# Information Processing—from Engineering Drawing to Manufacture*

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**Summary—This paper describes the development and capabilities of an engineering data processing system. It is a system specifically tailored to the requirements of engineering design and manufacturing technical data. The system functions with a minimum of data input from the engineer. This basic data is processed to perform design analysis and standards checking. Design documentation, computation of fabrication requirements and documentation, computation of numerical control data for automated manufacturing equipment, and compilation of history records are also system features. The system serves as a data communications and information retrieval facility. Convenient procedures and computer routines provide for design changes and incorporate new engineering features.**

## INTRODUCTION

A large amount of information is being published about Design Automation and various elements of data processing. This information usually can be rather precisely classified as pertaining to commercial vs scientific, administrative vs technical, engineering vs manufacturing, etc. Most papers presented to date on Design Automation have dealt with some particular phase or segment of a design process. In other words, there has been a tendency, perhaps unconciously, to build boundaries around information and its processing systems. In fact, most data processing equipment in existence today has one of the general classifications mentioned previously, i.e., scientific, commercial, etc.

This paper will describe a processing system which makes no distinction as to classification of data, and places no boundaries on its origin or destination. This system has been developed to meet the following requirements to support electronic data processing equipment production:

1) Require minimum basic data input to the system.
2) Provide complete information required to establish processes, make decisions, etc.
3) Reduce data processing time-cycle.
4) Improve data accuracy and reduce costs.
5) Relieve human burden of record keeping and data communication.
6) Provide historical and information retrieval records.
7) Provide the base for developing a complete management operating system.

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## SYSTEM DESCRIPTION

### Standards

The organization and effectiveness of almost any type of operation depend on the establishment of certain standards and regulations. Standards established for the processing system described in this paper were developed to provide maximum flexibility for every phase of the project. These five general areas of standards are:

1) Electronic circuit standards (see Figs. 1 and 3): Engineers developed a technique to interconnect basic electronic circuit elements in a universal manner. The criterion for interconnection was established in a standardized format and includes loading values, pulse phasing, voltage requirements, etc.

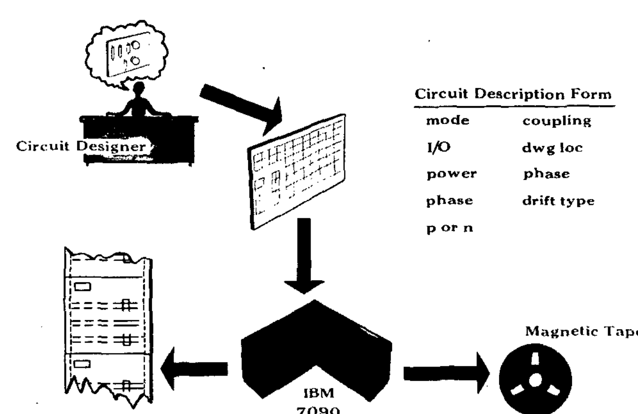


Fig. 1.—Circuit description data recording.

2) Circuit packaging standards (see Figs. 2(a) and 2(b): Two standard circuit packages have been established. The basic package is a card approximately 3 × 5 inches equipped with a tab, containing 16 terminal prongs, that plugs into a small socket. Transistors, diodes, resistors, etc. are mounted on this card and electrically connected by printed-circuit wiring. The second package is formed by joining two single units edgewise to create a "twin card." Thus this card can contain more than double the amount of circuitry (and 32 terminals) but still plugs into two standard sockets.

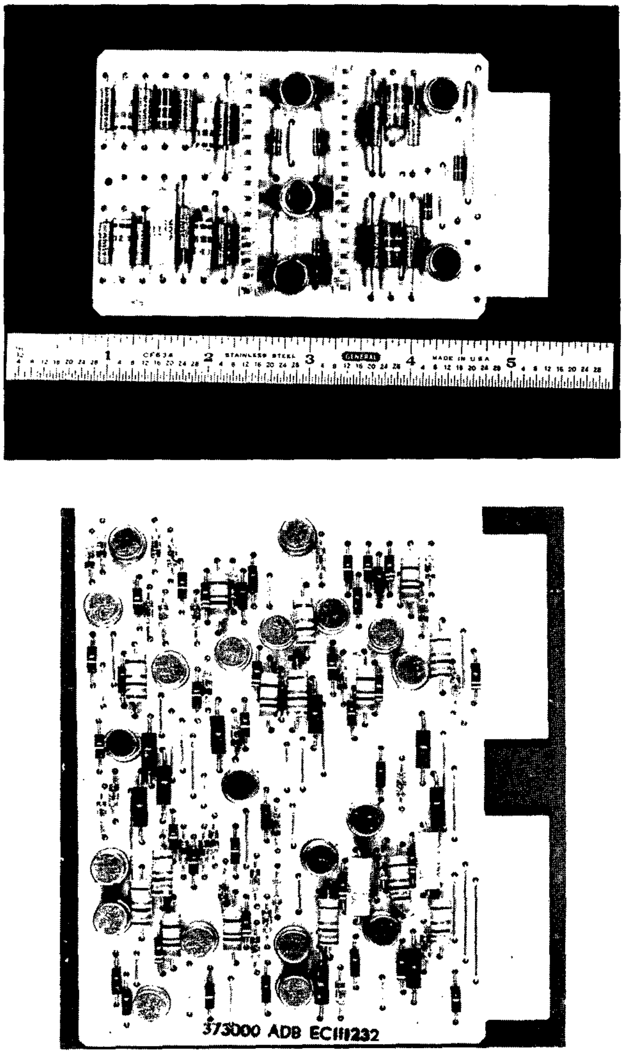

Fig. 2.—(a) IBM SMS circuit card package (single card). (b) IBM SMS circuit card package (twin card).

To date, almost 2000 types of standard cards have been designed to meet a wide range of functional electronic requirements. Standard specification procedures and format have enabled using all these cards in the universal system.

3) Panel and frame standards (see Fig. 3): All panels are constructed of standard sockets having terminals for wire-wrap connections.

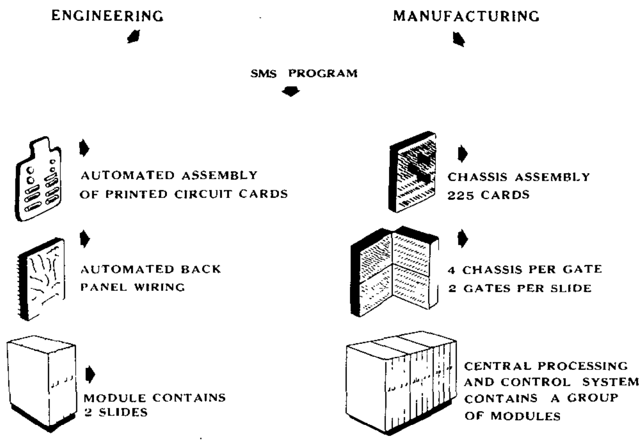


Fig. 3.—Schematic of panel frame and modular construction.

Different size panels are constructed by varying the number of rows of sockets and the number of sockets per row. Thus all panels have identical characteristics as far as point-to-point wiring is concerned; only the extremities of the panels vary. Various sized machine units can be assembled by different arrangements of a selected size panel (Fig. 4): This enables a great variation of size of machine unit—from very small single-unit systems to large systems containing many modules, frames, panels, and cards. Four standard-size panels now are in use with row/socket configurations of 6 × 26, 6 × 40, 8 × 28, and 10 × 28.

4) Automatic production equipment (see Fig. 5): All panels are wired and tested by automatic equipment. The machine that wires panels is instructed by punched cards produced as a normal output from a computer process. A blank panel is installed in the wiring machine and a continuous strand of wire is threaded from its barrel-like container. A deck of punched cards is placed in the reader, and the machine proceeds to install one wire for each punched card. All

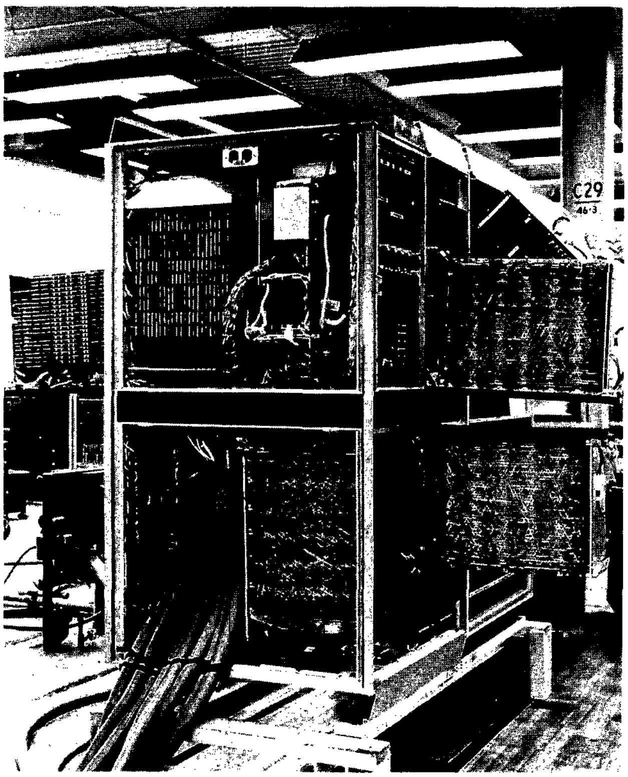

Fig. 4.—Wired panels in the IBM 1401 Data Processing System Central Processing Unit.

panel sizes can be wired by this machine with proper panel-installation orientation.

A second machine, named the Back Panel Tester, checks for proper circuit connections on the entire panel. This machine checks for proper service wiring (input voltage busses), ground connections, and coax shield grounding (if used). A test is made for "opens" and "shorts." A console typewriter records all conditions not meeting the machine tests. This machine receives its instructions from data recorded on magnetic tape. The tape is one of the normal computer outputs.

Fig. 5.—Gardner-Denver automatic wire wrap machines used to fabricate panels.

5) Computer programs: An organized set of standard computer programs (under supervisory control of a monitor program) is used to process all data. Some of these programs are oriented to technology and standards to perform the technical operations required.

**Processing Facility**

A centralized computer (Fig. 6) facility has been established to serve all areas. The computer equipment presently in use includes an IBM 709, 7090, and two 1401 tape systems. The amount and

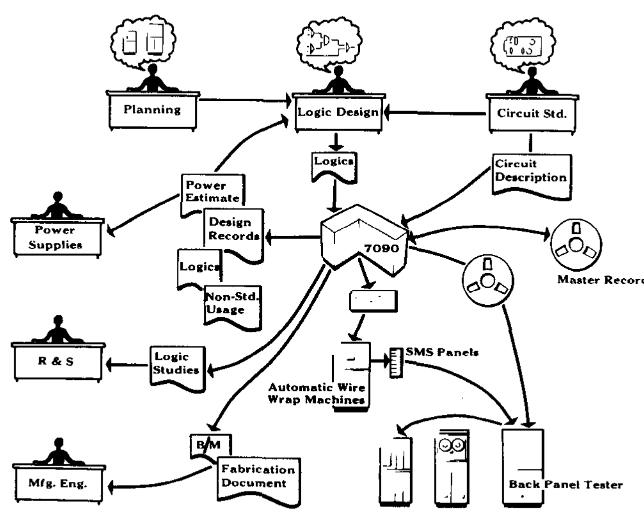


Fig. 6.—Schematic of centralized computer facility used in design automation phases of IBM machines and systems.

size of equipment will vary with the work load and complexity of operations. Plans are under way to install an IBM 1410 Data Processing System equipped with disk files and Tele-Processing. The files will be the 1301 type and will be used jointly by the IBM 1410 and 7090 systems. Future plans will be discussed in more detail in a later section of this paper.

**Input Data**

Much of the input data used during the computing process is contained on magnetic tape and is referred to by the computer as required. An example is the circuits descriptions tape. This tape contains complete technical data relating to all electronic circuits and card packages. The circuits have been given code numbers which are used universally for referencing purposes. The computer uses the circuit numbers to reference data on the circuits descriptions tape. Similar techniques are used to give the computer technical data on panel standards, automatic production equipment, etc.

One can see that the computer is given various standards information only once. Provision is also made to update, add, or delete this data as required. Therefore, the design engineer has only to specify a very minimum discrete design data to have his design originated and implemented.

A preprinted grid form is provided to simplify the job of specifying this design. The grid contains block areas which the engineer uses to insert reference data for some particular standard circuit. Lines drawn freehand between the blocks illustrate the interconnection pattern of the standard circuits. Additional pages are used for additional circuits if the design cannot be provided for on one page. The larger-size panels may require as many as 120 pages to express the total design for the panel. These pages are referred to as "logic sketches." A system of page and line numbering has been developed to permit complete interrelation of all design data in a given machine system. This system permits referencing to other panels, units, frames, etc., as well as between pages for a given panel.

Data on these logic sketches is encoded and punched into cards. The cards are written on tape, which becomes the input to the computer.

## COMPUTER PROCESSING

Engineering designs are processed in four general phases, which are:

1) Data Recording and Electronic Design-Checking (single-sheet basis).
2) Data Assimilation and System Checking.
3) Design Fabrication and Documentation.
4) Numerical Controls and Manufacturing Documents Generation.

**1) Data Recording and Electronic Design-Checking**

The first data recording process is to record all standards information on magnetic tape. Forms (see Fig. 7) are provided the engineers for recording and submitting various technical data. In

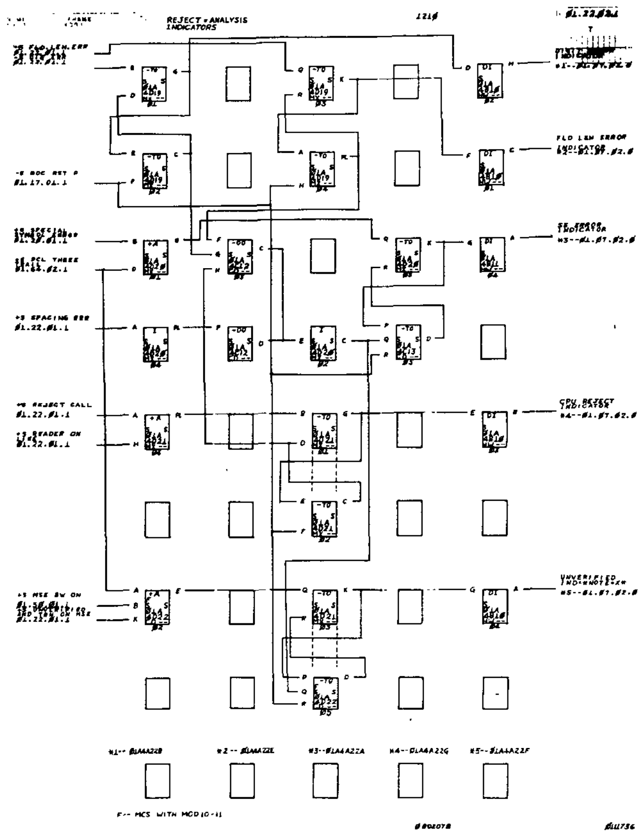

Fig. 7.—Preprinted grid form with engineer's circuits description data.

the case of electronic circuits and card packages, this data is recorded on the circuits description tape. Data from this tape may be printed out to create a catalogue of standard packages and specifications. This catalogue is distributed to the various engineering facilities for reference during the design process.

The magnetic tape containing logic sketch information is the primary production input to the system. As stated previously, this tape expresses a design as an interconnection pattern of standard circuit elements. First, this design is completely analyzed by the computer to test for conformance to technical specifications and established design practices. A listing is produced and sent to the engineer outlining all inconsistencies detected by the computer. Design modifications usually are submitted on a subsequent computer run to make corrections. The logic sketch information is compiled into a special format and recorded on magnetic tape. This data includes all technical design data as well as logic sketch number, engineering level indicator, date, machine type, and other relevant data. This tape is used as the Master Logic record for engineering change updating, history records, input to other computer processes, etc. Data is extracted and processed from this Master Logic record to produce a computer-printed logic diagram (referred to as ALD—Automated Logic Diagram; see Fig. 8). When this phase of the computer process is completed, each logic sketch has:

a) Been recorded on magnetic tape
b) Been completely checked for technical and clerical accuracy, and
c) An ALD printed.

This phase of the process has treated each logic sketch individually but has not related any one sketch to all the others. The reason for this is to provide the most efficient process of error correction, engineering level updating, information retrieval, and accurate data recording.

The foregoing description reviews the first phase of the computer process which provides for entry and processing of original logic sketches or design data. These same computer programs can also be used for updating Master Logic records

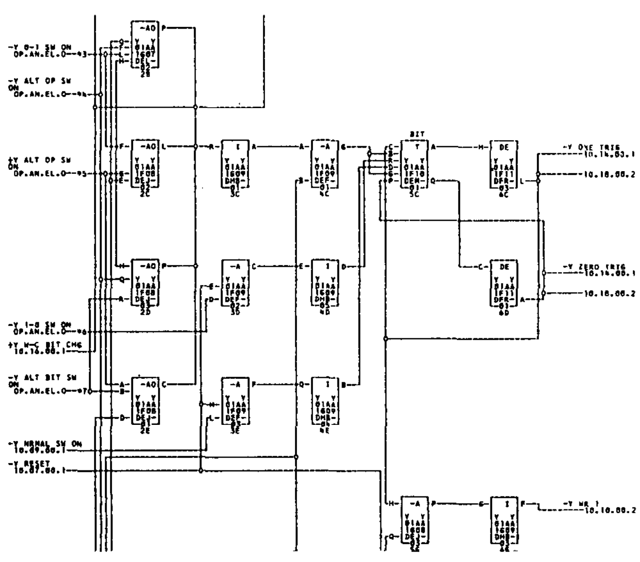

Fig. 8.—Automated Logic Diagram (ALD) machine printout.

with design changes. The engineer does this by marking the ALD received from a prior computer run. Additions are indicated by marking with red pencil. Deletions are indicated by green markings. These markings are encoded, punched into cards, recorded on magnetic tape, and used as input to the computer. Note that only the changed data is used as input. The computer then searches for the appropriate record on the Master Logic tape for the original design data. This data is read from the tape record and matched with the changed data. A complete new data record is created (the old record is not affected), and all computer operations (checks, etc.) are performed on this record. An ALD is printed and the new record recorded on magnetic tape with proper identification for future reference.

Thus, it can be seen that the Master Logic record serves as the basic data for:

a) Computer output-document generation
b) Creating complete new records from only input change data, and
c) For historical records and reference purposes.

One of the more exciting advantages of this process is where a basic product design is modified to meet a wide variety of individual market requirements. The basic design is contained on the Master Logic tape. Design modifications or refinements tailored for a special situation can be made quickly and efficiently.

### 2) Data Assimilation and System Checking

The preceding description of the computer process deals with the input data on an individual logic sketch basis only. This second phase of the process relates all data on the total set of logic sketches. Now the computer makes a complete check to insure that all lines on all logic sketches. couple together properly, and that no clerical and/or technical inconsistencies exist. Certain types of inconsistencies can be corrected by the computer, but the engineer always must approve these changes. Other types of inconsistencies are referred directly to the engineer.for his change.

One can see that the computer has become the answer to the communication problem between the many persons usually involved in an engineering project. At the same time the clerical checks are made, the computer also makes a thorough design analysis to make certain that technical specifications and design practices meet specifications.

At the end of this phase of the computer process, all design data, clerical operations, and basic data-recording is complete. In other words, the design is now ready for implementation.

### 3) Design Fabrication and Documentation

A number of intermediate data tapes were developed during phase 2) of the computer processing. One of these tapes contained a definition of the point-to-point wiring that must be installed on the panel sockets into which circuit cards are plugged. The computer next proceeds to design the wiring that will be installed on the panel. Three major factors are considered:

a) Intercapacitance coupling and mutual induction of signals between wires
b) Physical build-up, and
c) Performance of the automatic machine that installs the wires.

The computer designs wire routes, specifies wire types and the installation procedure. This data is recorded on an intermediate tape for a future process.

Various other manufacturing, engineering, and field service documents are developed during this process. Included are various Bills of Material required to construct the panel, a chart showing types of circuit cards (see Fig. 9) and their locations, listings of line names of diagrams, and listings for use in checking panel assembly.

Another feature of this process is a provision to feed input data directly into the programs by manual means. This permits an engineer to prespecify certain design criteria; for example, that a particular wire be of coaxial cable, etc. Also, small engineering changes can be made quickly without having to follow through phases 1) and 2) of the

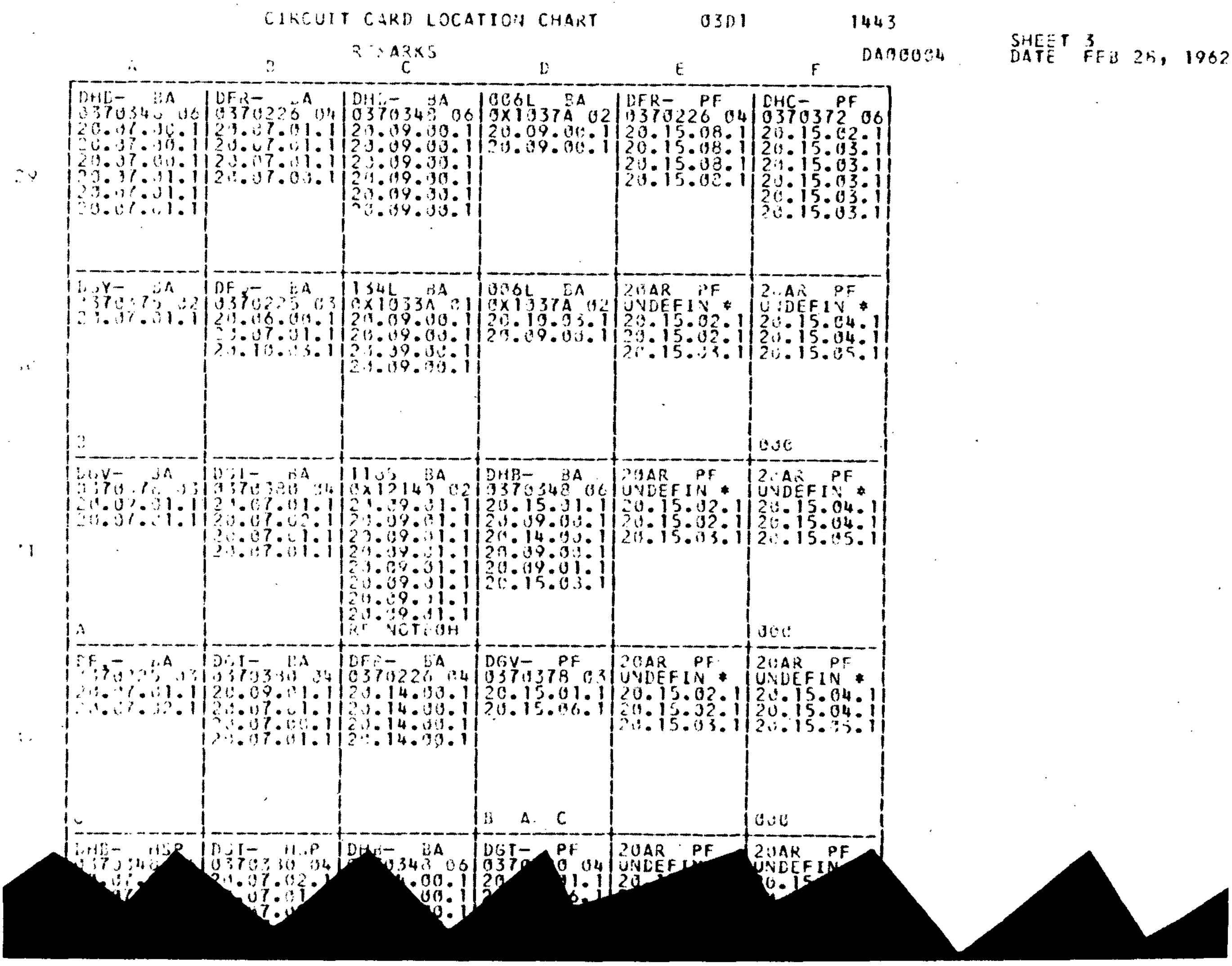


Fig. 9.—Machine printout for circuit card location chart data.

computer processing. Of course, phase 1) must be used eventually to effect proper updating of the Master Logic tape.

#### 4) Numerical Controls and Manufacturing Documents Generation

The intermediate tapes, created by the previous design processes, are used as input to this phase of the computer process. One program uses the wiring design data to generate numerical controls for the machine that will automatically install the wires. The output is punched cards. One punched card contains all information necessary for the automatic installation of one wire from a continuous reel of wire onto an unwired panel. Thus a panel requiring 2000 wires will require numerical control data from 2000 punched cards.

Other numerical control data includes a magnetic tape to instruct a high speed, panel testing machine. This reel of tape and the back panel testing machine can precisely check every electrical connection on a several-thousand-wire panel in a few minutes. A typewriter prints out a listing indicating the type and location of any wiring errors that may be found. This listing is used as manual instructions for any rework that may be required. Similar data is provided for assembling and testing circuit card packages. Still another computer program generates a second program which is in turn used for testing the finished product, and is an aid for locating any trouble detected. This program accompanies the manufactured system to its ultimate installation and may be used by servicing personnel.

Manufacturing documents of various types are also provided. These include B/M (Bills of Materials), rework instructions for engineering changes, manual instruction lists, etc. This information is used in a wide range of operations. For instance, B/M data is related to Manufacturing Build-schedules, and the resultant data is used as input data for purchasing, production control, financial, inventory control, and other applications.

## SUMMARY

The foregoing discussion has reviewed a data processing system, with brief reference to companion engineering and manufacturing operations, utilized for producing electronic data processing equipment. An analysis of this information will reveal a system as shown in Fig. 6. The complete system is rather complex and has required many man years to develop. Major effort was required by engineering, manufacturing, and data processing groups. However, the results are most rewarding. IBM is producing electronic data processing equipment today at a rate and quality which would have been thought impossible only a few years ago. The lead time to design, release to manufacturing, and accelerate to full production has been cut to less than one half of the time required five years ago. In addition, present-day data processing systems are far more complex, and require processing many times the volume of data necessary to design and manufacture than their predecessors.

Other benefits of this computer processing system have been the ability to operate multiple manufacturing operations and easily transfer the manufacture of products from one location to another. A procedure has been developed whereby most data necessary to manufacture an item is communicated to the factory via magnetic tape. It is a simple process to produce multiple sets of tapes for as many manufacturing locations as required. The transfer of products from one location to another is also relatively easy, providing both locations have standardized records and formats. Peak production requirements can be handled by sending tapes to another plant for parallel production operations.

This system had its beginning several years ago as a record-keeping program for wiring machine panels. The program was then improved to the point where the computer actually designed the wiring. Later a machine was conceived to automatically wire panels from computer-generated instructions. Other programs were developed to draw ALD's on a standard printer equipped with special type characters, and perform electronic design checking. Finally, the individual programs were linked to form a continuous system—from engineer to finished manufactured product. Each segment was developed to meet the greatest need of the moment. Also, in almost every case, the program justified itself in savings of one type or another. In other words, the system was developed on the basis of "greatest need" and economic justification.

The author believes that the concepts of the system described here for electronic products can be generally applied to other areas of technology and engineering design. In fact, computers are being used today to solve individual design problems in all phases of engineering including mechanics, hydraulics, optics, aeronautics, automotive, bridge construction, architecture, and shipbuilding. In many of these areas the individual programs only need to be connected into a continuous system.

Probably the most severe and frustrating problem of all is the development of necessary agreements and compromises by individual groups for the over-all gain of the company. This paper has shown how the system performs without regard for invisible or responsibility boundaries, and it is these same boundaries that give the systems planner his greatest challenge.

## FUTURE

The system shown in Fig. 6 may suggest there is little room for further improvement. Nothing could be more incorrect. In fact, the solution of every problem or the development of each new program seems to suggest the need for several more refinements not previously anticipated.

Figs. 10, 11, and 12 show what now seems to be a utopian system. This system actually is a series of computer installations with a very fast interconnecting communication system. Each computer installation is designed to perform in a particular applications environment and to contribute to the total requirement for information processing. The communication system linking the computers makes information in one available to all others, subject to program control. Data is stored in random access devices to provide a completely automatic system for data updating or information retrieval. Real-time communication is provided to all areas of management, engineering, and manufacturing by way of on-line remote terminal equipment. Manufacturing equipment and operations are controlled by special process-control computers which receive production requirements data from other computers. Thus, an engineer can enter basic design information into a terminal unit situated on his desk, and almost instantaneously change the assembly of a unit on the production line. However, it is more probable that this data would go through a series of computer programs, be related to various other data, and present a summation of the situation back to the engineer. An example would be determining the

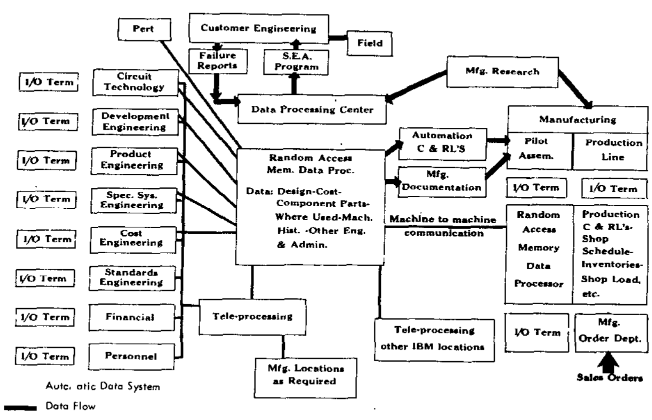


Fig. 10.—Idealized information processing system for a design automation facility.

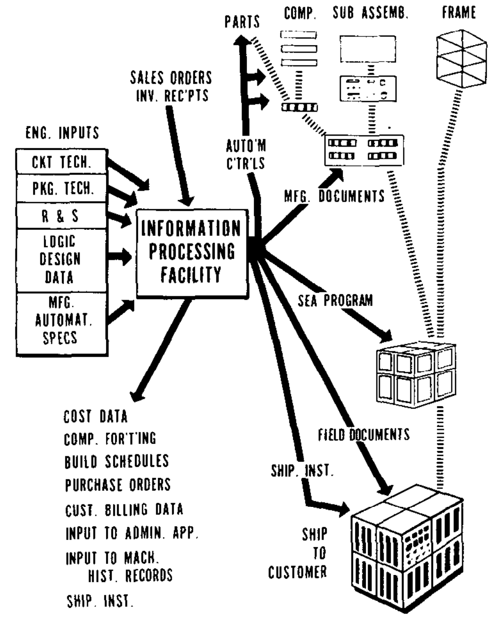


Fig. 11.—Data flow in an idealized information processing system.

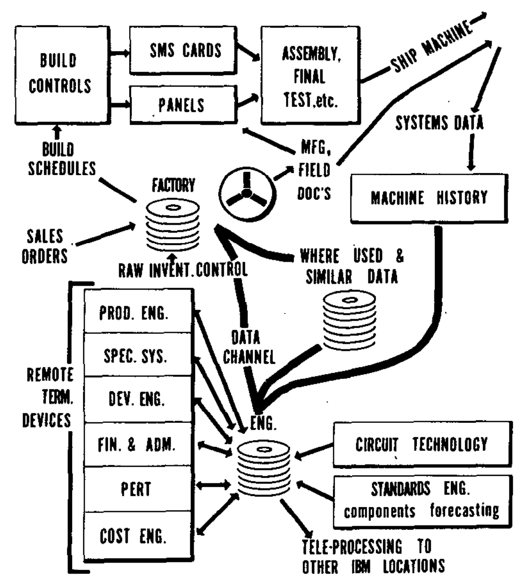


Fig. 12.—Proposed over-all system plan for an idealized data processing system.

impact of a suggested engineering change (design modification). Complete data would be channeled back to the engineer regarding costs, parts to be scrapped or reworked, effect on production schedules, inventory effects and adjustments required, and finally, the effect on product profit.

Today, a high percentage of engineering talent is concerned with technology application and manufacturing support. Many of these engineers can now turn to the more creative science of technology development. At the same time many new and exciting career positions are opening up for automation specialists. Although many people are just now becoming aware of it, a new revolution is taking place in the U.S.A.[1] today. This is a combination of 1) a new chapter in the Industrial Revolution, and 2) a race to develop exciting new technologies for the benefit of all mankind. This evolution of our industrial system will mean unheralded success for organizations which capitalize on its advantages.

1 "Business in 1961," editorial, TIME; December 29, 1961.