JOINT VENTURE AT MASSACHUSETTS GENERAL

bolt beranek and newman at the hospital

by DR. JORDAN J. BARUCH and G. OCTO BARNETT, M.D.

□ **Q:** Dr. Baruch, what are the objectives of the BBN-MGH Hospital Computer Project?

Dr. Baruch: Basically, what we're trying to provide is a computer environment which will foster the growth of medicine. We're interested in applying computation to the fields of patient care, research and administration. Some of these can be subdivided. Patient care, for example, can be the routine activities such as keeping track of drugs and doctors' orders or more extended activity where, say, a psychiatrist may be using the computer to help analyze test scores.

The project began about three years ago with a small time-shared computer. It started with a heavily administrative emphasis. We built a "little hospital system" (Fig. 1) which permitted us to assemble parts of the medical record on an experimental basis—very small sets of data, for a few mock patients actually—and to do many of the operations which we felt would be necessary in an actual hospital environment. When it became clear that the principles were valid enough to warrant further investigation and the capacity of the equipment was too small to permit such further investigation, we increased our facility size and went on to build what we fondly call the "big hospital system." In this system we have the capacity, at least insofar as machines and concepts are concerned, to amass the medical records of many patients, interrogate these records through the machine from many terminals and hopefully analyze the results of the interrogation. The system is large and has these capabilities, as I say, only in concept and hardware.

Q: Dr. Barnett, what problems do you see from the hospital's point of view in getting a system of this kind operating?

Dr. Barnett: I would say the first problem is that of specifying exactly what information we want to collect; this requires the explicit identification of the actual problems

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of medical practice in a hospital. It is probably true that many of the record keeping methods we use are somewhat archaic and represent the carry-over of practices developed 30 to 50 years ago. Much of medical practice can be described as forms of information processing and communication. It is clear, therefore, that we should attempt to take advantage of the advances in this scientific area that are being applied in other disciplines.

Fig. 1

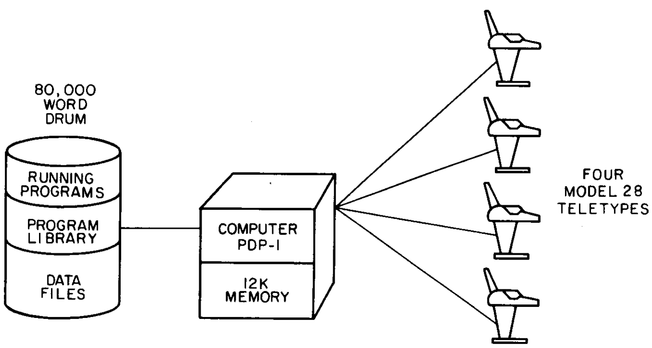

Fig. 2

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LABORATORY REPORT  4:08 PM 10/14/1965
1  PATIENT? .12005   NORMAND,SUSAN
2  DATE?  10/2/1965
3  N DAYS?  7
PLEASE WAIT...
ADJUST PAGE; TYPE "ENTER".

LABORATORY REPORTS                                      NORMAND,SUSAN
7  DAYS BEGINNING OCT 2, 1965 - SHEET 1                  123-54-89

                            DATE SPECIMEN COLLECTED
                            OCT    OCT    OCT    OCT    OCT    OCT    OCT
                              2      3      4      5      6      7      8

              *   *  HEMATOLOGY REPORTS   *   *

HEMOGLOBIN                  13.6                 14.0
     GM./%
HEMATOCRIT                   45.    40.           34.                   42.
     %
WBC COUNT                 12500. 11700.         8700.  7500.          7500.
     /CU.MM.

WBC DIFF IN %
     POLYS                   82.                  82.
     BANDS
     LYMPHS                   8.                  11.
     MONOS                   10.                   7.
     EOS
     BASOS
     PLATELETS                N                    N
   OCT 2  -  +- VAR SIZE RBC'S.
   OCT 5  -  +- VAR SIZE RBC'S.

                  *   *   URINE ANALYSIS   *

ROUTINE  VOL (ML)
   COLOR                     AMB                                      7      8
   PH                        6.0                                   CONTINUED
   SP. GRAV.               1.015
   ALB

LABORATORY REPORTS CONTINUED                             NORMAND,SUSAN
7 DAYS BEGINNING OCT 2, 1965 - SHEET 2                   123-54-89

                            DATE SPECIMEN COLLECTED
                            OCT    OCT    OCT    OCT    OCT    OCT    OCT
                              2      3      4      5      6      7      8

LIVER FUNCTION REPORTS CONT'D

BSP RETENTION                                              15.
     % AT 45 MIN.
CHOLESTEROL                                                              152
      MG.%

           *   *  REPORTS ON BLOOD OR SERUM METABOLITES  *   *

UREA NITROGEN                 9      8             13                     15
     (BUN)  MG.%

                                                END OF LABORATORY REPORTS
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Q: How do you correlate this information?

Dr. Barnett: A good example is in the presentation of the laboratory reports. Laboratory tests are ordered by specific names on specific dates. However, in the presentation to the physician, it is very important that the tests be displayed in a chronological order and by logical groups, such as serum electrolytes, liver function tests, tests of urine function, etc. Some tests, of course, having relevance to different groups may well appear twice in the listing (Fig. 2).

Q: Do you find that you get better quality input because of the system's ability to validity check information as it's coming in?

Dr. Barnett: Yes indeed. This is one of the more powerful features of the on-line system we are developing. For example, one of the difficulties we have in the hospital is that many of the drugs have rather complicated spellings. To make sure that drug orders are correctly entered, we check drug name against a formulary. If no exact match is found, the person operating the Teletype is presented with a list of drugs having similar sounding names and requested to choose the desired one. In addition, we take advantage of the fact that many drugs have a dose limit which is rarely exceeded, and check all orders against dose limit. If, because of error in interpretation of an order, or because of error in remembering the proper dosage, a quantity of drug larger than this limit is specified, the computer returns with the information that this is an unusually large dose and requests a specific confirmation of the order. Also, many drugs can be given only by a specific route, such as intravenously, or by mouth. By checking the route of each prescription item the program assures that the order is valid in this regard.

I would like to point out, however, the individual physician still has ultimate responsibility for a given prescription order. The program allows the operator to override the formulary limits. However, when this formulary override feature is used on any given prescription item, notification is printed out on a Teletype in the Pharmacy Office so that the Formulary Committee can collect information about the actual utilization of drugs in the hospital and thus make sure that the formulary items reflect actual common practice.

Q: Does the system provide any support for doctors doing statistical research into records?

Dr. Barnett: Yes. There are two classes of problems for which the present computer system has proven to be extremely useful. The first has to do with the entry, manipulation and retrieval of data in large files, such as the pathology records, the file of all of the records of demographic data on patient admissions, the file on various subgroups of disease populations. A number of physicians have found the system to be extremely useful in creating and updating these on-line and in retrieving the information with a very free and flexible control language. This has been done using batch processing methods but the availability of on-line techniques allows a much more useful manipulation of these files.

Q: Could you give us a description, Dr. Barnett, of how a doctor actually uses this information storage and retrieval and statistical research system?

Dr. Barnett: A program is available that allows the physician or the research worker to describe the structure of the file. There are also programs which are used to enter data into this file either from punched cards or directly from the Teletype. This latter method has this advantage: the on-line system can be used to check the syntax and the content of the data as to its acceptability at the time it is entered. This type of on-line checking seems very useful in that it allows relatively untrained operators to enter data. The data then can be manipulated in a variety of fashions: new fields being created, simple mathematical operations performed on the data, and subpopulations of the data extracted by inputting specific descriptors concerning the characteristics of the subpopulation. Finally, these data can be displayed in tabular form and various statistical manipulations carried out, such as chi-square testing for significance, etc.

Q: Have you had any reaction from your nursing staff to the way that user programs look from the Teletypes? Do the user programs help the nurses, or are they merely an impediment to the practice of medicine as they see them?

Dr. Barnett: We have had only limited experience with use of the programs in the Patient Care areas. For the most part the programs have been used by nurses of our own laboratory staff, but these individuals are not typical. In the development and specification of the programs we have been quite concerned with the problem of acceptability and usefulness of these programs to persons who are neither trained in the art of programming nor particularly motivated to use a computer. Therefore, we have been concerned with the external appearance of the programs, with adding self-teaching features, with making variations of programs available to fit the relative sophistication and experience of users. The input programs are set up to carry on a dialogue where the computer system controls to a major extent the type and form of the input and where the operator is mainly concerned with answering correctly a given question from the computer. We have provided a technique whereby the operator can request information about the form of answer that is required. In addition, the programs are set up so that the operator can change the questions from either a very short abbreviated form to a longer form depending upon the experience of the operator (Fig. 3).

Q: What about the response time?

Dr. Barnett: We actually have little quantitative data on any sort of consumer usage of the system. It is clear that even with a very slowly responding computer system we can perform many of these tasks orders of magnitude faster than present techniques, so even a very slowly responding system could be quite acceptable. However, we have also noted that after a person becomes familiar with using the system and discovers that its speed depends on the total load on the system, a certain intolerance to slow response develops. In other words, when the user becomes experienced he also becomes less tolerant and would like to have fast response time on all occasions.

Fig. 3

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3:31 PM 10/14/1965  BUB'S(06)  RR1
CALL MEDX  EAG
MEDICATION ORDER

1  T  T   (Program starts in short form. T for time, T=now)
2  D  T   (D means Date?  T=today)
3  DR  ←/ (Change to long form)
3  DOCTOR  JECKYLL, W
4  PATIENT  CASTLEMAN, LOKI  FIX (Patient is specified by room space)
4  PATIENT  ←HOW  E.G. 150-1  152-1 CASTLEMAN, LOKI     F  000-02-00
5  ORDER
  5.1     RX,ASPERIN,3MG\\00MG,PO,TID,I     (Backslash means cross-out)
...DO YOU MEAN...
    1    ASPIRIN GUM
    2    ASPIRIN EC
    3    ASPIRIN SUPP
    4    ASPIRIN COMP
    5    ASPIRIN BUFFERED
    6    ASPIRIN

  SELECT N...  6
  5.2
6  INITIALS  ←/   (Change to short form)
6  INIT  ←LIST    (Give a clean listing of the entry)


MEDICATION ORDER

1  T  T
2  D  T
3  DR  JECKYLL, W
4  PT  152-1 CASTLEMAN, LOKI     F  000-02-00
5  ORDER
  5.1     RX,ASPIRIN,300MG,PO,TID,I
  5.2
6  INIT  EAG

-THANK YOU-
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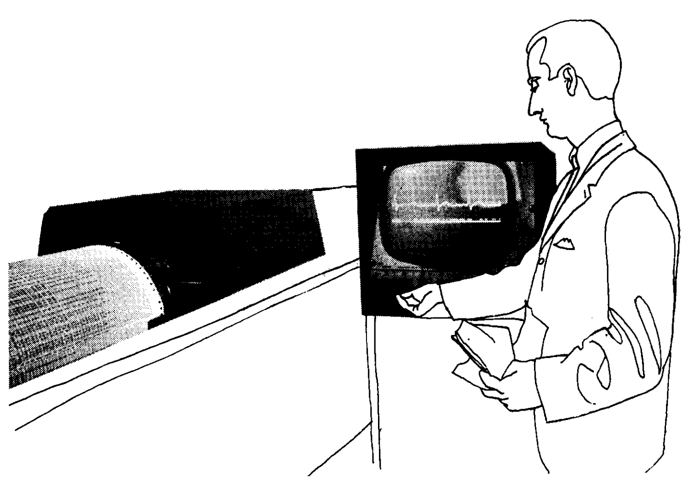
Q: Can you give me some idea of what response times you do get? If, for example, a nurse is typing in a medication order and this takes place as a series of questions by the computer and responses by her, how long does it take for the computer to come back with the next question?

Dr. Barnett: In a typical instance under the present load of the system, the time lag is so short as to be hardly detectable. Even in the worst case this lag will be only a few seconds. However, there are some programs which require extensive manipulation of the data internally before typing out a response, and in some cases the time lag can be as long as a minute or two, which then becomes rather unacceptable to the experienced user.

Dr. Baruch: Those delays arise from the queueing to use the big drum storage. We are modifying the exec so that the delays will be avoided for those user programs that interact with users at the expense of those that are of lower priority.

Q: Whenever I talk to the hospital people, I get the impression that, next to getting the patients well, getting the bills out is the most important thing to them. Are you programming to get out patient bills as a part of this system?



Dr. Baruch: Because there is in general such a simple transform between an accurate record of what has happened to the patient and the patient bill, we haven't bothered with the actual billing programming. We feel that that is a relatively easy extension of the work we are doing.

Q: Dr. Barnett, what do you have to say about the rather casual attitude toward bringing the money in?

Dr. Barnett: Well, I think I would be thrown out of the hospital by my administrator if I adopted quite so casual an attitude. However, I certainly would agree with Dr. Baruch that our primary emphasis has been on the development of a system which will improve our ability to give medical care with only a very secondary interest in the billing problem. I think that this emphasis of ours, however, is an important one, and that in the long run it will lead to development of a much more powerful and sophisticated system than if we started out with an accounting-type system and tried to extend it in some fashion to a medical communication or information-retrieval system. I think the latter function is so important and so much more complicated that it should be the one that should be emphasized primarily.

Q: Getting back to the hospital computer center. What equipment are you using?

Dr. Baruch: The central processor is a modified PDP-1 manufactured by Digital Equipment Corp. (Fig. 4). The modifications include instructions to facilitate 6-bit character handling, memory protection to cause trapping to the exec program when a user program tries to perform an instruction that addresses outside its own core, a trapped-instruction buffer to help the exec handle trapped instructions, and a 16-channel sequence break system and a crystal controlled real-time clock which provides 32 ms interrupts for time slicing and 1-min. interrupts for time-of-day. There are three independent banks of memory, each with its own memory address register and memory buffer. The 12K bank is used for storage of the exec and common routines and the two 4K memories hold user programs. Two other "processor like" devices, once started by the central processor, can operate independently and simultaneously: the high-speed swapping drum stores up to 32 programs in the time-sharing queue; the data channel handles transfers between memory and the Univac FASTRAND and tapes. The FASTRAND gives us 50 million characters of random access storage. The interconnections between the three memories and the three processors are controlled by an electronic crossbar switch which is controlled by the central processor. The Teletype interface has a 1-character transmitter buffer and a 1-character receiver buffer for each of 64 lines. The exec does the rest of the buffering internally.

Q: That seems like an awful lot of stuff to keep running all at once. What happens when lightning strikes and power fails? How do you safeguard the running of the system to make sure that the hospital doesn't get harmed by a power failure?

Dr. Baruch: We have assumed throughout our development work (and incidentally, please remember that we are a research project and not as yet a data repository for the hospital) that data can be destroyed by a power failure. We have assumed in the worst case, for example, that the power will change just one instruction which will cause the system to ingest its own tail and rapidly swallow itself, wiping itself clear at the same time. One could conceivably reduce the probability of having this happen by having two systems, or reduce it still further by having three. I think when you get up past three, rather than reducing the probability of serious failure you start increasing it.

We have taken a somewhat different tack, however. We say we have one system; and the hospital, no matter how much the backup, must be able to run without it. The hospital cannot be made completely dependent upon its system. We, therefore, are very careful in our programs to produce hard copy at the Patient Care Unit and other locations which will be sufficient to permit the hospital to carry on its activities without the system's help. Naturally, as time passes these pieces of paper can be thrown away since the state of the system is preserved every 24 hours. So we need no more than 24 hours' worth of such hard copy.

Q: Do you have any impression, even at this early date, of the frequency of detected errors which arise from hardware or program malfunction as compared with those from human malfunction?

Dr. Barnett: We have some quantitative data on a very small subset of the programs now functioning. For instance, in the transmission of test results from the laboratory to Patient Care areas, over a two-month period involving some 3,000 laboratory reports there was no case of any computer loss of data or erroneous manipulation of data. There was an error rate of .7% in input of the data by the operator, but this error rate compares very favorably with the hand transcription techniques in present use. In those programming areas where we are still in the very early stages of implementation there is a much higher error rate than this, but we expect to be able to identify the causes of these errors and correct them.

Q: When you spoke of an error rate of .7% what did you include?

Dr. Barnett: That is a total of errors in the identification of the test, the identification of the patient, and in the data for a given test. In all of these cases, over three-fourths of the errors were detected when they were entered or shortly thereafter and were corrected in the laboratory itself. The actual error rate of results appearing on the floor was less than .3%.

Q: Getting back to the hardware, how about communications?

Dr. Baruch: I was coming to that. The central processor has access to dedicated telegraph lines through a communications interface (DEC Mod. 630) which can handle up to 64 lines. The lines end in the user terminals.

Our terminals are general purpose keyboard printing telegraph instruments, rather than dense coded keyboard instruments which limit you to a fairly poor vocabulary. Specifically, we use model 33 Teletypes. Several are located at various places in the hospital, others are in our offices for the use of the programmers, and five are in schools around Boston. The system is configured by the programmers for the use of the medical people at the moment, with the schools as paying guests.

Q: Why did you refer to the Teletypes as keyboard printing telegraph?

Dr. Baruch: Because the important characteristic of the terminal is not its manufacturer but the fact that it is a machine which converts alphabetic and numeric characters to code, which means the user then assembles the word rather than having little words printed on buttons, like "Stop," "Go," "Aspirin," "BUN" and so forth.

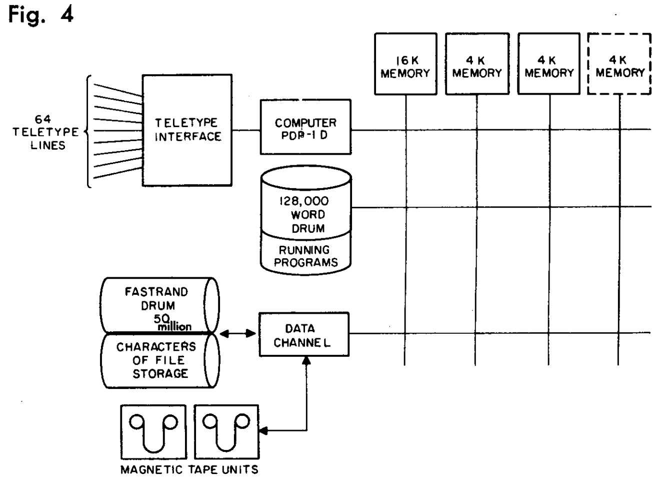
Q: Don't you find Teletypes awfully noisy for use in a hospital?

Dr. Baruch: We sure do! That's why we designed and built quieting enclosures for them (Fig. 5).

Q: You commented a moment ago that dense-coded keyboards "limit you to a fairly poor vocabulary." On the other hand they provide efficiencies by taking advantage of the redundancies in the material they communicate. Don't you find clear text inefficient?

Dr. Baruch: Yes, as a matter of fact. It was to meet that problem that we designed an input device that we call a Datacoder (Fig. 6). It works in conjunction with a Teletype so we have the best of both worlds. When you position its pointer and push the send button, the Teletype sends two characters to the computer representing eight bits of X and eight bits of Y, coordinately. It is

Fig. 4



a simple matter to write a program that can decode (by table lookup) the resulting dense-coded input.

Q: Is the densely coded input then stored in its densely-coded form for economy of storage or is it translated back into its full-blown text meaning in the system?

Dr. Baruch: From long experience, we're devout believers in Murphy's Law which states, "If anything can go wrong, it will!" As a result, we neither assume that the right button was pushed nor that the communications lines transmitted the right signal. Rather, when we get densely coded information it's transformed into an English string or the equivalent and printed back at the user for his further verification. And that's done immediately. The form of internal storage is an independent decision that we make for each case. Input data verification is one of the necessities of any real-time system.

Q: Oscilloscope output is well known to be fast and well-coupled to people who read fast. How come you don't propose to use it?

Dr. Baruch: Well, the maintenance of the display on a scope requires either local memory or a broad-band line to the computer. We are, at the moment, particularly conscious of the cost of the task we are undertaking. As engineers, we do not feel that it really accomplishes anything to transfer information around in the hospital in some sterile atmosphere devoid of cost considerations.

Q: You mentioned some terminals in schools.

Dr. Baruch: Yes, by agreement with the hospital and the National Institutes of Health, another project under the Dept. of Health, Education and Welfare involves the use by the Massachusetts State Dept. of Education of remote terminals in the teaching of mathematics. Several schools—interestingly enough, ranging as low as the third grade—are experimenting with the use of a simple mathematical manipulation program TELCOMP as an aid to teaching mathematics in the classroom.

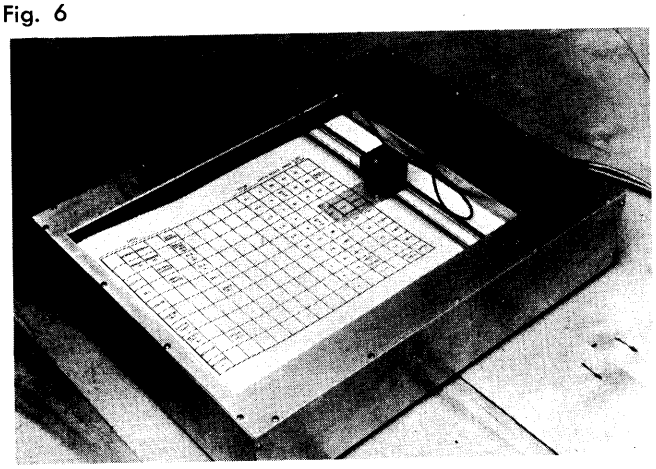
Q: I understand BBN is also offering a commercial on-line computation service for engineers. Is that on this machine?

Dr. Baruch: No, that's a separate machine which is also a modified PDP-1. Some confusion has arisen because we have used the name TELCOMP for both of our versions of the JOSS language, which was originally developed by Cliff Shaw at RAND Corp.

Q: Was the programming of that system done under the hospital project?

Dr. Baruch: No. The commercial version was programmed entirely separately because that's quite a different machine and has neither the time-sharing facilities of this machine nor the memory capacity, nor many other features. As a matter of fact, we hope that we will be able to "borrow" much of the coding that they have done for use by the hospital researchers when they want to do mathematical manipulation.

Fig. 6



Q: Has TELCOMP proved to be useful in the medical field?

Dr. Barnett: Yes indeed. The MGH is a very large research institution; our research budget from the National Institutes of Health is over $10 million this year. We have a large number of investigators who have a variety of relatively simple mathematical routines that are carried out every day. The availability of an on-line system of the power of JOSS has proven to be an extremely useful and very desirable feature of a computer within a hospital medical research institution. Examples of the use of this system are in the processing of data from a scintillation counter, from amino acid analyzer, from an ultracentrifuge, etc. In each of these cases an investigator collects a set of data of about 20 to 200 points and then performs relatively well-prescribed manipulations on these data in a routine fashion day after day.

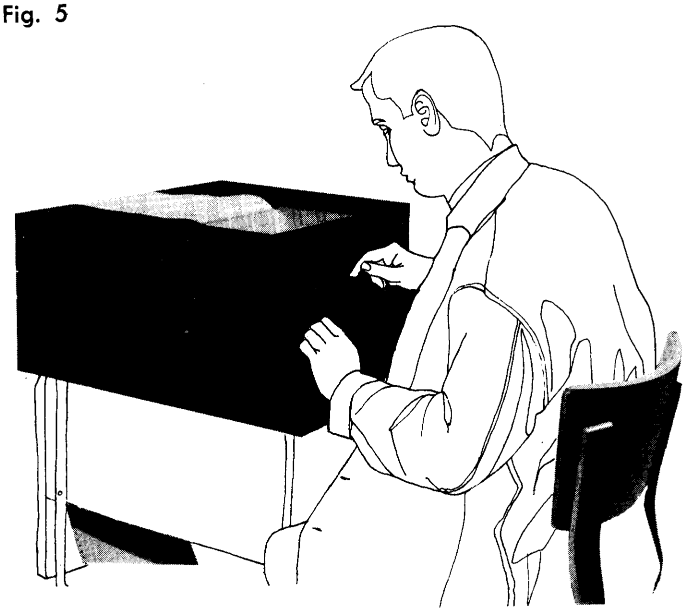
Q: Does the TELCOMP language enable a research doctor to write his own programs for performing transforms on measurements?

Dr. Barnett: The language is quite straightforward. Many of the individual research workers have written their own programs to carry out their work with very little difficulty.

Q: Suppose I'm a hospital administrator planning a new hospital and I want to know what effect the prospect of systems of this kind should have on the architecture of the hospital. What provision should I make for this revolution in medical information handling?

Dr. Baruch: This is a very pertinent question. At a minimum, one needs room for terminals in almost all areas of the hospital and provision for easy running of communications lines. The American Hospital Assn. is currently preparing a book, *Data Processing in the Hospital,* which is meant for use specifically by administrators and boards of trustees who are planning new facilities, expansions of old facilities, remodeling or just a continual updating that's so characteristic of the hospital community.

Fig. 5



I am hoping further that as the information handling becomes more of a natural process within the hospitals, the Hospital Engineers Group of the AHA will take the information processing systems as part of their responsibility and provide the professional leadership for it within the hospital community.

Q: If a hospital administrator came to you today and asked for service, could you provide it on this machine?

Dr. Baruch: No, this machine is dedicated to a research project and is, as yet, not available for service to hospitals in general. □