, and is open four hours each week. After six weeks of effort, the 1962 issues were not made available, although earlier and later issues were freely loaned.

Kemeny proposes some solutions which would be of value to all researchers, including top management looking for decision-making clues. Books consulted as often as once a week would be kept on college campuses. All other books would be located in one central library, perhaps in Washington, D. C. The volumes would be divided into subjects, subjects into branches. The fundamental unit of storage, search, and retrieval would be known as an item, and would represent roughly a chapter of a book or an article in a journal. If a branch of a certain subject had 10^6 items, they could all be stored on a tape 3300 feet in length. (In 1962, when Kemeny's article was published, 2400 feet of tape was the maximum length available. In April, 1963, a new thinner-base computer tape which is stronger than the old tapes and is 3400 feet long was announced.[25])

How would the individual retrieve this information? Every subscriber to the central library would have a receiving unit. The individual would dial the code number for the branch, and then the subdivision of the branch, for the particular subject in which he was interested. He could even dial the master catalog for a particular subject and flip through the cards over the viewer on his receiving unit. The user would not be viewing the actual items, but would see copies of them which the reproducer on the viewing unit would have taped and displayed. This tape could be carried home for leisurely study. (In 1962, a machine such as this was not on the market. But in May, 1963, a new device was announced which has been tested at Oak Ridge, Tennessee. Information on tape can be retrieved for viewing in seconds. The user, by pressing a button, can obtain a copy as large as 18 by 24 inches in just a few more seconds.[26])

Information for Control.--One approach to the efficient control of manufacturing considers three different time cycles.[27] Future operations are planned, and an attempt is made to anticipate difficulties. Present operations are observed so that necessary adjustments can be made if operations deviate from planned goals. Records of past operations are scrutinized so that future plans can be improved. Data is collected for three essential purposes. Control data is required for on-the-spot decisions; accounting data is needed for periodic action; operating data is used for planning and review. An important goal of an integrated data processing system is to tie these types of data together.

The control data system, in turn can be subdivided into six important areas.[28] All control starts with the updating of records covering sales, in-process production, inventory, forecasts, costs, backorders, and so on. The second element of control is the computation of operating control limits. For example, inventory control limits might be determined on the basis of a determination of the appropriate protective stocks, or buffer stocks, and the necessary working stocks.

A third control area is the preparation of action reports or schedules to control the operating functions. For example, when new products are scheduled for production, the computer will issue reports and schedules outlining the requirements in terms of raw materials, labor, equipment, and work priorities. Follow-up is the fourth aspect of control, and is an important feature of any efficient operation. In this way, any variances from the established schedules should be captured quickly.

The fifth element of control is exception reporting. The computer reviews the actual status of each product and compares it against predetermined control limits in regard to inventory, lot size, cost, and so forth. Any deviations are printed out for supervisory or managerial attention. The last aspect of control is performance reporting. These may appear, for example, as periodic over-all reports, or as a summary of the exception reports for a particular period.

Planning Information Different from Control Information.--Management often assumes that the information gathered for control purposes is all that is needed for the pursuit of the planning function. But there are several important differences between the two.

Planning information should not be broken down by functions. It must be integrated into over-all patterns since planning is an over-all function. Control information, of course, is used to measure performance in specific organizational areas.

Planning information must cover relatively long periods of time, in order to detect long-term trends. Control information must be more timely; in a fully-automated plant, it may even be measured in microseconds.

Planning information must be refined. Mountains of highly-detailed information are of little value. Long-range planning in particular requires only the skimpiest outline of the present situation. Control, on the other hand, often depends on stockpiling extremely precise information in order to isolate any problems which may arise.

Finally, planning information must be directed toward the future. Control information is gathered to show what has occurred in the past and how it occurred.

Information for Planning.--Due partly to rapid growth and diversification, organizations are showing many structural changes. Most companies take it for granted that the information necessary for the performance of the management function just flows naturally to the top of the organization. This is true for some of the internal information, especially the accounting information. But the external information, if it arrives at all, comes in irregularly, informally, and often inaccurately.

What information does the planner need? Daniel points out that it is very difficult to find out from the executive, himself, what information he makes use of.[29] For one thing, he simply may not be aware of the ways in which he is being kept up to date. His associates, his subordinates, his business friends, and his customers may all provide him with key information on a regular basis. Then, too, he is apt to think of information only in terms of his company's accounting reports. The problem here, of course, is that these reports are designed to meet various governmental regulations andare, therefore, not the best possible guides for executive planning. Accounting reports tell nothing about the future, are expressed only in financial terms, and contain very few facts about external conditions. Even more important is the fact that these reports contain little, if anything, in the way of analyses of the relationships among variables, analyses which are essential for competent executive decision-making.

Information for planning might be classified in two basic categories: environmental and internal. Under the heading environmental information would be included statistics regarding population growth and distribution; wholesale, retail, and commodity price indices; transportation availability and costs; balance of payments, foreign exchange rates, convertibility; labor skills, availability, turnover, and wages.

An extremely important item under environmental information is competitive data. Under this heading would be facts on past performance in terms of competitive profitability, return on investment, and share of market. It would indicate any changes in product lines, management line-ups, and price strategies. Future plans in terms of acquisitions or other expansions, and research and development efforts, would also be explored.

Internal information would cover sales, costs, and cost behavior in relation to volume changes. There would also be details on share of market, productivity, and delivery performance. Nonquantitative information should be presented for consideration also, including the state of such elusive factors as community and labor relations.

The Nature of Planning.--Planning might be considered a matter of deciding in advance what to do. It means making decisions regarding the future. At the top executive level, it includes creative thinking. Planning involves searching for solutions to those problems which appear on the surface and also searching for problems which might crop up in the future. It means being able to include sufficient flexibility so as to cope with future developments. Planning generally involves a set of interrelated decisions, not just a single, all-inclusive decision. It means plans for the short-term and the long-term which must be integrated and coordinated.

Planning is a time for concentration and preparation. The executive skills used are quite different from those involved in putting out daily or weekly "fires." Planning is an integrated effort designed to chart the future of the organization as a whole. It is never really completed because periodic reviews of long-range plans are necessary as the company moves into the future. Koontz and O'Donnell call this the "principle of navigational change".[30]

Planning might be considered the starting point of a significant organizational loop. When a plan has been approved, the next management move is the execution of the plan. As execution proceeds, there is a feedback of information to the planners so that they can measure performance and isolate any problem areas. This completes the loop: planning to execution to control to planning.

Planning must of necessity precede other management functions including organizing, directing, and controlling. It is performed by all managers at all levels. However, top level executives are most concerned with broad company-wide plans and with plans that reach well into the future. But, at every level, the first step is to establish the objective.

Setting the Objective.--Management is guided to a large extent in this function by the purpose of the firm since this purpose necessarily conditions all other objectives. It should be noted that, in recent years, the premise that every business is operated in such a way as to maximize profits has been substantially revised. Governments, unions, competitors, customers, and the general public have reshaped this classic company objective. But whatever the company purpose, every objective must conform to it. In reality, the best plan is usually one that maximizes profits over the long run since the "newer objectives" usually cannot be met without some investment of profits.

Ordinarily there will be a hierarchy of objectives. There will be the broad, long-term objectives which cover corporate-wide activities. There will also be the narrower objectives covering shorter periods of time and smaller units of the corporation. Probably objectives will also be established for divisions and departments in each of the smaller units.

Every objective ought to be scrutinized in several critical areas.[31] Does it show any potential for continued corporate growth? Is it going to be affected by any currently visible technological changes, and, if so, is there a compensating flexibility built into the plan? What will happen if there is a major decline in the business cycle? Has an investigation been made of the performance of the leading competitors for clues as to their opinions of the potential in the field?

Some idea of the problems inherent in setting an objective is given in a case related by Payne.[32] The executive planning team of a major corporation was convinced that its members had a clear understanding of the corporate objectives. They proceeded immediately in their long-range planning to the details of the sales effort the company would put into each product in each of the years ahead. But when they were asked to agree on the corporate objectives for the same period and to put their opinions into writing, it took many weeks before an approach to the future was established which every member would accept.

Alternatives for Achieving the Objective.--Once an objective has been established, attention must be focused on the means to achieve that objective. It is unlikely that there will be only one plan or strategy suitable for reaching the desired goal. In fact, good planners are apt to develop a very long list of plans worthy of consideration.

Le Breton and Henning suggest a plan for eliminating some of the alternatives.[33] As a first step, the objective and the alternative plans should be analyzed carefully and stated as precisely and clearly as possible. In this way, any irrelevant alternatives can be eliminated. Then, some possibilities can probably be eliminated because they clash with company policies and procedures. Others may be impossible because of limited resources of one or more kinds. Some alternatives will be too time-consuming or too costly.

Evaluating the Alternatives.--Usually the original alternatives can be reduced in number through careful selection. Sometimes, however, re-study will suggest additional alternatives. In any event, some method of evaluation is needed. Le Breton and Henning suggest selecting the significant variables for each alternative and assigning values to each variable. Considerable judgment is essential in assigning values, especially when reliable facts do not exist on which these values can be based. In other words, the assigning of values is seldom an automatic process, especially in view of the trend to more comprehensive plans which extend over long periods of time.

The Problem of Uncertainty.--Plans are based on future expectations, and the future is always uncertain. Production and purchasing schedules are based largely on anticipated sales. Sales, in turn, will be affected by price and style and quality, and by competitive activities. However, there is always a range within which each variable must fall and the consideration of these ranges gives the plan more flexibility. A probability distribution can be developed using figures within each range. Here, of course, experience and judgment play an important role in establishing a range, in selecting figures within a range, and in assigning probability values to each figure chosen.

Planning Is an Intellectual Process.--A plan is almost invariably a product of some degree of creative thinking on the part of the planner. According to Haimann, "It is mental work; it requires a mental predisposition to think before acting, to act in the light of facts rather than guesses, and generally speaking to do things in an orderly way."[34]

The planning process deals in abstract concepts as well as concrete tangibles. In the early stages of planning, it will be difficult for the planner to express his ideas. But as effort is expended, the abstract concepts will begin to fit together in a communicable plan. At this point the plan can be evaluated in several ways: (1) by experimenting with the actual men and equipment; (2) by constructing equations describing the various alternatives; and (3) by conducting simulated experiments, or system simulation.[35] Sometimes a combination of two of these ways is needed before a plan can receive the planner's final blessing.

The Importance of Measurement.--In the words of Spencer and Siegelman, "Management wants and needs to have essential relationships and predictions expressed in quantitative terms if it is to formulate plans involving the hiring of x number of workers, the scheduling of y units of production, or the marketing of z units of output. In other words, plans must generally be reduced to numerical terms if they are to guide the decision makers whose function it is to steer the firm's course into the future."[36]

And now the door is open to simulation.

What Is Simulation?--One approach to understanding the meaning of the word simulation is presented by Cheng.[37] He suggests two types of simulation. In one instance , the simulation is being done by man, as in the case of war games, in which army officers make decisions under simulated battle conditions. The other type of simulation is simulation done by the computer. The computer behaves as instructed by the man who has programmed it, reacts according to the data supplied, and gives out results; the computer may be behaving as a production department, as a railroad, or as a particular firm in a particular industry.

Another interesting concept introduced by Cheng is the double-level simulation. The example of this presented involves a stockroom clerk who makes decisions in a simulated situation, at the same time as a computer is making decisions for the same situation. As soon as the computer is able to surpass the decision-making ability of the stockroom clerk, the computer is theoretically able to handle the clerk's function.

What Is the Basic Concept?.--Given the requirements of some particular situation, a model is constructed. It is then programmed for the computer. The model might be a set of linear equations or a series of statistical relationships. The computer uses the programmed model to search for the best alternative which meets the various requirements, which will include the available capacities and some particular optimum objective. In a complex situation, there may be so many possible alternatives that even a computer search for the "best one" would take an impractical length of time, so some judgment must be used in setting up restrictions to avoid this waste.

Where Does Simulation Work Best?.--Simulation works wonders in those situations where the interrelationships of the variables involved are complex and difficult to measure. It is most applicable when the cost and profit factors are large and when the large quantities of information involved can be quantified and set within limits.

Because simulation tends to be expensive, it is probably used to a greater extent by larger organizations. However, even a small operation can afford the use of rented equipment and talent, and the rapid growth of computer service organizations indicates that this is indeed being done.

Lindsay states that a computer simulation approach has many important advantages:[38]

> "1. The ability to handle uncertainty by means of probability analysis.
>
> 2. The ability to handle very complex problems and to find either the precisely or the approximately best answer.
>
> 3. The ability to analyze--at least to some extent--the implications of competitive situations and the relative merits of alternative strategies.
>
> 4. The ability to try out literally hundreds of alternative assumptions, strategies, and decision rules.
>
> 5. A limited ability to evaluate risk.
>
> 6. The ability to analyze dynamic situations in which each decision sets the conditions under which the following decisions must be made.
>
> 7. The ability to analyze the effects of time-lags in actual decision processes.
>
> 8. The ability to make "sensitivity analyses" by means of which one can determine whether a small change in a single factor will result in a major or a minor change in the outcome. If the former, the simulation model will show the degree to which the critical factor must be controlled to avoid violent fluctuations.

9. The ability to analyze quickly new and unexpected situations so that decisions to take advantage of opportunities can be made promptly.

War Games.--The military has been using simulations for many years. It all started with relatively simple map exercises and field maneuvers, which are both still in use. But war games have advanced to the point where the Navy has spent as much as $7 million to construct one special gaming computer for training officers in weapon use.[39] Games are very valuable here because it would be costly and destructive to provide on-the-job training. Games are very useful in business for much the same reasons.

Business Games.--The case method is often used to simulate business conditions. It provides practice for students in dealing with complex situations and in applying analytical problem-solving techniques. Role playing techniques are also helpful in that they demand a more personalized interaction between the players themselves and between each player and the situation.

The business game combines some elements of the case method and role-playing with some extra benefits. Decisions are still required and teamwork is still important. But now the player knows what the results are following each decision and he is faced with a new situation in an on-going business which demands decisions seemingly without end.

The business game player contends with many variables over which he has full control, and many variables which are beyond his environment. All these variables interact, but again the player has some full knowledge of how certain interactions take place and must determine other interactions according to his observations of the results of his decisions. This is clearly an improvement over the static case method.

Advantages of a Mathematical Model.--Probably the best discussion of mathematical models available is that by Vazsonyi.[40] He points out that mathematical models make it possible to describe and comprehend the facts of many situations far better than any verbal description could possibly do. The development of the model often uncovers relations between variables which are not apparent when only words are used. Some situations which have always been "felt" may turn out to have very real meanings in terms of cause and effect relationships. All the major variables can be considered simultaneously. If factors have been overlooked, the model can be expanded easily at any time to include them. And once the model is completed, it is possible to use mathematical techniques that otherwise might have appeared to have no value in solving the particular problem.

Where Have the Mathematical Techniques Come From?.--Most of the techniques used today have been the direct result of the growth of the field of Operations Research.[41] The objective of Operations Research is to find the best decisions relative to as large a portion of the total organization as possible. If, for example, a maintenance problem is being considered, an attempt would be made to determine what alternative would be best for the production department as a whole. Also, consideration would be given to the affect of each alternative on the other departments and on the business as a whole. Operations Research is concerned with a whole chain of effects as far out as these effects are significant.

By 1957, more than half of the corporations in the United States were using Operations Research.[42] All aircraft manufacturers use Operations Research, which is understandable in view of the fact that its use mushroomed in the early 1940's, thanks to government-supported research. Most chemical, electrical machinery, food, metals, utilities, and transportation companies use Operations Research to a great extent.

As far as actual applications are concerned, production, long-range planning, sales and marketing, and inventory control rank very high. There is much less use in such areas as advertising, personnel, and purchasing.

PERT.--The Program Evaluation and Review Technique was developed in 1958 at the Navy Special Projects Office by a project team which studied the application of statistical and mathematical methods to the planning, evaluation, and control of research and development efforts.[43] PERT was first applied to the development of the Polaris submarine. By 1961, the technique had found application in certain areas of the Air Force, Army, and special agencies of the government as well as in private industry.

PERT is used to define what must be done in order to accomplish program objectives on time. One of the major advantages of PERT is that it provides a method for the diagramming of a program. A network consisting of each event and its relationship to every other event is expressed. PERT uses time as the common denominator to reflect planned resource application and performance specifications.

Critical-Path Method.--This is really a variation of PERT which was developed by E. I. du Pont de Nemour Company.[44] Instead of estimating time-spans, this method considers time estimates over a range of facility or cost levels, and as a result, provides a range of project durations with an associated range of project costs. The mathematics involved guarantee that CPM data processing will establish the absolute minimum cost of attaining any feasible project duration.

Management Operating System.--IBM has developed what it calls a management operating system (MOS) for manufacturing industries.[45] It uses six basic management operation functions which are common to most manufacturing companies, regardless of the type of industry. Some of these functions implement planning, others implement execution.

Forecasting initiates the cycle and produces the master plan on which all activity is based. Materials planning develops the master plan for materials. Inventory management completes the material plan and practically executes it. Scheduling develops the master plan for machines and manpower and starts it into action. Dispatching completes the execution of the plan. Operations evaluation is the planning function which replans the five preceding functions on the basis of an evaluation of the execution.

The goals of MOS are lower investment in materials inventory, increased utilization of machines, higher efficiency of manpower, and increased profit.

Industrial Dynamics.--One of the most complex studies now being evaluated is the work initiated by Forrester.[46] Industrial dynamics is the study of mathematical models for analyzing the stability and fluctuation of industrial and economic systems. It includes closed-loop, information-feedback characteristics, and decision-making procedures.

Five interacting subsystems are incorporated: material flow, order flow, money flow, capital equipment generation and usage, and manpower employment and mobility. These are interconnected by an information and decision-making network. Situations are represented by non-linear mathematical systems.

Applications of Simulation Techniques.--One of the most spectacular simulation efforts was that done for Project Mercury.[47] Computer routines checked the worldwide tracking and instrumentation network during the hours and minutes before launch. All stations were polled to see if they were ready for transmission and gave each one a test exercise for evaluation of accuracy. Weak links were spotted at once and corrected.

In the field of business applications, a major food processing company uses a simulation model before deciding where and how to ship raw materials to refineries. The model in the computer is a representation of the company, including warehouse facilities, shipping fleet, refineries, and cost and operating factors. Latest crop production and capacity figures are fed into the computer which provides an updated picture of what will happen under varying conditions.

Another company uses simulation to find out what union demands will do to its cost structure. Bargaining alternatives are fed into the computer for determination, within minutes, of just how far the company can go in meeting union demands without upsetting its economic balance.

In banking, simulation tests new branches to see if the area and site are sufficiently profitable. Job shops use computers to decide which job gets done first when two arrive at a single spot at the same time. Major oil refineries use simulation to determine what effect a new type of crude oil will have upon output.

Again in the spectacular area are two new projects announced recently in the newspapers. Russia is attempting to simulate the input-output interaction of more than 600 basic industries in order to assure better industrial planning in the future.[48] Back home, the United States is working hard on a project to program its diplomatic relations.

An extremely complicated simulation project has been underway for several years under the leadership of Orcutt.[49] The objective of the project is to develop an accurate and dynamic model of the American economy so that policy-makers can be forewarned of impending changes and also so that they can test their policies before they are introduced. This model would incorporate both macrocomponents, such as the household, business, and government sectors, and microcomponents, such as industries, firms, and even such minute subdivisions as sex, race, and family size. Orcutt predicts that within four years a workable model of the economy will be available in view of the computer and programming developments that are now taking place.

CHAPTER V

INTEGRATED ELECTRONIC DATA PROCESSING: ADVANTAGES AND PROBLEMS

What Is Integrated Data Processing?.--Optner explains integrated data processing as the "linking of individual data processing tasks intimately, so that they cease to function of and for themselves, but exist as a part of a total functioning unit."[50] In this system, there is a hierarchy of subsystems in which lower level systems become inputs to higher level systems. In addition, each level operates under certain controls utilizing the results of output wherever possible as a feedback to modify input.

The first data processing equipment had the disadvantage of being unable to perform more than one function at a time. Bookkeeping, billing and accounting machines were needed to perform the functions of computing, sorting, distributing, and recording. Information had to be moved by hand from one machine to another and had to be transcribed before it could be entered into the second machine. Time was wasted and errors were introduced.

The first try at overcoming this problem was in the form of punched card equipment. But even here the element of human error was not eliminated. Cards had to be transported from machine to machine and each operation had to be initiated.

But with the development of the computer, these old problems were solved. Now a single electronic unit could perform the arithmetic operations, perform logical operations, record and remember and recall data, communicate to humans or other machines, direct itself in a predetermined manner, and check the results of its operations. In addition, the computer operated more quickly, more accurately, more dependably, and often more economically than human data processors.

Two Basic Types of Applications.--In some companies, computers are used only to keep records. Thus, the ability to handle data is used but the calculating and logical abilities are ignored. In most integrated data processing systems, however, the computer is used to keep records and to analyze those records through programmed series of computations.

Payrolls.--The most widely programmed application of industrial computers is for payroll operations.[51] This is understandable since it is common to all businesses. Withholding taxes and compulsory union deductions had made it a rather complex operation and large staffs of clerks were required to get out all the pay checks and the related records. The computer was faster, more accurate, and more economical than the previous methods, but this single application was not, in itself, sufficient to justify installing the system.

Accounting to the Rescue.--Because of the expense involved in procuring and installing a computer-centered data processing system, its value had to be assured in more than a single area. So, partly because of the inherent complexity of the accounting function, and partly because of the fact that the accounting manager usually headed the feasibility study, the accounting function was singled out for special attention. A recent survey showed that a very large percentage of American corporations have programmed at least a part of the accounting function.[52]

The impact of this change in the area of accounting has been the development of many new tools to aid management in its decisions concerning future activities. Today's accountant is commonly accepted as a key member of the top management team because he has new methods at his disposal whereby he can create better forecasts regarding costs and profits than ever before possible.[53]

Wider Integration.--Accounting is not the only department which has integrated all of its functions. There are many instances where individual areas in a corporation are making maximum use of the data processing facilities available. Conspicuous among these are production and scheduling, and inventory.

Now, there are certainly many instances where these inter-departmental applications have really paid off. For example, as far back as 1954, the John Plain mail-order house, which handled 15,000 orders per day, replaced 60 inventory clerks with a computer and ten operators.[54] Sperry Rand recently installed a new Product Administration and Contract Control system which needs nine operators to handle data that previously occupied 201 employees.[55]

It should be noted that not too much information is being published regarding manpower savings. The trend seems to be to announce the new equipment, praise its speed and accuracy, and provide figures showing that employment in the company is increasing every year.

But the facts show that very few corporations have extended their integration throughout the organization.

<u>True Integration</u>.--There are several recent examples which show that a few progressive organizations are beginning to realize the potential inherent in an integrated electronic data processing system.

Helene Curtis uses its system to analyze sales potentials for all of its products by area.[56] In addition, the company does what might be considered "paperwork" on this same system: inventory, payroll, billing, purchasing and many other routine accounting jobs. The goal is to integrate sales, accounting, and manufacturing operations in order to improve its competitive position, lower personnel costs, improve manufacturing efficiency, speed up service, and improve products.

Purex Corporation is using IBM's MOS program which ties all manufacturing operations into one computer-controlled bundle.[57] This might seem like a factory technique, but it links the office to production and distribution in a way never approached by any other system. The computer is fed data on sales and inventory, and issues schedules for production and for shipments to warehouses. Routine decisions are handled quietly and perfectly by the computer and only situations calling for special action are printed out. Thus, managers, foremen and other supervisors are free to concentrate on their primary task of solving problem situations.

Programs similar to that used by Purex are also being utilized by American Bosch Arma and by Electric Autolite. These rather exceptional cases would seem indicative of the present state of integration in American industry.

Intelligence Center.--It is clear that the electronic data processing systems are being used for both management and control functions. There is a great deal of work being done by research groups in this country in an attempt to tie up the manufacturing corporation in one handy computer program. Except in the case of an extremely simple and presently non-existent type of industry, it would seem that the computer will never take over completely. On the other hand, there are areas which do not at the present time seem to be under investigation which would seem much more promising in the short run.

As Malcolm points out, "The crux of any organization is not so much the static arrangement of its components which the 'normal' organization chart pictures but rather the dynamic relationship between them as the whole system operates, which the chart does not show."[58] In its operation, there will be some quantifiable results, but these are not all going to be self-evident. It takes an astute intelligence center consisting of the best possible equipment and brains plus competent executive talent to fill in those gaps which will remain for many years to come.

In its broader meaning, the word "intelligence" takes on some military connotations. There would seem to be room for some research of this sort in industry, too. The present mathematical models of manufacturing industries are not yet perfect, but they are still valuable. An able intelligence center in any firm ought to be able to use these models to develop more concrete information on what the competition is doing. This calls for data which may not be readily available, but most of it can be obtained easily and honestly. Customers often are willing to issue facts on who got what orders at what price. There is much in the way of industry-wide data which can be reinterpreted for specific firms. Conventions, trade meetings, stockholders meetings, journalist's stories, and the salesmen's grapevine are all possible sources. The missing links must, of course, be estimated, but the results will be much more meaningful than a general guess on what the competition has done, is doing, and plans to do.

A wide-awake intelligence center can also pick up odd bits of information and see if any meaning of value to the company can be isolated. For example, sandpaper sales are carefully watched by the Minnesota Mining and Manufacturing because they find that sandpaper sales pick up "a little ahead of the economy in general."[59] And, contrary to what you might expect, auto-leasing firms claim that when mileage falls off, the economy is rising because sales are easy and salesmen quit early.

The intelligence center ought also to be of value in handling confidential information. This would include new product and production techniques, new plans for relocation, for mergers, for eliminating lines or plants. Personal information such as medical or efficiency reports belong in this area, as do time study reports, and salary increase and promotion decisions. The point is that not only can information leak to competitors and employees, but that in the transfer it is apt to be distorted, and an intelligence center can be expected to behave with more discretion.

Finally, if any successful program is ever written to integrate every function in an organization, it will have to incorporate those things that "everyone knows." It is not always easy to recognize these do's and don'ts and often the members of the organization are unaware of some of the rules they automatically follow. Perhaps some intelligence work would be of help here, in getting down on paper the things that everybody is aware of regarding this employee, that customer, and those products.

<u>The Same Old System</u>.--If the data processing system isn't working, the chances are that the problem is more than the presence or lack of an electronic system. Some companies keep on doing things the same old way regardless of the potentialities of the equipment at their disposal. Not only should the information system be carefully analyzed before installing electronic equipment, it must also be analyzed at regular intervals as long as the company is in business. There is no point in putting out regular reports when they are only needed two or three times in five years. There is no value in storing records to answer questions which will never be asked. The effective system will increase management's ability by analyzing the information needed for management decision-making and expediting its delivery. It will also be the connecting link between all the units of the organization regardless of their location or desire for independence.

The manager who is buried in information should send his system to an analyst. He has probably failed to set up rules in advance by which the computer can make the routine decisions and leave only the exceptions for the manager's consideration.

Wrong Data; Wrong Questions.--It is well to remember that data is subject to many inaccuracies over which the electronic data processing system has no control whatsoever. Information obtained by observation, under questioning, or as a result of experimentation is obviously subject to many human errors.[60] The information that arrives for processing may be misinterpreted or two items may be accidentally transposed. It may even be recorded improperly. Then, when the results are issued by the system, there again is the possibility of misinterpretation.

As Norbert Wiener has pointed out, Hamlet had a problem which he defined as follows: "What had happened to the late King of Denmark and what should he, Hamlet, do about it?"[61] Hamlet asked a ghost what to do and received a very detailed reply. Wiener thinks he deserved the answer he got to the wrong question. "He had asked about his father when as any psychologist will tell you, he should have asked about himself and his relations with his mother."

The Disappearance of Middle Management.--Leavitt and Whisler and many other authorities have expressed some concern over the impact of the new electronic methods on organizational boundaries.[62] In particular, mention is often made of the fact that the work of middle managers may become programmed and that less skill and authority will be necessary in these jobs. At the same time, of course, the top managers will be gaining in stature and importance. This means that the major training ground for top management, the middle management level, will be eliminated as the integrated data processing systems become more complex.

Actually, trainees should be ready to move up to the top jobs in better shape than ever before. The computer helps solve the problem it has created. Business games and actual simulations of parts or all of the employee's organization mean that he can make decisions over and over until he becomes proficient. Furthermore, this mechanized training program keeps perfect records, prevents covering up of errors, and eliminates any opportunity to shift the responsibility for a decision which produced poor results. It may even make learning more interesting for the trainee since he can handle many more and many different types of decisions than he might have faced as he climbed the old ladder.

Centralization.--Some concern has been expressed regarding the possibility of a trend back to centralization. One expert believes that most corporations will only centralize what-to-do, the long-range planning functions, and that the how-to-do-it will remain in the hands of the decentralized units.[63] There is no reason why a centralized data processing system should mean the replacement of a company's entire decentralization setup. The data processing system can serve the function of seeing that exceptional conditions everywhere are called to top management attention at both the main headquarters and the decentralized headquarters. For administrative purposes, the decentralized arrangements can remain unchanged, thus maintaining improved manageability, flexibility, and better customer service.

Concentration of Power.--If there is a really serious problem in an integrated system, it revolves around the power which will be in the hands of the manager of the system. This will be particularly dangerous if top management is so complacent that it feels that whatever the computer prints out is a sufficient basis for all decisions. On the other hand, if the full benefits are to be obtained from this "intelligence" center, management must be willing to grant sufficient power to the manager.

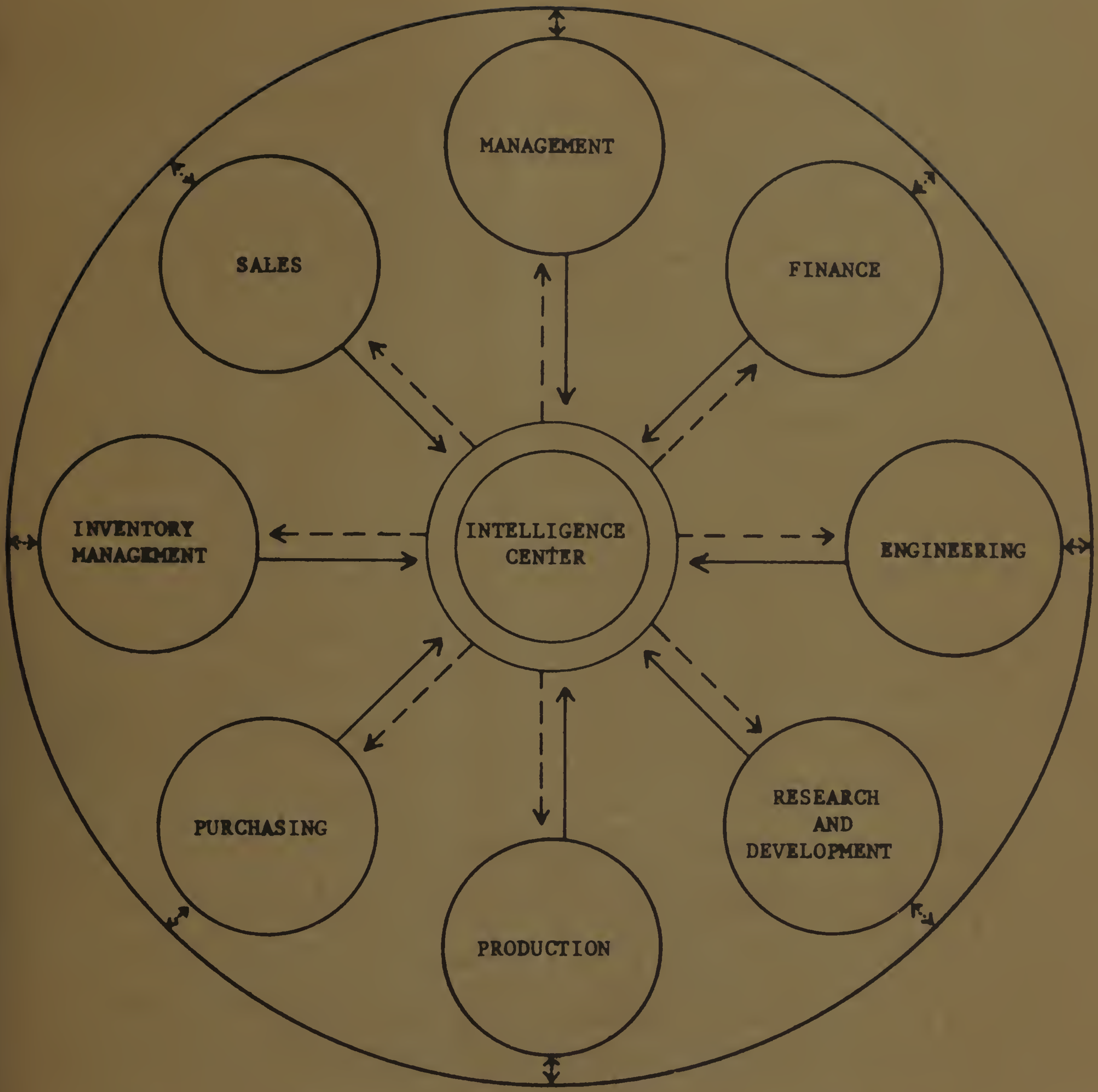
CHAPTER VI

MODELS FOR CONSIDERATION

Satellite Model 1A.--This model was designed to point out in some measure the complexity of the environment immediately surrounding the intelligence center of a manufacturing company. The elements in this model are arranged in a very orderly manner, but it must be emphasized that there are many interrelated and integrated subsystems lying below the surface. Furthermore, even if it were possible to identify all of these subsystems, it is unlikely that a perfect representation would be possible, particularly in view of the fact that an on-going organization is always something more than the sum of its parts.

In any manufacturing company, it is possible to identify two main flows, a product flow and an information flow. In the case of the product flow, raw materials and labor and tools are combined to make some product for which a use is expected either internally or externally. This use or demand for the product might be considered as an origin of the information flow since the demand inspires the organization to plan the means for satisfying the demand.

In planning an intelligence center, the information flow must be carefully studied. For example, an investigation



MODEL 1A: THE INTERNAL SATELLITES OF THE MANUFACTURING COMPANY

⟶ DATA
- - → DECISIONS AND REPORTS
←·····→ COMPUTER BYPASS
(FORMAL AND INFORMAL)

would be undertaken to find out what written materials are being used. Some of these materials will be in the form of inputs and outputs, others will consist of records in files. Internal memoranda and correspondence files would be scrutinized carefully. Equally important is that information which is not put into writing and which can be discovered only by actually living with the organization.

Integration is one of the keys to a successful intelligence center. Product demand comes to the organization in the form of orders received by the sales department. Sales submits the order to the finance department for credit clearance, from where it is forwarded either to the shipping department, if the material ordered is in stock, or to the production department. If the order means an increase in previous production plans, then the purchasing department must be notified to obtain additional raw materials, and the receiving and accounting departments must be properly informed. Then, when the raw materials arrive, receiving notifies production and accounting. In producing, shipping, and billing the customer's goods, much more information flows into the accounting department, and between the organization and its customer. Obviously, there is a certain amount of common information in the areas of production, accounting, sales, shipping, and receiving. This information must be efficiently integrated into the intelligence center. The routing of data must be traced from origin to destination and arranged in chronological sequence, perhaps by means of flow diagrams. Probably some duplication of effort can be uncovered. By reducing the number of different pieces of information traveling through the organization, both paperwork costs and opportunities for errors in transcribing data can be reduced.

Clearly, an intelligence center is not going to spring up overnight. It can be based on a general plan, such as Model 1A and Model 1B, but it will come into existence only through the implementation of a logical series of steps. Perhaps the best starting point is the "finance" satellite. This satellite has been selected for two reasons. In the first place, ordinarily there is more data processed here than in any other division of the manufacturing organization. Secondly, there is usually talent available in this department which is experienced in some formmof data processing. Included in this satellite is the accounting department, which, as indicated above, ties together many other satellites. But the accounting department is still too complex a unit with which to begin.

An important function of the accounting department is payroll processing. It was pointed out earlier that this function is the most widely programmed business application of the computer. Payroll accounting involves the collection and integration of such data as:

Salary and wage rates supplied by personnel.

Special incentive payments from personnel or from sales budgets.

Time cards from the production department showing regular time and overtime.

Withholding and social security taxes from the federal government.

Withholding taxes from state and local governments.

Pension contributions from personnel.

Deductions for union dues from union management.

Deductions for U. S. savings bonds, stock bonus plans, and charity contributions from employees.

After gathering this information, the payroll department must calculate the appropriate net pay for each employee and prepare checks or cash for distribution. It must also update its files for each employee and distribute the payments made to the appropriate cost accounts.

Once the payroll has been programmed adequately, then the other accounting functions can be tackled. The next step would be the programming of the other finance responsibilities. Then, it would seem sensible to select that satellite for programming which has the second greatest volume of data processing needs, then the third greatest, and so on.

However, even when every satellite in Model 1A has been programmed, it still cannot stand as a simulation model of the organization. There are many external factors which also must be taken into consideration.

<u>Satellite Model 1B</u>.--This model brings out some additional satellites which must be incorporated in any working intelligence center. It should not be viewed as a separate entity

MODEL 1B: THE EXTERNAL SATELLITES OF THE MANUFACTURING COMPANY

⟷ INFORMATION FLOW

but is really the other "half" of Model 1A, and it ought to be visualized as if it were joined to Model 1A. Not only is there a steady information flow between the intelligence center and each of the external satellites, but there is also communication between the satellites themselves.

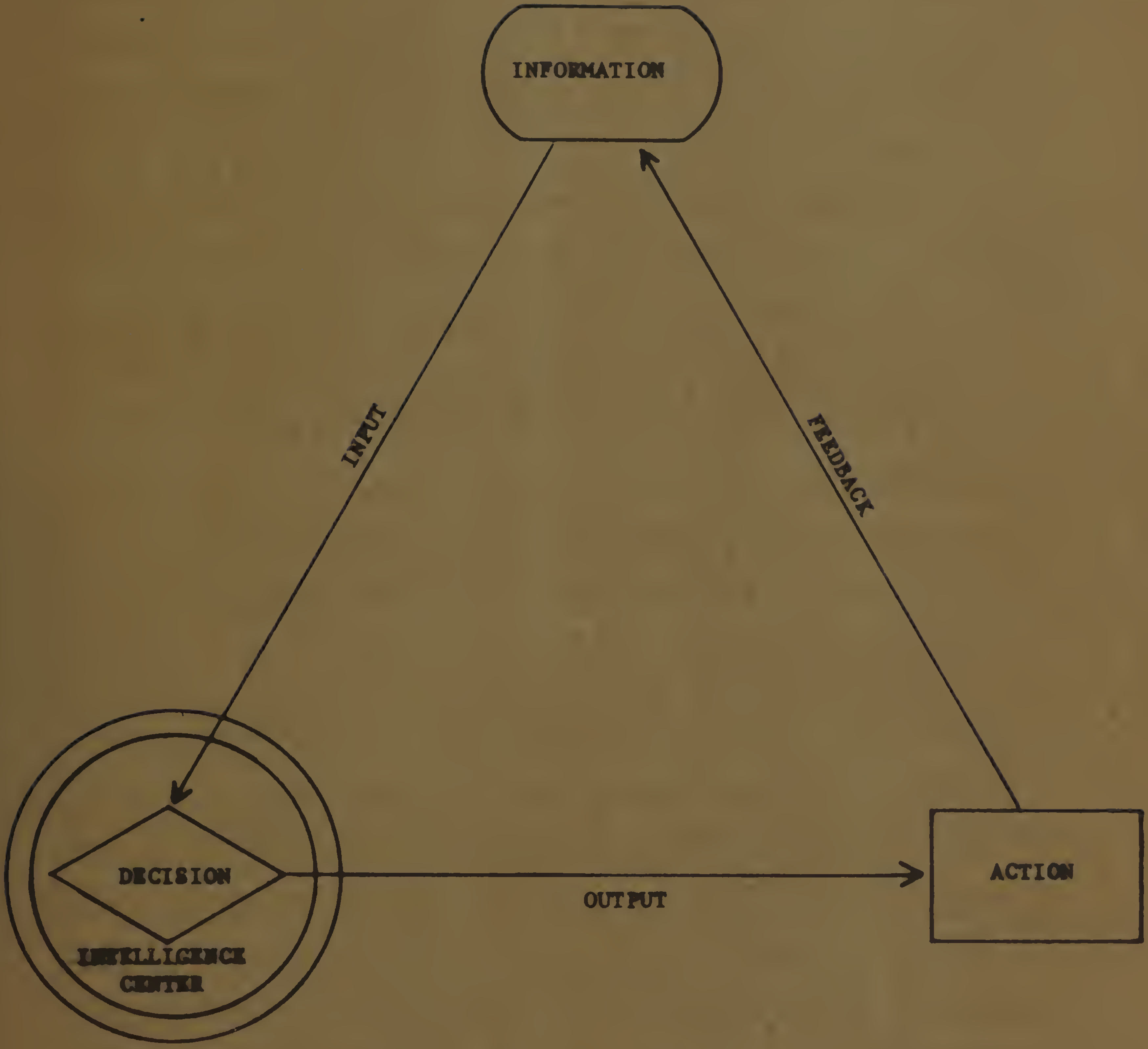
A most important part of Model 1B is the competitor satellite. This really brings into focus "intelligence" in the sense of reconnaissance for "enemy" information.

What sort of information would be sought in order to program the actions and reactions of the "competitor" satellite? In general, facts would be needed about competitive performance in the past for each product and for each market, and about the capabilities and resources of competitors in regard to every product and market.

More specifically, data on the past performance of competitors would include for each product, items such as sales volume and share of market. This information is easily obtained in many cases from published financial and other reports. Then, the current performance of these competitors would be investigated, particularly in regard to new product developments and changes in management and price policies. Here it becomes more difficult to obtain facts and full details probably will never be available. However, many changes will be announced publicly, and others will be made available to the intelligence center if salesmen and customers and suppliers are surveyed regularly. Still more information can be obtained by management representation at all trade shows and meetings and even at competitive stockholders' meetings. Finally, information would be desirable regarding the future plans of competitors. This is the most difficult area in which to obtain facts and the sources are little different from those suggested for current information. It should be noted that even if the information gathered is not absolutely accurate, it will often be more valuable than an outright guess.

The other satellites would be approached in a similar manner. Hopefully, as all the internal satellites and all the external satellites are programmed, they will be integrated properly so that the end result is a working simulation model of the manufacturing company. This model would be used by management to simulate the probable consequences of important actions such as changing prices, installing new inventory systems, and altering advertising budgets. In addition, this model would become a prototype for developing a working model for competitive organizations.

Model 2. Basic Intelligence Center Flow.--This model is intended to describe the action of the intelligence center when it receives information which calls for some decision to be made. The pattern shown would be followed whenever any information was received. In some instances, the decision would be to file the information, in which case there is no



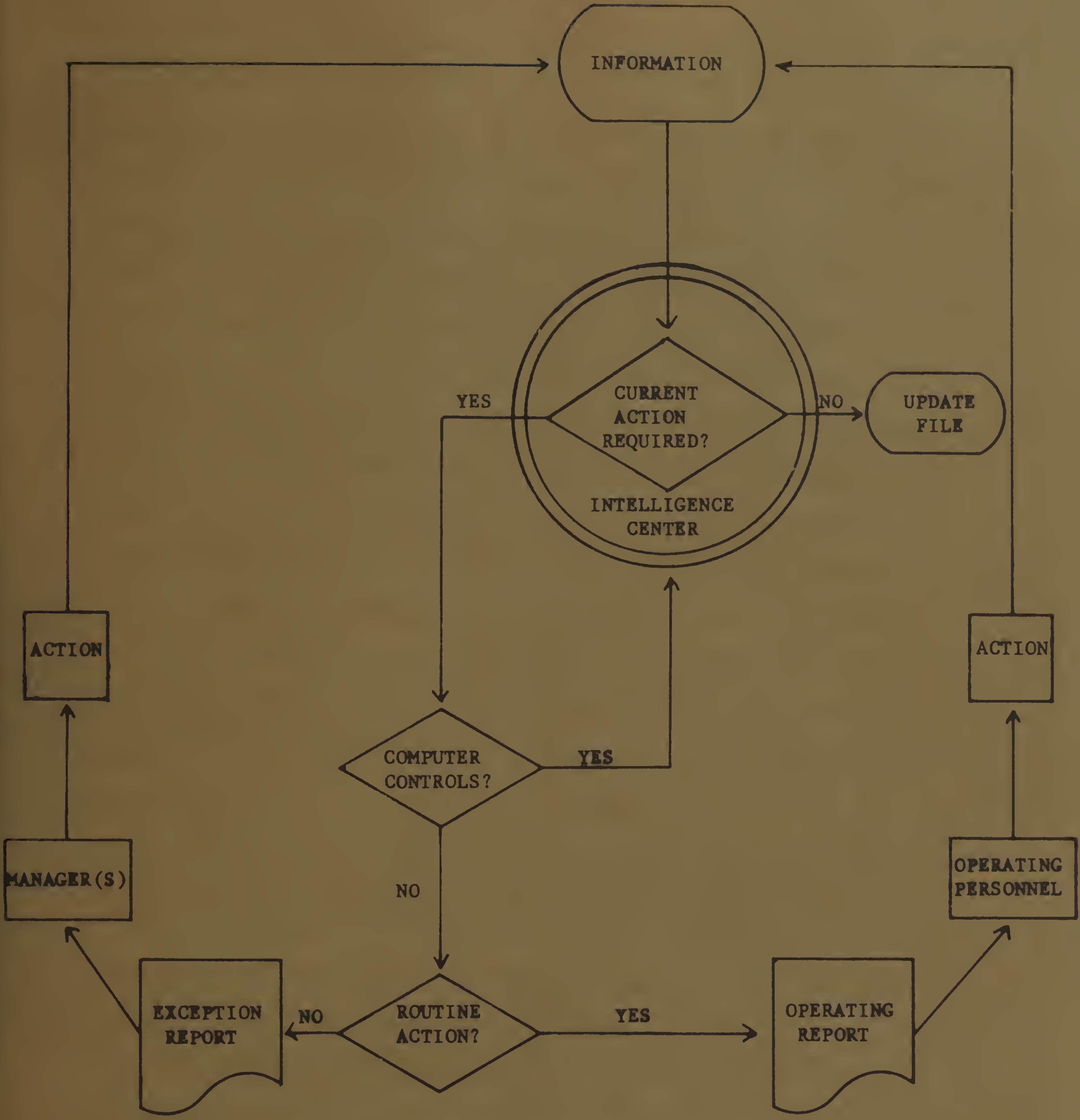
MODEL 2: BASIC INTELLIGENCE CENTER FLOW

immediate feedback. However, eventually this information will be used for some purpose which will feed back to the information source. Presumably no information is stored by the center unless it is expected to be of some value at some point in time.

Some output will be of a corrective nature, perhaps in the form of exception reports. The intelligence center will have been informed of the desired state of affairs, will receive information regarding the actual conditions, and will put out whatever may be necessary to undertake corrective action.

Again, it must be stated that the organization is a complex, interlocking network of information channels. There are many areas in which decisions are required and it is the whole composed from these areas which forms the ongoing organization.

Model 3. General Intelligence Center Flow.--This model shows in more detail the response of the intelligence center to the receipt of information. It must first of all decide whether or not immediate action is required. If the information is to be retained for future use, then the center simply will update its files for that particular subject. If current action is essential, then the center must determine whether this is action that can be taken by the center (the computer), itself, or whether man and/or machine action is in order.

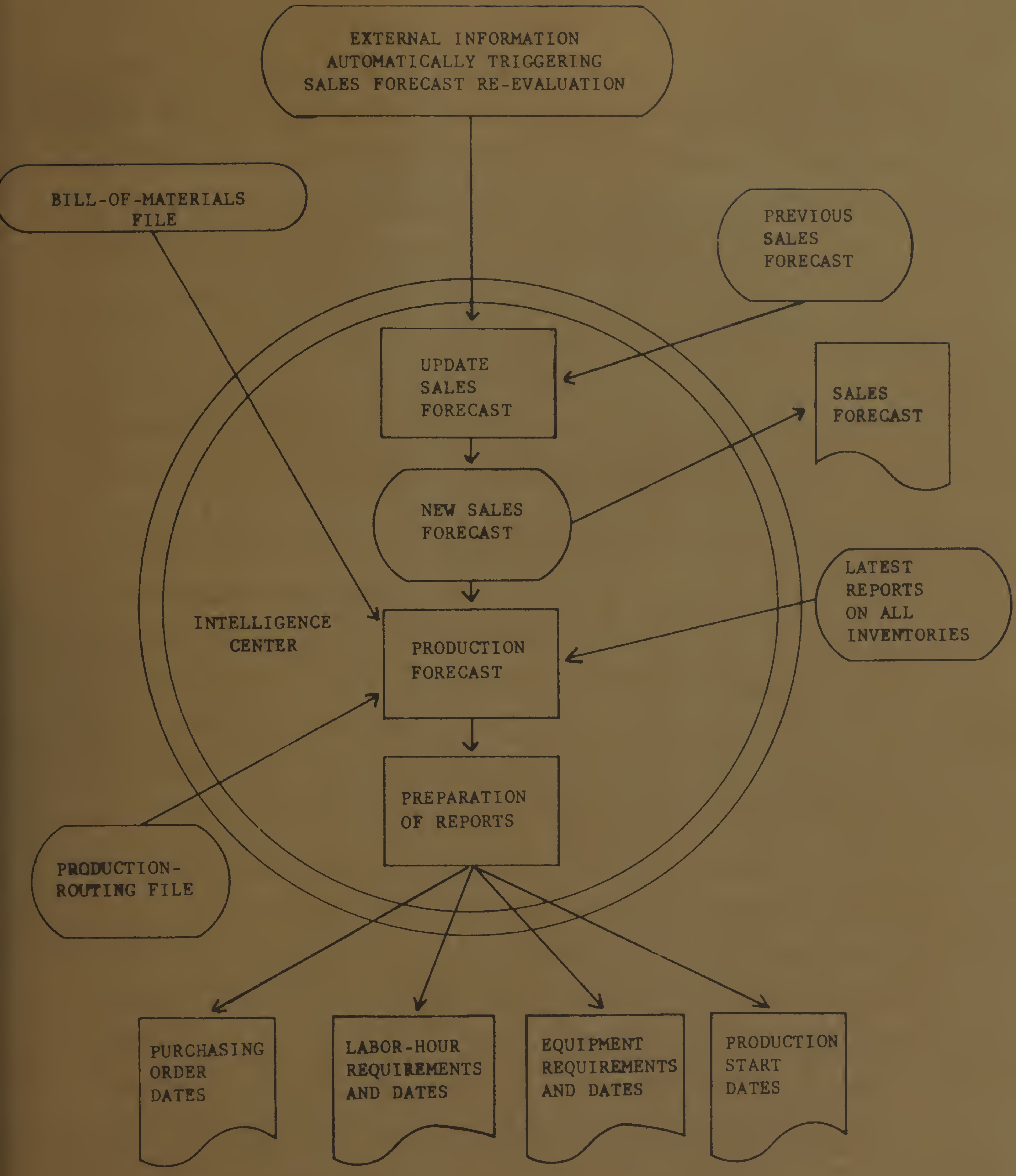


MODEL 3: GENERAL INTELLIGENCE CENTER FLOW

If the center cannot handle the action, it must next decide whether routine action will satisfy the needs of the situation, and, if so, then an operating report is printed out to alert the operating personnel. When this report has been acted upon, the intelligence center is properly notified. However, when an exceptional situation develops, then the intelligence center communicates with middle or upper management who will take action and then report back to the center.

Exception reports are likely to crop up in many areas of the organization. In production control, for example, an exception report might be issued whenever raw materials inventories fall sufficiently to penetrate into protective stocks. In this instance, the exception report probably would be directed to the attention of operating management. However, in the event that the protective stock was used up and raw materials were actually back ordered, then the exception report might call the attention of middle or upper management to the situation.

Model 4. Application for Production Forecasting.--In this model, the assumption has been made that some outside event, such as the shutting down of a competitive plant or a price reduction by a major competitor, has made it necessary to reevaluate the sales and production forecasts. The intelligence center takes this new information, determines its probable effect on the previous sales forecast, and prepares



MODEL 4: APPLICATION OF INTELLIGENCE CENTER FOR PRODUCTION FORECASTING

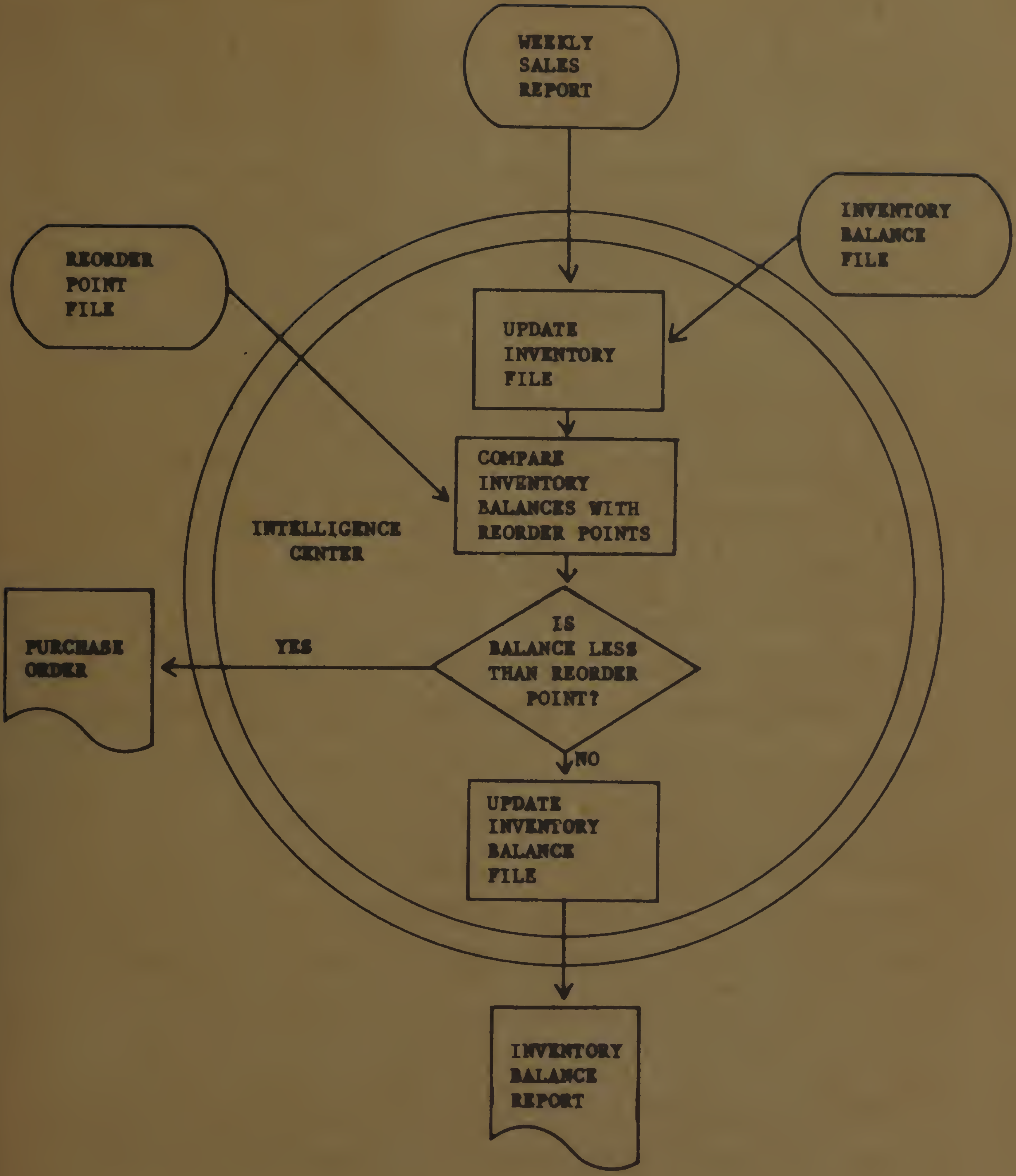
and issues a new forecast. It checks the new sales forecast against its fill-of-materials, production-routing, and inventory files. Revised reports are then computed and issued showing the required dates for issuing purchase orders, for hiring labor, for setting up equipment, and for starting production.

Note that this model is useful also for management simulation to determine the affect of any internal product or price changes on the company's sales forecast. An important advantage of any computer model of this sort is that more actions can be tested more quickly than ever before possible.

Model 5. Application for Minimizing Stock-Outs.--In this model, the assumption is made that it is to the advantage of the corporation to maintain sufficient inventories of products to meet every reasonable demand for them. The profits lost due to stock-outs far exceed the cost of maintaining the inventories.

Reports on sales are submitted to the intelligence center on a daily basis in order to update the inventory files. The new inventory balances are compared with the established re-order points, and purchase orders are written for economical order quantities. Finally, the center issues a new inventory balance report which will show, also, the items and delivery dates requested on the purchase orders.

Clearly, this model will be of particular value to a

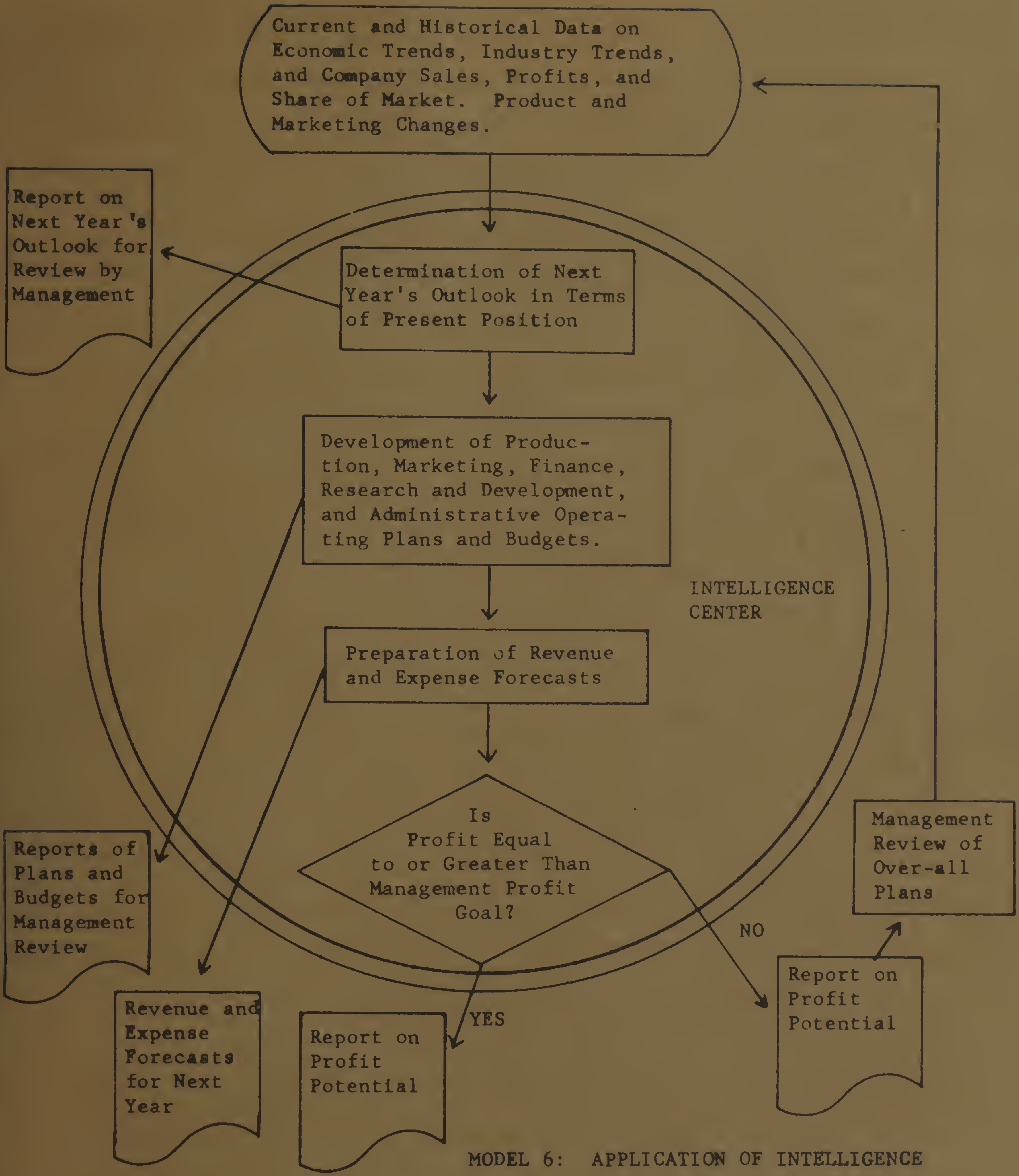


MODEL 5: APPLICATION OF INTELLIGENCE CENTER FOR MINIMIZING STOCK-OUTS

company which must handle several thousand different items. It will be able to keep on top of its inventory problems more quickly and more accurately.

Model 6. Application for General Planning.--This model again requires vast quantities of data. It starts with the collection of data concerning the economy, the industry, and the company, itself. The intelligence center analyzes this data for trends and submits its interpretation of next year's outlook for study by the company management.

The center uses its analysis of future prospects for the company as a basis for determining the necessary operating plans and budgets for all departments including production, finance, marketing, research, and administration. Then, revenue and expense forecasts are calculated, and the projected income is checked to determine whether or not the next year's prospective income will pass the profitability tests established by the company's management. These tests might include gross profit percentage and contribution calculations although the latter must be an approximation due to the difficulties involved in identifying all the direct costs. In the event that the profitability requirements are not met, then management must re-evaluate its over-all plans and see where changes can be made that will improve its position. The intelligence center will be of great help to management in this re-evaluation, since every step of the

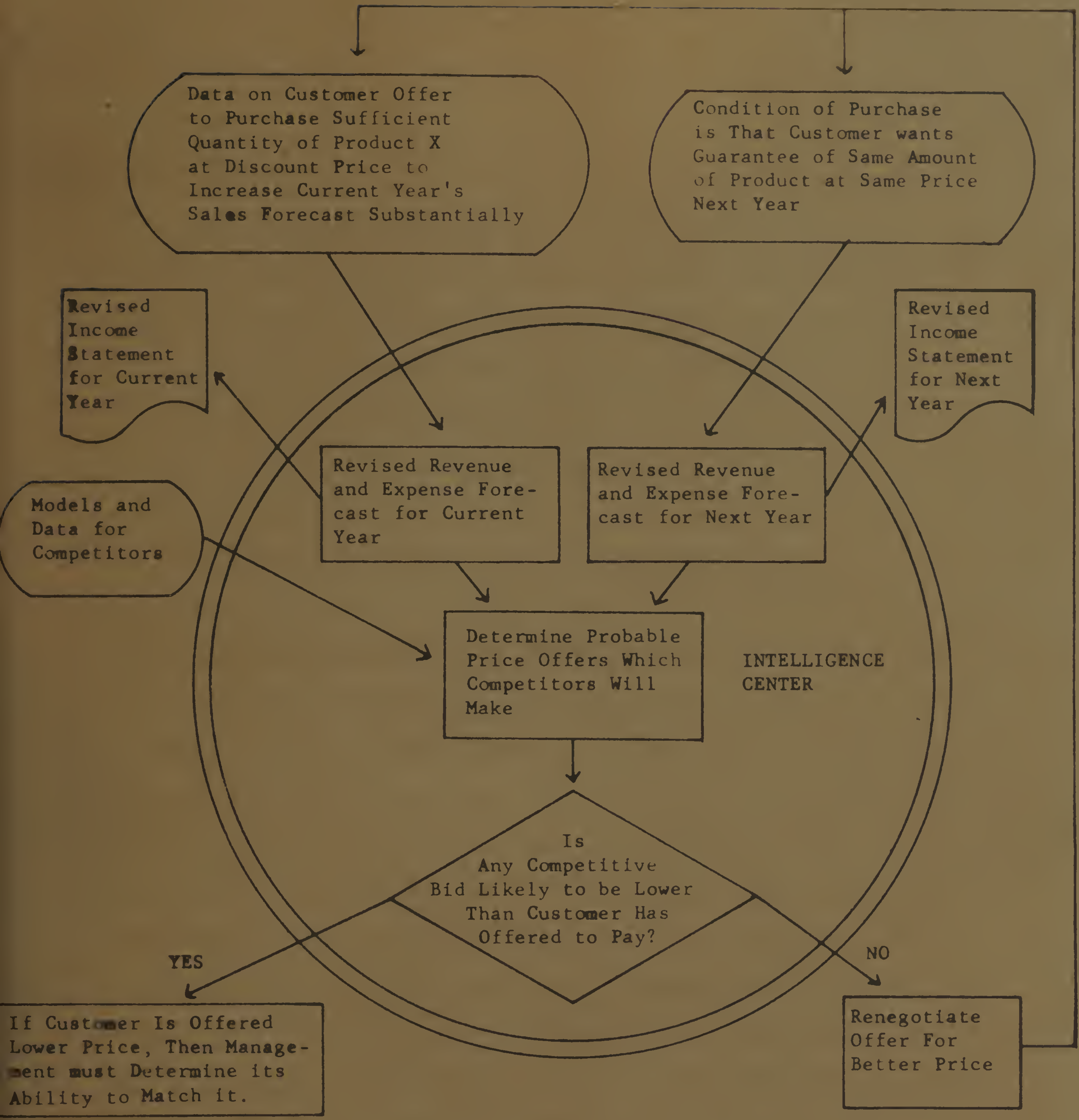


MODEL 6: APPLICATION OF INTELLIGENCE CENTER FOR GENERAL PLANNING

center's analysis can be printed out for study.

Model 7, Application for Screening Customer Offer.--In this model, the competitive models mentioned in the discussion of Model 12 are put to good use. An important customer has offered to purchase a substantial quantity of a certain product this year and an equal quantity next year, but his terms are that he be given a certain discount. The intelligence center first computes the effect of the acceptance of this order on its income statements for this year and next year. If the company's profitability requirements are not met, then the offer may be rejected unless special circumstances, such as idle capacity, make the proposal palatable. But if the company's profitability requirements are met if the order is accepted, the intelligence center then calculates the probable price offers which competitors will make if they learn of the prospective purchases. If it appears that no competitor can meet the offer, then management is informed so that it can renegotiate for a better price. If, on the other hand, it appears that one or more competitors can meet or underbid the price, management may wish to offer a better price at once or may prefer to wait and see if the purchase can be closed before any competitors find out about it.

Data Flow and Decision Flow.--In discussing these models, the emphasis clearly has been on processing data. However, the



MODEL 7: APPLICATION OF INTELLIGENCE CENTER FOR SCREENING CUSTOMER OFFERS

word "programming" should be understood to include a description of the dynamic behavior of the data which actually gives meaning and substance to the satellites and to the organization as a whole. Only in this way can a model be developed which describes the actual operating conditions, and which can be used as a simulation model. The description may involve sets of mathematical, statistical, and heuristic relationships which simulate the decision flow in the company. It is the particular combination of data flow and decision flow that gives each organization its special character and its competitive advantages.

Difficulties may arise in the matter of perspective. An intelligence center is not going to look the same to the production manager, for example, as it will to the top executives. The production manger will see and understand the intelligence center primarily in terms of what it can do for him. He is not going to be interested in what benefits the center can provide for other departments. The top management, on the other hand, will view the center mostly as an aid in making longer-range plans and in handling exceptional situations. A completely different attitude may be taken by middle management, which will see the computer taking over many of its so-called decision functions, most of which were simply run-of-the-mill follow-ups of pre-established organization policies.

It is probably safe to predict that the top management of the future will be trained to identify changes in information flow and in decision flow within the organization and to create those additional changes necessary to keep the intelligence center functioning effectively. But there are many "unknowns" concerning the affect of the intelligence center on the organization of the future. What will be the shape of the hierarchical structure? How much of middle management will actually be deleted? Will a new theory of organizations be required?

CHAPTER VII

CONCLUSION

There should be no doubt at this point that the potential of the computer in an integrated data processing system has scarcely been tapped. Even in the ordinary sense, where an integrated system simply attempts to tie together the internal information flow, progress has been limited. If this meaning is extended to include the use of the system as a real intelligence center, then the progress must be considered negligible. However, several of the models could serve as starting points in the intelligence center direction, just as accounting applications were the starting points in basic internal integration.

The possibility of a complete mathematical model of an industrial organization, one which might replace the human factors entirely, seems rather remote at this point. There is one extremely important gap which presents a really challenging problem; how does top management make decisions? The top managers seem to be in some sort of agreement concerning decision making and perhaps some expert will be able to program their approach:

> Charles Cox, president of Kennecott Copper, says, "I don't think businessmen know how to make decisions. I know I don't."

> Benjamin Fairless, former chairman of U. S. Steel, comments, "You don't know how you do it; you just do it."
>
> Dwight Joyce, president of Glidden Company, says, "If a vice president asks me how I was able to choose the right course, I would have to say, 'I'm damned if I know.'"

Suggestions for Further Study

1. Since computers are taking over the routine decision-making functions of top executives, how will this affect their policy-making and planning techniques? Will the absence of routine, relatively thought-free tasks, make these top management jobs seem too easy, or will the pressure actually increase since there will be fewer excuses for poor performance?
2. There is a great deal of discussion about preventing executives from being swamped with data. Is the present trend of cutting back on quantity going to have any effect on the creativity of the company? Specifically, in the case of the sales manager, who once had an assistant who did nothing but analyze sales statistics, and who used to pore over the figures himself, will the absence of this task put too much distance between the manager and his problems? Will it remove the indications or tips for profitable innovations?
3. In the area of intelligence, competitive model building might be an extremely beneficial project. The starting point might be the best available mathematical model

for a particular company. Then, equivalent models would be developed for each of that company's competitors, making use of all possible sources of data on each competitor.

4. Much more research and development work is needed before a full-scale intelligence center of the sort suggested in Models 1A and 1B can become a reality. It has been demonstrated that the center can be divided into satellites, and that these satellites, in turn, can be further subdivided. There would seem to be many opportunities for investigation and programming some of these subdivisions with the hope that they can be combined later with other programmed subdivisions and that eventually a complete center will become possible.

BIBLIOGRAPHY

Chapter I

Borko, Harold (ed.). *Computer Applications in the Behavioral Sciences*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1962.

Gregory, Robert Henry, and Van Horn, Richard L. *Automatic Data-Processing Systems: Principles and Procedures*. Belmont, California: Wadsworth Publishing Co., 1962.

Kozmetsky, George, and Kircher, Paul. *Electronic Computers and Management Control*. New York: McGraw-Hill Book Co., Inc., 1956.

Chapter II

Berkeley, Edmund C. *The Computer Revolution*. Garden City, New York: Doubleday & Co., Inc., 1962.

Borko, Harold. *Computer Applications in the Behavioral Sciences*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1962.

"Calculating Machines", *Encyclopaedia Britannica*, 1958, Vol. 4, p. 553.

Englebardt, Stanley L. *Computers*. New York: Pyramid Publications, 1962.

Glenn, William H., and Johnson, Donovan A. *Computing Devices*. St. Louis: Webster Publishing Co., 1961.

Gregory, Robert Henry, and Van Horn, Richard L. *Automatic Data-Processing Systems: Principles and Procedures*. Belmont, California: Wadsworth Publishing Co., 1962.

Martin, Edley W. *Electronic Data Processing, an Introduction*. Homewood, Ill.: Richard D. Irwin, Inc., 1961.

Morrison, Philip, and Morrison, Emily. *Charles Babbage and His Calculating Engines*. New York: Dover Publications, Inc., 1961.

Wilkes, M. V. Automatic Digital Computers. New York: John Wiley and Sons, Inc., 1956.

Chapter III

Berkeley, Edmund C. The Computer Revolution. Garden City, New York: Doubleday and Co., Inc., 1962.

Borko, Harold. Computer Applications in the Behavioral Sciences. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1962.

"Calculating Machines", Encyclopaedia Britannica, 1958, Vol. 4, p. 553.

Engleberdt, Stanley L. Computers. New York: Pyramid Publications, 1962.

Glenn, William H., and Johnson, Donovan A. Computing Devices. St. Louis: Webster Publishing Co., 1961.

Gorn, Saul, and Manheimer, Wallace. The Electronic Brain and What It Can Do. Chicago: Science Research Associates, Inc., 1956.

Kozmetsky, George and Kircher, Paul. Electronic Computers and Management Control. New York: McGraw-Hill Book, Co., Inc., 1956.

Levsson, Joseph H. (ed.). Electronic Business Machines. New York: Philosophical Library, 1960.

Martin, Edley W. Electronic Data Processing, an Introduction. Homewood, Illinois: Richard D. Irwin, Inc., 1961.

References

1. Fritz, W. Barkley. "Selected Definitions", Communications of the ACM, VI (April, 1963), pp. 152-158.

2. Sluckin, W. Minds and Machines. Baltimore: Penguin Books, 1954, pp. 188-202.

3. Berkeley, Edmund C. The Computer Revolution. Garden City, New York: Doubleday and Co., Inc., 1962, pp. 20-23.

4. Gelernter, H. L., and Rochester, N. "Intelligent Behavior in Problem-Solving Machines", *IBM Journal*, II (October, 1958), pp. 336-45.

5. Shannon, C. E. "A Chess-Playing Machine," *The World of Mathematics*, *IV*. New York: Simon and Schuster, (1956), pp. 2099-2123.

6. MacCalum, D. M., and Smith, J. B. "Mechanized Engineering," *Electronic Engineering*, XXIII (April, 1951), pp. 125-133.

7. "Computer Useful in Heart Studies," *The New York Times*, May 28, 1963, p. 19.

8. "I.B.M. Machine Translates Chinese into English," *The New York Times*, May 28, 1963, p. 16.

9. Oettinger, A. G. "Programming a Digital Computer to Learn," *Philosophy Magazine*, XLII (December, 1952), 1243-63.

10. Newell, A., Shaw, J. C., and Simon, H. A., "The Processes of Creative Thinking," *RAND Journal P-1320*, September, 1958.

11. Wiener, Norbert. *Cybernetics*. New York: John Wiley and Sons, Inc., 1958.

12. Borko, Harold. *Computer Applications in the Behavioral Sciences*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1962, p. 20.

13. Samuel, Arthur L. "Artificial Intelligence: A Frontier of Automation," *The Annals of the American Academy of Political and Social Sciences*, CCCXL (March, 1962), pp. 10-20.

14. von Neumann, John. *The Computer and the Brain*. New Haven: Yale University Press, 1958.

15. Wiener, Norbert. *Cybernetics, Control and Communication in the Animal and the Machine*. New York: John Wiley and Sons, Inc., 1948.

16. Weaver, Warren. *The Mathematical Theory of Communication*. Urbana, Ill.: The University of Illinois, Press, 1949.

17. "Communication: How Much Gets Through?," *Management Review*, L (March, 1961).

18. Wiener, Norbert. *The Human Use of Human Beings: Cybernetics and Society*. Garden City, N.Y.: Doubleday and Co., 1950, p. 61.

19. Leavitt, Harold J., and Whisler, Thomas L. "Management in the 1980's," *Harvard Business Review*, XXXVI (November-December, 1958), pp. 41-48.

20. Barnard, Chester I. *The Functions of the Executive*. Cambridge, Mass.; Harvard University Press, 1951, p. 217.

21. Boulding, Kenneth E. "The Jungle of Hugeness," *Saturday Review*, LI (March, 1958), pp. 4-13.

22. "Fortune Poll," *Fortune*, XXXIV (October, 1946), p. 14.

23. Graham, Ben S. "Paperwork Simplification," *Modern Management*, VIII (February, 1948), p. 22.

24. Kemeny, John G. "A Library for 2000 A.D., "*Management and the Computer of the Future*. ed. M. Greenberger. New York: John Wiley and Sons, Inc., 1962, pp. 135-145.

25. News Release, Audio Devices, New York City, April, 1963.

26. "Devices Retrieve Microfilm Data," *The New York Times*, May 19, 1963.

27. McPherson, Edwin M. "Planning for a Computer," *American Machinist*, September 17, 1962, pp. 141-155.

28. Plant, Harold O. "Why Purchasing Must Be Coordinated With Other Departments in a Comprehensive EDP System," Speech, Computer Workshop of the National Association of Purchasing Agents, June 5, 1962, Chicago, Illinois.

29. Daniel, D. Ronald. "Management Information Crisis," *Harvard Business Review*. XXXIX (September-October, 1961), pp. 111-121.

30. Koontz, Harold, and O'Donnell, Cyril. *Principles of Management*. New York: McGraw-Hill Book Co., Inc., 1959, pp. 578-582.

31. Gilmore, Frank F., and Brandenburg, Richard G. "*Anatomy* of Corporate Planning," *Harvard Business Review*, XL (November-December, 1962), pp. 61-69.

32. Payne, Bruce. Planning for Company Growth. New York: McGraw-Hill Book Company, Inc., 1963.

33. LeBreton, Preston P., and Henning, Dale A. Planning Theory. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1961, pp. 38-97.

34. Haimann, Theo. Professional Management: Theory and Practice. Boston: Houghton Mifflin Co., 1962, p. 64.

35. Top Management Decision. New York: American Management Association, Inc., 1957., p. 38.

36. Spencer, Milton H., and Siegelman, Louis. Managerial Economics. Homewood, Illinois: Richard D. Irwin, Inc., 1959, p. 50.

37. Cheng, Pao L. "Computer Simulation as a New Methodology in Business and Economic Research and Teaching," Colloquim, School of Business Administration, University of Massachusetts, October 12, 1961.

38. Lindsay, R. A. New Techniques for Management Decision-Making. New York: McGraw-Hill Book Co., Inc., 1958.

39. Green, Jay R., and Sisson, Roger L. Dynamic Management Decision Games. New York: John Wiley and Sons, Inc., 1959, pp. 1-4.

40. Vazsonyi, Andrew. Scientific Programming in Business and Industry. New York: John Wiley and Sons, Inc., 1958, p. 18.

41. Churchman, W. W., Ackoff, W. L., and Arnoff, E. L. Introduction to Operations Research. New York: John Wiley and Sons, Inc., 1957.

42. Hertz, David B. "Industrial Operations Research in the United States," Operations Research Reconsidered. AMA Management Report No. 10. New York: American Management Association, Inc., 1958.

43. "Instruction Manual and Systems and Procedures for the Program Evaluation System (PERT). Special Projects Office, Bureau of Naval Weapons, Department of the Navy, Washington, D. C.

44. Kelley, J. E., Jr., and Walker, M. R. "Critical Path Planning and Scheduling: An Introduction," Pamphlet. Ambler. Pa.: Mauchly Associates, 1959.

45. "IBM Management Operating System for Manufacturing Industries," General Information Manual. White Plains, N.Y.: IBM Technical Publications, 1960.

46. Forrester, Jay W. "Models of Dynamic Behavior of Industrial and Economic Systems," a section of Industrial Dynamics Class Notes--Memorandum D-46, August 1, 1959. Cambridge, Mass.; Massachusetts Institute of Technology.

47. Englebardt, Stanley L. Computers. New York: Pyramid Publications, 1962.

48. "Soviet Computer Plans Economy," The New York Times, April 14, 1963, page 32.

49. Orcutt, Guy H. "Views on Simulation and Models of Social Systems," a paper given at the Simulation Conference sponsored by the Western Management Science Institute of the University of California in Los Angeles, September 12-15, 1961.

50. Optner, Stanford L. Systems Analysis for Business Management. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960, p. 59.

51. Englebardt, Stanley L. Computers. New York: Pyramid Publications, 1962.

52. "Central Media Bureau Poll," Advertising Age, December 10, 1962, p. 88.

53. Ifft, L. G., Jr. "Integration of Data Processing and Its Impact on Accounting," NAA Journal, September, 1962, p. 17.

54. Lessing, Lawrence P. Automatic Control (by the editors of Scientific American). New York: Simon and Schuster, 1955.

55. "Management by Computer," Time, December 21, 1962, p. 67.

56. "How Helene Curtis Industries Applies the IBM 1410 Data Processing System to Sales Forecasting and Inventory Control Problems," IBM SAles Bulletin 320-1699, 1963.

57. Englebardt, Stanley L. Computers. New York: Pyramid Publications, 1962, pp. 143-148.

58. Malcolm, Donald G., and Rowe, Alan J. (eds.). *Management Control Systems*. New York: John Wiley and Sons, Inc., 1960.

59. "Offbeat Indicators," *Management Review*, June, 1961.

60. LeBreton, Preston P., and Henning, Dale A. *Planning Theory*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1961, pp. 88-97.

61. Wiener, Norbert. "Hamlet's Low-Speed Computer," *Saturday Review*, April 7, 1962, p. 46.

62. Leavitt, Harold J., and Whisler, Thomas L. "Management in the 1980's", *Harvard Business Review*, November-December, 1958, pp. 41-49.

63. Hoos, Ida R. *Automation in the Office*. Washington, D.C.: Public Affairs Press, 1961, pp. 730-34.

THESIS COMMITTEE APPROVAL:

Pao Lun Cheng Chairman June 14, 1963
(Pao L. Cheng) (date)

Frank A. Singer 6-14-63
(Frank A. Singer) (date)

Robert L. Rowell JUN 14 1963
(Robert L. Rowell) (date)