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RECOMMENDATIONS FOR AN IMPROVED DATA PROCESSING FACILITY FOR BIO-SCIENCE LABORATORIES

Alexander A. McKenzie

Prepared for:

Bio-Science Laboratories
7600 Tyrone Avenue
Van Nuys, California

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INTRODUCTION

During the three month period from November 1968 through January 1969, Bolt Beranek and Newman Inc. (BBN) has conducted a study of the present operations and data processing needs of Bio-Science Laboratories, Inc. (BSL) under the terms of the contract and ammendment reproduced in the Appendix. The study was conducted by A. McKenzie, F. Heart, and P. Castleman of the Systems Development Department in Cambridge with the assistance of other BBN personnel from Cambridge and Van Nuys. This document, the final written report of this study, contains BBN's conclusions and recommendations.

Bio-Science Laboratories currently operates a comprehensive automated data processing facility. This facility maintains computer-accessible information files related to patient and client accounts receivable, customer container inventory levels, work in progress at BSL, and other vital data. The current system provides "work sheets" for all tests, in the form of punched cards on a test-by-test basis, and produces various listings (or indices) of completed work. However, the small size of bulk storage, the emphasis on punched cards, the centralized batch processing mode of operation, and the limited capacity of the central computer cause several major difficulties in the operation of the facility. For example, the enormous amount of manual labor required to produce the laboratory test cards causes a loss of timeliness of the information conveyed to the laboratories by this mechanism. Because of the centralized, batch processing mode of operation, the clerical staff must answer inquiries from clients by searching card files, rather than by interrogating the data base available to the computer. The relatively disorganized flow of information to the laboratories places a heavy burden of clerical responsibility on the highly-trained technical staff and, as BSL grows, makes it more and more difficult to locate misfiled ("lost") test cards and other paperwork.

Faced with these problems, and with an ever increasing work load, BSL has realized that a radically different computer system organization could be of major importance in the continued successful growth of the laboratories. Specifically, BSL has realized that an on-line system with data accessible to terminals represents the rough general approach that ought to be considered. BSL has already done some investigation of this possibility and has been further encouraged by the recommendations of a prior group of data processing professionals who were engaged to consider the problem. Bolt Beranek and Newman is in full agreement with the prior conclusion that an on-line terminal driven system is appropriate to the BSL problem. This final report discusses some of the many functions that must be considered in such a system design and concludes by suggesting a particular design for the system with some estimates for the costs that are involved.

This report recommends the outline of such a system design, some of the crucial details, and the general character of a set of hardware and software that we feel achieve the desired objective of providing the necessary data to every portion of BSL in a timely, organized, and responsive way.

This new system organization need not be implemented in one step. We recommend, in fact, that implementation proceed on a "phased" basis. For example, even if the entry procedure is to be changed, the change need not occur at the same time that test cards are eliminated, since the entry of specimen data and the production of work sheets (including test cards) are entirely separate functions. Similarly, decisions related to direct connection of the LINC-8 to the real-time computer are not affected by, and do not affect, any other aspects of the system.

Keeping this notion of phased implementation in mind, we will now describe the system as it should appear after all phases of implementation are completed.

1. THE ENTRY PROCESS

The first and largest source of information about specimens that arrive at BSL is obtained during the entry process. Specimens are unpacked, and the information about them translated from the request slips into machine-readable form. This process is currently handled as several distinct steps; the entire mode of operation is geared to the concept of a batch processing computer system. In addition to the batch orientation, there are a number of hand-transcription operations that are duplicated later by the computer system.

The current entry process works well enough if the information processed by the computer need not reach the laboratories until well after the arrival of the specimens. The method must be changed, however, if scheduling information, work sheets, etc., are to be available at laboratory terminals in time to be useful. Ideally, specimen information should be available to the computer system at the same time that the corresponding specimens are ready for delivery to the laboratories. This can most easily be accomplished by assigning data and specimen entry to the same individual, rather than the present procedure of separating those two functions.

However, some problems may be encountered if both specimen and data entry are performed by the same individual. The first relates to potential turnover of employees. It is our understanding that, currently, keypunch personnel turn over at a significantly higher rate than entry room personnel. This seems reasonable, since keypunching skills are in great demand by a large number of industries in the Los Angeles area, while the skills of the entry room personnel are highly specialized and virtually unique to BSL operation. If the entry room personnel are trained to operate a keyboard device for data entry, they will immediately be much more desirable as recruits for other organizations. This is likely to increase the turnover of entry room personnel, causing additional recruiting and training problems for Bio-Science. For this reason, if the functions of data and specimen entry are to be combined into one task, BSL must insure that salaries and working conditions for the individuals performing this task remain competitive in order to reduce or eliminate the turnover problem.

The second potential problem involved in combining the functions is the possibility of introducing major delays in the delivery of specimens to the laboratory. There are several methods of calculating the current work rate of the entry personnel. If the entire entry room staff (including splitters, checkers, etc.) is taken into account, the rate of entry is approximately 22.2 specimens per person per hour. A more realistic figure, developed by Mr. Bennett of BSL, is derived from the fact that approximately 17,000 specimens per week are "entered" (this neglects splitting, checking, etc.) by the equivalent of 10 full-time employees. This means that the average entry rate is close to 43 specimens per person per hour. In addition, it is worth noting that during a period of <u>peak</u> production (the half-hour period preceding the 11:30 AM "cutoff" for delivery of request slips to keypunch), four entry girls were observed to be working at an average rate somewhere between 114 and 153 specimens of serum per person per hour.

The speed of production in the keypunch department is almost equally elusive, it can be estimated at anything from 45 to 80 specimens per person per hour, but a reasonable figure to use is probably 60 specimens per person per hour. Thus, a relatively experienced individual might be expected to enter 43 specimens/hour, keypunch 60 specimens/hour, or both enter and keypunch specimens at the rate of 25 specimens/hour. If the above figures are an accurate representation of the current production rates, then the equivalent of 17 full-time entry personnel should be able to perform all the functions of both entry and keypunch without causing any additional delay in delivery of specimens to the laboratories. The addition of the equivalent of seven full-time entry personnel to the current staff will, of course, be compensated by a similar reduction in the current keypunch staff.

Our recommendation, based on these calculations, is to combine the functions of entry and keypunch. The laboratories will obtain the benefit of having all information about the specimens stored almost immediately in the computer files, without any slowdown in the delivery of specimens. The entry personnel, of course, will be operating some type of terminal device connected to the computer system, rather than a card-punching device. We believe that the correct choice of terminal device is a Model 35 Teletype with sprocket feed and horizontal tabulation, using a combination form including a preprinted entry area and a set of self-adhesive labels. The entry personnel would type all information from the request slip into one area of the form, the computer system would then automatically type out a small label including test codes and specimen number for attachment to the specimen container. (The entry area of the form would also be self-adhesive, and could be attached to the original request slip for later sight verification, if desired.) Using this system, specimen numbers would be assigned by the computer system, eliminating a source of transcription error. It would be possible to maintain separate sequences of specimen numbers for high-volume tests such as T4. In addition, the information on the specimen label would be legible and complete, since it would be prepared from the entry data by the computer system.

The Model 35 Teletype is a common, relatively inexpensive device with a long history of reliable service in other computer systems. It operates at 100 words per minute, much faster than the speed at which the entry personnel are expected to type input. By using preprinted entry forms, and by using the automatic tabulation feature, time spent by the system in output and formatting will be kept to an acceptable minimum. The incorporation of check digits in the account numbers and test codes, and automatic checking of these numbers by the computer system, will help to reduce errors without verification of the input by a second typist.

Figure 1 is an example of the type of form we recommend for use in the input process. It illustrates the type of information to be preprinted, the type of information to be input by the entry personnel, and the type of output to be produced by the computer system. The small label area at the right, including specimen number, test codes, and volume information would be attached to the specimen container. It should be noted that we have not fully investigated the mechanical details of this method, and that we may recommend changes to the method at the conclusion of full investigation.

TEST CODES	1014,3287	ACCOUNT #	12749	54-3781	54-3781
PATIENT NAME	SMITH H J B3724	SEX M AGE	27	VOLUME NOTV	101
REFERRING MD	JONES	ADDITIONAL SPECIMEN?	N		328
EXTERNAL REMARKS	P/O 12345				
INTERNAL REMARKS					NOTV
PHONE RESULTS?	DISCOUNT PERCENT	INSURANCE NUMBERS	CONTAINER ORDER?	#2	
BILLING ADDRESS					

FIGURE 1

Small text (e.g., "TEST CODES") is preprinted information.
Underlined text (e.g., "SMITH...") is typed by entry personnel.
Other text (e.g., "54-3781") is typed by computer system.

Note that check digits for test codes are input by entry personnel, but are not output on the specimen label by the computer system.

We estimate that ten to twelve terminals will be required in the entry room. Ten entry personnel using this system should work at approximately the same rate as six entry personnel under the current system; similarly twelve people using our recommended system should be equivalent to seven under the present system.

2. THE PRODUCTION LABORATORIES

The primary users of the information stored in the computer system by the entry process are the laboratory personnel. During the performance of the required tests, they will require summaries of outstanding tests, worksheets, statistical information, and answers to specific requests. As the entry room personnel enter data, the system will organize and cross-index it to facilitate the various types of retrievals that may be desired; in particular, the specimen data should be indexed by specimen number, test code(s), account number, and patient name. The indexes will also be sub-ordered on time of entry, so that a listing compiled from them (e.g., all specimen numbers for a particular test code) will appear in the same order in which the specimens were received.

In order for the laboratory personnel to use the computer system to its fullest capacity, we strongly recommend the installation of an input/output terminal device in almost every laboratory. If the system design called for installation of only a few terminals at relatively centralized locations, we feel that both physical and psychological factors would encourage the laboratory personnel to use the system as a batch system, thereby vitiating the basic advantages of the "real-time" design. There are, however, a few laboratories where the volume of testing is so low, or so batch oriented, that the sharing of a single terminal appears feasible at the current level of operation. Thus it would probably be reasonable for the Aldosterone laboratory to use the terminal in the Toxicology laboratory, and for the Endocrinology II laboratory to use the terminals in the Endo I and Endo III sections. With these exceptions, however, we believe that each of the production laboratories, including each of the two Chemistry sections, should be equipped with its own terminal.

There are several factors affecting the choice of particular terminal devices. Since we believe that the terminals should be used to produce work sheets, obviously a printing device should be included. If this is true, it then appears that CRT display devices should not be included, since both a CRT and a printing device combined in a single terminal is not economically justifiable. Some of the terminals, in particular those in the Thyroid and Automation laboratories, must be able to handle high-volume printing if they are to be used for work sheet preparation; the most common types of terminals (i.e., Teletypes and Selectric typewriters) would probably be too slow for these laboratories. On the other hand, maintenance considerations make it undesirable to install many different types of terminal equipment at BSL, so to some extent we must exclude the idea of matching terminal specifications to the requirements of each individual laboratory. Our <u>preliminary</u> recommendation is for the use of the NCR EM-T1 Thermal Page Printer, in combination with a keyboard (e.g., the Honeywell "Micro Switch" Keyboard). This printing device operates at a speed of 30 characters/second (300 words/minute), a rate which we believe is sufficient to meet the needs of the laboratories. The device is inexpensive and extremely quiet. At a rate of 30 characters/second the Page Printer could generate a work sheet for a T^4 batch in well under five minutes; this rate should certainly be sufficient to keep up with the normal work flow in all laboratories. However, this printer is not yet in full production and a final recommendation must therefore await further investigation.

Using these input/output terminals, the laboratory personnel will retrieve information from the central data files as an aid to daily operation. The system that we recommend will provide the capability for four principal categories of information retrieval; these are summary compilation, work sheet generation, statistical information related to test results, and inquiries about specific specimens, patients, or clients. Each of these categories is discussed briefly below. Overall, however, the intent of these provisions is: to provide the supervisory personnel with up-to-date information about current work load and overdue tests; to replace the variety of work sheets and test cards currently in existence with more uniform and legible documents; to reduce the amount of transcription, thereby eliminating one potential source of error; and to provide rapid and effective location of information about specimens in the lab or recently completed. The total effect of these changes will be to reduce the amount of time spent by the laboratory staff on paperwork, thus freeing them for technical work.

Summary Compilation

We believe that the supervisory staff in many of the laboratories will be able to make better scheduling judgments if they can obtain comprehensive information about the laboratory workload. This is particularly true in laboratories, like the Chemistry sections, where there are many different tests with only a few specimens for each. In order to supply this information, we believe that several different types of summary listings should be available to the supervisors who want them. Figures 2 through 5 give examples of the types of summary listings that we feel would be useful. [With regard to these typescripts, as well as with all the other typescripts which are present in this report, a number of preliminary comments are appropriate.

1. They are <u>examples</u>; the actual details of a really suitable typescript for each case would have to be worked out with the appropriate BSL personnel in the course of an implementation effort (Phase 3). It is obviously not appropriate to develop these examples in great detail at this time. This effort should be conducted jointly with appropriate BSL personnel and would be a non-trivial job.

2. In each typescript, the characters that would be typed by the user are indicated by underlining. In operation, no characters would be underlined.

3. The typescripts do not illustrate several features of "human engineering" that would be available to all users of all terminals. Specifically, it would be possible for the operator to interrupt the output if he had made a mistake and was doing the wrong thing. Similarly, it would be possible to make simple error corrections or to start a particular input line over. Finally, considerable attention would be paid to carefully minimizing the amount of typing that would be required by an experienced user, as well as minimizing the amount of output typing necessary for the identification of things with which the user was completely familiar.]

Figure 2 shows the shortest laboratory summary. The user types "L" and the computer completes the word "LISTING". The computer then identifies the laboratory in which the terminal is located and prints the date and time. We believe that this information should appear on all output generated in any of the laboratories, so that confusion about the timeliness of past outputs can be avoided. The computer then asks which tests should be summarized and, in this example, the user types a "number sign". The system responds by printing the name and test code of each test assigned to the laboratory, the total number of specimens in progress, the number for which work sheets have been generated by the system, and the number of specimens that are overdue. The listing is terminated by the "END OF LIST" line, which also appears on every other laboratory printout.

```
LISTING

BIO-ASSAY   12/5/68   2:10 PM

TEST? #
                          TOTAL   W   OVER
TEST 514   FSH              3     1     0
TEST 515   HGH              1     0     0
TEST 517   RENIN            2     2     0
TEST 535   INSULIN          8     4     2

END OF LIST
```

FIGURE 2

Figure 3 shows a more complete listing, including the specimen number for each sample in the lab. The specimen numbers appear in chronological order of entry. This listing also includes information about which specimens are overdue and which have had worksheets generated by the system.

```
LISTING

BIO-ASSAY  12/5/68  2:23 PM

TEST?  ALL

TEST 514  FSH          3 SPECIMENS
  94-7251 W
  98-4939
  01-0056

TEST 515  HGH          1 SPECIMENS
  01-0056

TEST 517  RENIN        2 SPECIMENS
  96-3877 W
  98-5000 W

TEST 535  INSULIN      8 SPECIMENS
  96-3817 W   OVER
  96-3924 W   OVER
  94-7113 W
  98-5000
  01-0134 W
  01-0179
  01-3242
  99-8213

END OF LIST
```

FIGURE 3

Figure 4 is an example of the same type of listing for particular tests as specified by the user. Note that test number 941 does not appear in the other examples because there are no specimens in process for this test. Of course, for some very long or high-volume tests, such as Aldosterone, a listing of this kind would consist primarily of specimens for which work sheets had already been generated, and this information will normally be unnecessary.

```
LISTING

BIO-ASSAY  12/5/68  2:40 PM

TEST? 535  INSULIN    8 SPECIMENS
  96-3817  W  OVER
  96-3924  W  OVER
  94-7113  W
  98-5000
  01-0134  W
  01-0179
  01-3242
  99-8213

TEST? 941  PYROGEN    0 SPECIMENS

TEST?

END OF LIST
```

FIGURE 4

Accordingly, Figure 5 shows a method of obtaining a listing of only the most recently entered specimens. In this example, the user typed "NW" after the test code and the system searched the list of specimens until the oldest specimen that had not had a work sheet prepared was found. The listing of specimens was started at that point.

```
LISTING

BIO-ASSAY  12/5/68  2:51 PM

TEST? 535NW  INSULIN  8 SPECIMENS
  98-5000
  01-0134  W
  01-0179
  01-3242
  99-8213

TEST?

END OF LIST
```

FIGURE 5

Finally, some laboratories will at times have to use terminals located in other laboratories; in particular, this will always be true where two or more laboratories share one terminal, but other instances may arise in cases of terminal breakdown. Figure 6 illustrates a method of producing any of the previous listings from a terminal located in another laboratory.

```
XLISTING  12/5/68  3:18 PM

LAB?  ALDO

TEST?      .
           .
           .
           .
```

FIGURE 6

Work Sheet Generation

One of the most noticable effects on current laboratory operations caused by the installation of a terminal-oriented system will be the elimination of test cards. The computer system, however, will have the capability to generate work sheets at the laboratory terminals as they are needed, and in an order specified by the laboratory personnel. We believe that there are some, perhaps many, tests for which pre-printed work sheets are more desirable than those that could economically be prepared by a computer terminal. On the other hand, work sheets prepared by the system will not require any transcription of specimen numbers or other data, thereby eliminating a possible source of error. We are not prepared, at this time, to recommend which of the work sheets currently in use at BSL should be retained; this is a question which BSL management must eventually decide. It is certain, however, that at least those tests for which the test cards now serve as work sheets should have work sheets prepared by the computer system.

Figure 7 is an example of the preparation of a work sheet for test number 535. The user types "W" to call the work sheet program, and the system responds with the laboratory name, date, and time. (As with the summary listings, if the work sheet were prepared in another laboratory, the user would type "XW" and the system would ask for the abbreviated name of the laboratory where the test was to be performed.) The user then specifies the test code of the test for which a work sheet is desired, and the system responds by asking for the specimen numbers to be included on the work sheet. At this point, the user may type individual specimen numbers, "ranges" of specimen numbers, or a combination of the two. In the example, the user has given a single specimen number, followed by a "range" which includes three specimen numbers. The range is in the same order (chronological by entry time), and includes the same specimens, as any of the listings (see, for example, Figure 4); it would only be reasonable for a user to specify a range if he were using a listing to determine the endpoints of the range. (N.B., The range is *not* in specimen-number order.)

In this example, we have shown the work area as a small blank space. In practice, we expect the BSL supervisory staff to specify the format of the work area for each test at the time the system is installed. In addition, a program will be supplied to allow the supervisory staff to alter the format of

```
WORKSHEET

BIO-ASSAY  12/5/68  3:41 PM

TEST?  535  INSULIN
  SPECIMENS?  998213, 985000-010179

99-8213     JONES H J                  ACCT. NO. 27304
            NOTV         AGE 17              MALE
            INTERNAL REMARKS:  REC'D FROZEN




98-5000     SMITH F  151566            ACCT. NO. 13098
            24 HR VOL                        MALE
            REMARKS:  COPY TO DR. FOSTER
            OTHER TESTS:  RENIN




01-0134     FEIN MARLENE               ACCT. NO. 13098
W           1527 ML      AGE 24              FEMALE
            OTHER SPECIMENS:  89-4051
12/3/68  7:58 PM  "356 MG/L"




01-0179     LOTHROP L                  ACCT. NO. 38427
            24 HR VOL    AGE 38              MALE




END OF LIST
```

FIGURE 7

any work area if this should become desirable. Thus, the work areas for different tests may vary in size, some may contain printing while others are blank; and, in general, each can be specialized to the requirements of the test to which it pertains. We expect, however, that the information about the specimens (the information shown printed in Figure 7) will be printed in the same format for all tests; one possible format is shown in the example.

Work sheets may be prepared by supervisors, technical personnel, laboratory clerks, or any other individuals designated by the BSL management and the supervisors. We expect the arrangements to vary from lab to lab, depending on the test volume, available personnel, and managerial attitudes. In any case, after a work sheet is prepared, it will be used by the technician performing the test. All calculations and other notes will be written on the work sheet by the technician and he will sign or initial it when testing is complete. Eventually the laboratory supervisor (or an assistant) will receive the sheet for review and signature. Finally, after the work sheet has been used as the source of data for posting results to the computer system, the work sheet with signatures will be microfilmed for long term storage to satisfy legal requirements.

Statistics

It may be important to provide certain statistical information on a "real-time" basis to the supervisory staff and to BSL management. For example, one type of statistical information of primary importance relates to the "pool" specimens that are run through many of the tests. A gradual shift in the average value of pool results may indicate deterioration of a reagent. The sudden occurrence of several out-of-range results may indicate a source of contamination or an error in test procedure. The supervisory staff should be able to retrieve information regarding these factors at any time. Other statistics, such as the mean of normal results for all tests, or the possible preparation of graphs of pool results, can be obtained more economically at the central computer site. We will require additional discussion with the management of BSL before deciding exactly what statistical information should be obtained in each way, but the system design recommended here allows a great deal of flexibility in making this decision. Certainly the laboratory personnel will at least have the facilities necessary to retrieve information related to the pool specimens.

Inquiries

At various times, laboratory personnel require information about particular specimens, patients, or clients. We believe that the availability of summary listings and the generation of complete and uniform work sheets will alleviate the need for this type of request; nevertheless, specific retrievals of this kind will be an important aid to the technical staff. For example, the computer system will alert the technical personnel to situations in which multiple specimens may have been received from a single patient at the time the work sheet is printed (see Figure 7, specimen number 01-0134); the system will do this by matching last name and account number. However, it will be up to the laboratory personnel to retrieve the data about these other specimens if they consider it important to do so.

The laboratory supervisors presently spend a significant portion of their time answering telephoned requests from clients for information about specimens they have submitted but which have not been reported. With a real-time system, containing all the information about each specimen in process at BSL, most of this work could be transferred to the office staff. Undoubtedly, however, some of these calls will be received by supervisors, and in these cases the laboratory staff will also want to make specific inquiries to the system about particular patient names or account numbers. Since the system will contain data on all tests for at least ten days after they are reported, the laboratory personnel should be able to answer all requests of this type.

Figures 8 through 11 are examples of specialized information retrieval requests. Although the retrieval programs can be started by typing "S", "P", "A", or "C" (for specimen number, patient name, account number, or client name respectively), Figure 8 shows that the user need not remember all these codes; typing "Q" will start a control program which will remind him which code to use. It should be noted that the only retrieval which gives complete information about test results, overdue tests, and remarks is the retrieval by specimen number. Retrievals by patient name or account number produce lists which will serve as indexes to the specimen numbers, while the retrieval by client name will assist in responding to telephoned questions from clients who do not know their account number. Client addresses are included with both client name and account number retrievals to assist in the decision whether to write or telephone if the laboratory personnel must contact the client about problems with particular specimens.

```
QUERY  12/5/68  4:07 PM

TYPE:   IF YOU KNOW THE:

  S     SPECIMEN NUMBER
  P     PATIENT NAME
  A     ACCOUNT NUMBER
  C     CLIENT NAME

SPECIMENS  12/5/68  4:08 PM


SPECIMEN NUMBER?    998213
JONES H J               ACCT. NO. 27304
NOTV        AGE 17          MALE
INTERNAL REMARKS:   REC'D FROZEN
     TEST 535 W


SPECIMEN NUMBER?    938214
JAMES SUSAN             ACCT. NO. 13098
                            FEMALE


REF MD:  WILLIAMS
     TEST 101       5.3 UG%         12/4/68
     TEST 217                       OVER

SPECIMEN NUMBER?

END OF LIST
```

FIGURE 8

```
PATIENT  12/5/68  4:19 PM

PATIENT NAME?  FEIN

FEIN MARLENE            ACCT. NO. 13098
89-4051         535

FEIN M                  ACCT. NO. 13098
01-0134         535

FEIN EUGENE             ACCT. NO. 07255
93-2751         101,536

PATIENT NAME?

END OF LIST
```

FIGURE 9

```
ACCOUNT  12/5/68  4:30 PM

ACCOUNT NUMBER?  13098
                 MEMORIAL HOSPITAL
                 CLEVELAND, OHIO

89-4051    FEIN MARLENE      535
98-5000    SMITH F           535
93-8214    JAMES SUSAN       101,217
01-0134    FEIN M            535

ACCOUNT NUMBER?

END OF LIST
```

FIGURE 10

FIGURE 11

```
CLIENT  12/5/68  4:37 PM

CLIENT NAME?  SNYDER CLINIC
              1234 MAIN ST.
              HACKENSACK, NJ 07601
       ACCT. NO. 27038

CLIENT NAME?

END OF LIST
```

3. RESULT POSTING

In addition to being principal users of information stored in the computer system, the individual laboratories are also a primary source of input to the system; this input is, of course, test results. Results might be input to the system in several ways, a process that we will call "posting" of results. For example, the laboratories might send all completed work sheets to a central point at BSL where a team of clerks would type all results on terminals connected to the system. This process would resemble the present method of result posting. Alternatively, all results might be posted from the laboratories in which they were obtained. In addition, some "compromise" between these two methods might be implemented; for example, there might be one full-time terminal clerk assigned to each floor of each wing for the purpose of result posting only.

The primary advantage of centralized result posting is the development of a skilled staff of clerical personnel who could be expected to post results rapidly and accurately, thus eliminating additional work by the laboratory technical personnel. Certainly, the keyboard operations involved in result posting are primarily clerical, and we firmly believe that none of the technical staff members should be burdened with a significant amount of clerical activity. Thus, the idea of a centralized posting facility has a strong appeal.

There are two principal advantages to posting results in the laboratories in which those results were developed. First, it places the responsibility for the complete testing and posting procedure in one area. Paperwork will not have to be transported from place to place within BSL, and the results obtained in one laboratory will not have to wait while results from some other laboratory are being posted. One individual, the laboratory supervisor, would then have the ability, as well as the responsibility, to insure that test results are reported out to the clients on time.

Second, and probably less important, a decentralized posting system would permit a meaningful *interchange* of information between the computer system and the laboratory staff member posting the results. The system will contain a wealth of information related to "expected" test results, such as the normal ranges, normal units, average and standard deviation of pool specimens, and results of other related tests on the same specimen. This information could be used as an aid in assessing the accuracy and acceptability of the test results; but to be useful it must be presented to someone in a position to judge its relevance. In fact, if pool specimens are out of range, the laboratory personnel should know this before any other results from the same batch are posted. Any of this information would be meaningless to clerical personnel at a central facility, and for a central clerk to check back with the laboratory on each questionable computer-generated message would cause so much delay and inconvenience that the messages would be almost worthless. This would not be true if the computer were interacting with a member of the laboratory technical staff, or even a clerk assigned specifically to work within the laboratory.

We do not believe that the third possible method for result posting, namely providing a number of semi-centralized result posting clerks and terminals, is a feasible alternative to the two methods discussed above. It is unlikely to affect significantly the ability of each clerk to deal with messages that might be generated by the computer system, and it will certainly not affect the ability of each supervisor to control the speed of result posting for his lab. On the other hand, it would have almost none of the advantages of a completely centralized pool of clerks. For example, with a completely centralized posting facility the effects of vacation or illness can be handled relatively smoothly, but if there were to be one clerk in each of several semi-centralized locations, this type of temporary personnel shortage would be likely to have a significant disruptive effect. The only advantage to this plan would be the decrease in distance that work sheets would need to be carried, and in our opinion this would have negligible effects on BSL operation.

Based on these considerations, our recommendation is to have results posted in the individual laboratories. In our judgment, the advantages to be gained in the timeliness of result posting and the improvement in allocation of responsibility and authority, as well as the possibility of information interchange, outweigh the advantages of a central clerical facility for result posting. It should be noted, however, that we have said nothing about which individuals will actually post the results, except that they will be laboratory personnel. We believe that each laboratory should function differently, because of differences in daily work load, number of different tests performed, and present methods of operation. In high volume laboratories, such as Thyroid and Automation, all results should be posted by a laboratory clerk. In laboratories like the Chemistry sections, where each of a large number of technicians takes responsibility for the complete testing of a small batch, it may be desirable for the individual technician to post the results of the tests he performs.

In short, we do not anticipate a uniform procedure for result posting (or, in fact, for any aspect of terminal operation), instead we conceive of a variety of procedures, specified by the BSL management, and tailored to the individual laboratory requirements. Of course, if the management of BSL prefers to institute uniform result posting procedures (for example, that results should always be posted by laboratory clerks), nothing we have recommended would preclude this decision. In addition, we realize that BSL may decide that results should be posted at a central facility, and our overall system design certainly permits this decision to be made.

Another important design question concerns the connection of automatic laboratory equipment to the new real-time computer system. At present, the only remote equipment that has been considered in any detail with respect to this issue is the LINC-8. However, it may be expected that, in the future, additional automatic equipment will appear in various parts of the laboratory and it will be appropriate to consider them in regard to this connection problem.

It is important that the central computer system be so configured that it is possible to connect such equipment to the central real-time system. As progress is made in laboratory automation, the input/output channels and the appropriate system capability must be available in order to permit such experimental connection. This general approach, however, does not necessarily mean that any particular equipment should be connected at any particular time. More specifically, there is the question of whether the LINC-8 should be connected to the central computer system at this time, during this major implementation. In accordance with our previous comments about "phasing", one may either choose to make such a connection now or to delay such a connection.

For the moment, the electrical connection of the LINC-8 system to the central real-time computer system should be deferred. It is our understanding that the current method of operation is to have all LINC-8 results reviewed by the laboratory personnel before they are transcribed to test cards. Since this process appears to be crucial, only very limited advantage would accrue from an electrical connection at this time. In the future, as experience with the system grows, the system design will permit direct connection of the LINC-8, or other automatic testing equipment, to the central computer system.

4. WIRE SERVICE

The aspects of the system which we have discussed previously are oriented toward assisting Bio-Science Laboratories with internal operations. Although a real-time system should be instrumental in eliminating lost specimens and overdue reporting from the individual laboratories, nothing that BSL does internally is likely to affect significantly the average turnaround time as seen by BSL's clients. In order to decrease the time between the mailing of a specimen and the delivery of a result report, BSL must make external improvements. This fact is the motivating force behind BSL's current experiment with wire service; an experiment which we fully believe should grow into a substantial aspect of the Bio-Science operation.

We strongly recommend two kinds of expansion of the BSL wire service. First, the number of clients provided with this service should be increased as much as possible. It is possible that as clients observe the decrease in reporting time to be obtained with this type of operation they are likely to increase the volume of business they submit to Bio-Science. This estimate, of course, can be checked against actual experience with present wire service customers during the next several months.

Second, the wire service operation is currently handled as a batch operation, involving several steps in the transmission of data and with the necessity for manual intervention at each step. After installation of a real-time system, it will be possible to provide automatic calling facilities connected directly to the computer, making it possible to report results to the wire service clients as soon as the results are posted at BSL. Even if the wire service clients continue to use the results they receive in batches, as some undoubtedly will, the batching will be performed at the client's convenience, rather than being dictated by the BSL operations. On the other hand, those clients who are prepared to use results as they are reported are likely to derive significant benefit from this type of wire service arrangement. We strongly recommend that an automatic dialing facility be included as part of the real-time system.

There is, of course, the question of which of the various available wire services will be most economical for BSL. Consideration must at least be given to WATS, Telex, and TWX service. At the current volume of wire service use, WATS service would definitely be the most expensive of these three; a choice between Telex and TWX service depends on a detailed analysis of the geographical distribution of wire service clients and is beyond the scope of this report. It is unlikely, however, that wire service transmission costs, or the cost of terminal equipment at the client locations, would be higher than they are at present. Automatic dialing equipment costs at BSL would be approximately the same as the current costs of transmission equipment, i.e., approximately $100 per month. In addition, some computer hardware would be required for connection to the automatic calling unit; we estimate that this equipment could be purchased for less than $3600.

5. THE BSL OFFICE

In addition to the laboratories, the BSL office can be considered a principal user of information stored in the computer system. Of course, the information needs of the office are quite different from those of the laboratories, in that the office does not need summary listings or work sheets. It is also unlikely, although not impossible, for the office to require the type of statistical information that the laboratories need. On the other hand, the type of specific information retrievals which will be requested from the laboratories will be one of the major aspects of the office use of the computer system. In addition, the office must be able to query and update the client master file, post payments from both clients and patients, enter special requests for containers, and perhaps retrieve information about the number of specific tests performed during the preceding week or month. It may also be desirable for the office staff to enter information on "advertising" mailing addresses and perform other relatively small tasks which are now a function of the Keypunch department; the intent of this type of assignment would be to eliminate completely the necessity of punched cards and card-processing equipment.

The laboratory retrieval programs for information stored in the on-line bulk storage, as illustrated in Figures 8 through 11, will also be used by the office staff to answer telephoned inquiries about specimens sent to BSL in the "recent" past. Occasionally, however, the office receives requests for "long-term" retrievals; that is, retrievals in cases where the results were reported to the client so long ago that the results are no longer present in the on-line storage devices.

We understand that most telephone requests are made within ten days of the time that the results are mailed to the client; therefore we do not believe that results for a given specimen should be stored on-line for more than eleven days after the last result for that specimen is posted. At the end of the eleven-day period, the system will transfer all information about the specimen to magnetic tape, which can then be permanently stored off-line (i.e., not physically connected to the computer system). As magnetic tapes are filled, they will be stored as part of BSL's permanent record of test results. It should be noted that the information on the tapes will be ordered on the date which a report was mailed; this will be approximately the same as the order in which the specimens were received. Thus, for any old result, establishing either the approximate date of submission by the client or the approximate date of reporting to the client will enable BSL to locate the set of magnetic tapes which should be searched for the actual information. Further, the information stored on tape will include the exact date of result posting for each test on each specimen. Those dates will enable the BSL staff to locate the work sheet for the given test in the microfilm files if a "hard-copy" record is required for legal reasons. It must be emphasized, however, that all results will be stored on tape and therefore the microfilm record need not be consulted during a routine long-term retrieval.

When a long-term retrieval is required, we believe that it should be handled as a batch process rather than as a "real-time" request, due to the time required to mount the necessary magnetic tapes and search them sequentially. In these cases, the office worker who receives the request will probably be required to fill out a form indicating account number, patient name, test name(s), approximate date of testing, and perhaps other identifying information. This form will then be delivered to an operator in the computer room, who will perform the retrieval as soon as possible. Although this type of request cannot be serviced immediately, it should always be possible to perform the retrieval by the following day. Of course, in some cases it may not be possible to specify all the identifying information; in particular, the account number may be impossible to ascertain if the request is very old. In these cases, the retrieval may produce a list of possible results, but this list will certainly be short enough for a person to scan visually.

Special programs will be supplied for each of the other office functions involving the computer system. As previously mentioned, these functions include updating the client master file, posting payments received, handling special container requests, and perhaps others such as updating advertising mailing lists. Figures 12 and 13 are examples of the use of a terminal for posting payments.

```
PAYMENTS RECEIVED  12/6/58  9:28 AM

TYPE A FOR BSL ACCOUNTS
TYPE P FOR PATIENT PAYMENTS
P

INVOICE?  537182   $10.00 DUE
PAID?  10

INVOICE?  357491   $25.00 DUE
PAID?  5

INVOICE?

END OF LIST
```

FIGURE 12

```
PAYMENTS RECEIVED  12/6/68  10:03 AM

TYPE A FOR BSL ACCOUNTS
TYPE P FOR PATIENT PAYMENTS
A

ACCOUNT?  38274   $394.25 DUE
PAID?  300

ACCOUNT?  18710   $ 52.88 DUE
PAID?  52.88

ACCOUNT?  54321   $ 49.50 DUE
PAID?  50

ACCOUNT?

END OF LIST
```

FIGURE 13

In the past, cathode ray tube (CRT) display devices have been suggested as the most desirable type of terminal equipment for use in the BSL office. We believe that the office terminals should not be CRT's; we recommend the use of keyboard/printer terminals of the same type as those to be installed in the laboratories. The principal advantage to CRT terminals, aside from their current appeal as modern gadgetry, is speed; it could be argued that in order to answer telephoned inquiries one must install the fastest possible output devices in the BSL office in order to handle information retrievals consisting of "long" lists. Even in the case of retrieval by patient name, however, a medium speed printer (30 characters per second) could print one complete entry in less than two seconds or 30 entries in less than a minute; this is reasonably well matched to the rate at which an individual can scan the list.

If lists of this type appeared to be too long for printout in a reasonable time (one might reasonably expect as many as 300 entries for the name "Smith") an additional type of retrieval could be used which would search by both patient name and account number as shown in Figure 14; this type of retrieval could also be used in the laboratory and would be almost certain to contain less than ten entries.

```
COMBINED PATIENT AND ACCOUNT  12/6/68  10:59 AM

PATIENT NAME?  FEIN
ACCOUNT NUMBER?  13098

FEIN MARLENE      89-4051  535
FEIN M            01-0134  535

PATIENT NAME?

END OF LIST
```

FIGURE 14

Since a keyboard/printer type of terminal is fast enough to handle the type of work performed in the office, other criteria must be used in the selection of the office terminals. If these devices are identical to the laboratory terminals, several important advantages will be gained. First, the programming task will be simplified, since one set of retrieval programs will be sufficient for both the office and the laboratories. Second, if the terminals are identical, then they can be interchanged in the event of malfunction; the clerks who operate the terminals can also be transferred from office to laboratory, or vice versa, in the event of a temporary clerical overload. Third, the number of spare terminals and parts, the number of outside service contracts, and the internal maintenance training requirements will be lower with one type of terminal for both the office and the laboratories. In addition, we believe that the hard copy produced by a keyboard/printer may be worthwhile as a temporary record of transactions in some cases, such as during the transition from one shift to another. Finally, we believe that the hardware cost of CRT's, including control equipment and special cabling, would be significantly higher than the hardware cost of an equal number of keyboard/printer terminals.

There may be other locations at BSL, in addition to the central office, where terminals are desirable. Such locations might include the executive offices, the mail room, the research offices, and the front desk. We do not believe that there is a pressing need for the installation of a terminal in any of these locations, and for economic reasons we recommend that terminals should not be placed in areas where they will not receive significant use. If, however, BSL decides to install terminals in any of these locations, or in any other areas of the laboratory, we believe that the terminals should be of the same type as those installed in the central office and the production laboratories, for the reasons cited above.

6. REMOTE LOCATIONS

In addition to the central facility in Van Nuys, BSL has or will have a number of remote facilities that might be considered for inclusion in the proposed real-time information system. Most of these, for example Samson Laboratories or the laboratory animal facility near San Francisco, are so far away that connection to a computer in Van Nuys would be prohibitively expensive. The two facilities in Beverly Hills and Century City, however, are close enough so that on-line connection through telephone company circuits must be considered practical.

Although we have not analyzed the operations at Beverly Hills and Century City during this study, we feel that some general comments about the connection of these laboratories to the central facility are in order. First, connection of these facilities to the system at the present time would probably be unwise. The volume of testing being performed at Beverly Hills is presently low, and can apparently be handled adequately by manual methods. Furthermore, the volume is expected to drop slightly as the Century City facility begins to function. Century City, on the other hand, is not yet even open for business, and although its future looks very promising it is still early to predict its growth pattern.

Second, current technology is certainly adequate to deal with the problems of connecting such a remote site to the central computer facility. (In fact, the NCR terminal we have recommended for use in the laboratories will be available as part of a complete remote terminal, with a telephone adapter, from

Computer Transceiver Systems, Inc.). Therefore, the eventual inclusion of the Century City office in the computer system is, from a <u>hardware</u> point of view, a completely straightforward task.

Third, the design of the system's software could be markedly affected by the inclusion of one or more remote laboratories. A multi-laboratory computer system requires a considerably more sophisticated design than a system serving a single laboratory. Many of the additional design requirements that must be considered in a multi-laboratory system are subtle and difficult to identify in advance. We will give one example of additional design that must be performed for a multi-laboratory system.

At present, any test code is uniquely associated with one and only one laboratory. Thus, with a single-laboratory system the test code for a specimen is sufficient to cause inclusion of that specimen on the correct summary listings and work sheets. If Century City were connected to the system, and if it performed any test with the same code as a test performed in Van Nuys, then the test code would be insufficient information to completely specify the correct laboratory for this specimen. This problem and other similar problems, can probably be handled in an unambiguous way if they are anticipated at the software design stage; trying to fix such problems after the fact will undoubtedly be difficult and expensive. For this reason, it is important for the BSL management to come to a decision regarding the eventual inclusion of the Century City facility (and perhaps other local facilities) in the computer system as soon as possible.

We estimate that the multi-laboratory system might require approximately 10% more development effort, and for this reason we feel that inclusion of the Century City facility should be avoided if possible. On the other hand, the primary consideration in making this decision is the ability of manual methods to handle efficiently the work load projected for each of these facilities during the foreseeable future. If the management of BSL believes that any computer assistance will be required, then we strongly recommend that the planning be done now.

7. BATCH PROCESSES

There are several computer system functions that can be performed most practically and economically as batch processes rather than as "real-time" processes. A real-time mode of operation is a virtual necessity for those functions in which there is a sense of "immediacy" about input or output of information; thus, functions like the entry of specimen data, the production of work sheets, and the handling of short-term retrievals cannot be treated as batch processes. On the other hand, any functions that do not require this sort of immediate response can at least be considered for batch processing. Several factors actually make it desirable to perform certain functions in a batch mode. The most important of these factors are:

1) A function that produces a great deal of output requires the use of an expensive printer. "Labor analysis" is an example of this type of function.

2) Non-computer considerations require batch processing in some other aspect of the function. An example is final result printing, where it is desirable to accumulate all reports going to a single address and mail them in one envelope.

3) The function requires output to be printed on special forms, as with patient billing.

4) The function requires the use of magnetic tape, which is not permenently connected to the computer system. An example mentioned previously is long-term retrieval.

In addition to the factors listed above, there is a persuasive economic argument for implementing as many functions as possible in a batch mode. One of the most expensive elements of a computer system is memory for program storage. Real-time programs must reside in this expensive type of storage at all times in order to be available for instantaneous use. Batch programs, however, may be permenently stored in a much less expensive storage medium, such as disk memory, magnetic tape, or punched cards, and only loaded into the expensive memory when they are required. Thus, several batch programs may use the same area of computer memory at different times, while each real-time program must have exclusive use of its own memory area. Consequently, each function which is performed by a real-time program adds significantly to the hardware cost, but hardware costs are essentially independent of the number of batch programs.

For these reasons, we have designated a set of functions which we believe should be implemented by batch programs. It will be the responsibility of a computer operator to run each of these batch programs according to a predetermined schedule. This will involve mounting the appropriate magnetic tapes (if any), loading a line printer with the appropriate forms, and initiating the loading and execution of the correct programs. The operator will occasionally perform other tasks related to the batch processing; for example, submitting search parameters to the long-term retrieval program through a computer console or a card reader. The batch programs should be written in a "high-level" language (e.g., FORTRAN, COBOL, or PL/1) if such a language is available with the computer to be used. This will reduce the cost of writing these programs and greatly simplify the process of making modifications as they become necessary. The functions that we recommend for batch processing are listed below:

1) *Result Printing* — This will include all text currently handled as attachments, and can probably include most or all of the "hand reports." All results to be sent to a single address will be grouped, as is done currently. This program can be run any number of times per day and, if desirable, could print only those results to be sent to a specific geographic area in certain runs.

2) *Request Slip Preparation* — Printing account numbers and other desired client information on request forms.

3) *Container Inventory* — Preparation of container mailing labels and updating the container inventory records.

4) *Billing and Accounting* — Preparation of bills for patients and clients, as well as other necessary accounting functions.

5) *Payroll* — Storing payroll information on magnetic tape will help to insure its privacy. This function includes preparation of pay checks and government forms for income tax, social security, etc.

6) *Long-term Storage Update* — The program that transfers specimen information from on-line storage to magnetic tape for long-term storage.

7) *Long-term Retrievals*

8) *Labor Analysis*

9) *Result Statistics* — These are the programs mentioned in our discussion of information retrieval from the laboratory. Additional discussion with BSL management is required to specify the division of statistics programs between batch and real-time modes of operation.

10) *Speed of Reporting*

11) *Advertising*

8. SYSTEM HARDWARE

In the preceding sections, we have approached the problem of specifying a real-time computer system from an operational point of view, describing the effects on several aspects of BSL's day-to-day procedures. We will now review some of the operational objectives for their implications in regard to the type of hardware configuration required to perform the necessary functions.

One important aspect of the system that we have described is the ability to perform both batch and real-time processing. There are three distinctly different ways of achieving this capability, as described below.

First, a single central processor (CPU) could perform real-time operations during the working day and batch processing at night. This would probably be the least expensive solution to the problem if it were feasible. Unfortunately, however, the requirements for real-time processing at BSL extend from approximately 7AM to 1AM each day. This would leave only six or seven hours each night for batch processing, preventive maintenance, and the testing of new programs and changes to existing programs. It would also mean that no batch processes, such as a second mailing, could be performed during the day. For these reasons, we feel that this method of implementation is completely unacceptable.

A second approach would also use a single CPU, but one that would be large enough to run both batch and real-time programs simultaneously. In this type of system, commonly known as foreground/background operation, the batch (or "background") programs are run during those time intervals when there is no real-time (or "foreground") activity. In addition to the foreground and background programs, a monitor program is required to allocate time to the various programs requesting it. Since the background capability would be used to provide testing of new programs and improvements to existing programs, and since these (possibly erroneous) programs must not be allowed to affect the real-time programs, the monitor must provide a relatively large measure of "protection" for the real-time system. While many such monitors have been constructed, they tend to be rather large and expensive. In addition, with either of these systems utilizing a single CPU, breakdowns and emergency repairs will halt all processing, including the real-time operations.

A third possible approach is the use of two CPU's sharing common data files. With this type of system, one CPU would perform all real-time processing and the other would be used for batch processing and program development. In addition, if the CPU's were identical, then the batch processor would serve as back-up for the real-time processor. In the event of failure in the real-time portion of the system, the CPU's could be reconnected in five to fifteen minutes, allowing repairs to be made without affecting the real-time operations. The obvious difficulty with this approach is the cost of an additional CPU; also, there are some hidden costs involved in making it possible for both CPU's to access common data files. However, none of the functions to be performed by the computer system require a great deal of computing power. The "bottlenecks" in the system will be the speeds of the mass storage devices, rather than the speed and power of the CPU. Thus each CPU can be quite small; CPU's of the correct size class for the BSL system have a purchase price on the order of $20,000. (This figure excludes the cost of computer memory for program storage, but approximately the same total amount of computer memory will be required whether there are one or two CPU's.) Therefore, our estimate of the difference in <u>total</u> hardware cost between a system using one CPU and a two CPU system, including the hidden costs mentioned above, is $25,000 to $35,000. This figure is quite close to the cost of implementing a foreground/background monitor and purchasing the additional computer memory which the monitor would require; in fact, the total cost of the monitor might easily be higher. *Our recommendation, then, is to construct a dual CPU system because of the small difference in cost, the simpler software system, and the greatly increased reliability to be gained from its "back-up" capability.*

Another aspect of the system affecting the hardware is the storage capacity required for the data that must be available in real time. Our preliminary calculations indicate a minimum storage capacity for on-line data of approximately 23 million characters, as shown in Table 1. In addition, on-line storage should probably be provided for some batch programs, for a "journal file" (to be used for recovery from computer breakdowns), and other small files. We believe that this data should be stored on several disk-pack drives, each of which has a capacity of 8 to 9 million characters. Although three such drives would probably provide sufficient storage, we recommend the initial installation of four disk drives, in order to provide for breakdown and emergency maintenance. In addition, tape drives must be available for several of the batch processes. These do not need to be high-speed drives; for economic reasons, we recommend that relatively low-speed drives be used. Three drives should certainly prove sufficient for all batch applications; one each for input and output, and one for a "scratch" or "work" storage medium.

TABLE 1: Estimate of On-Line Storage Requirements

Specimen Information	10.9 million characters
Indices to Specimen Information	1.8
Source File	2.5
Test File	.6
Billing Files	7.0
TOTAL	22.8 million characters

An additional aspect of the system to be considered is the method of interconnecting the two CPU's and the necessary peripheral equipment. Obviously, the remote terminals must be connected to the real-time CPU, and the on-line bulk storage must be connected to both; a high-speed line printer and the tape drives must be connected to the batch processor. Each CPU requires an operator's console. It will probably be desirable to attach both a card reader and card punch to the batch processor. The card-processing equipment would be used for program development, maintenance, and to establish the initial system. It might be possible, however, to eliminate the card punch from the system; further study and discussion are required to determine the necessity of the card equipment.

Finally, it might be desirable to have the tape drives connected to both CPU's rather than to the batch system alone. This would make it possible, for example, to store the "journal file" on tape rather than on disk. (This would probably also require an additional tape drive.) This question can be answered only when a specific computer is chosen, so that the cost of the extra hardware required to share the tape units can be determined.

Figure 15 is a block diagram of the system we recommend, based on the discussion above. Those aspects of the system still open to question are shown as broken lines. The "terminal interface" shown in the figure is the equipment used to connect all remote terminals, possibly including the LINC-8 at some future date, to the real-time CPU.

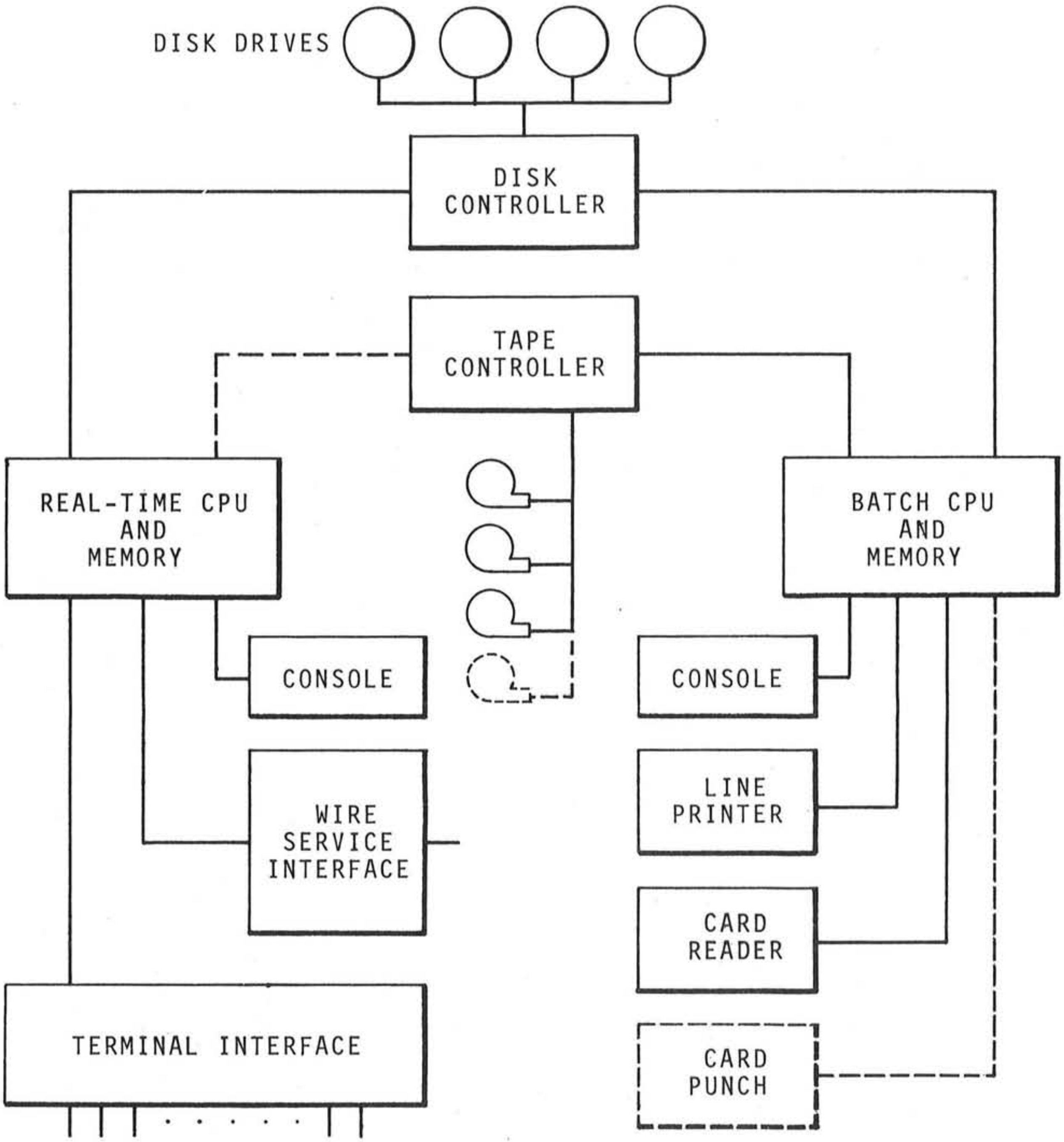
DISK DRIVES
DISK CONTROLLER
TAPE CONTROLLER
REAL-TIME CPU AND MEMORY
BATCH CPU AND MEMORY
CONSOLE
CONSOLE
WIRE SERVICE INTERFACE
LINE PRINTER
CARD READER
TERMINAL INTERFACE
CARD PUNCH

FIGURE 15

9. COST ESTIMATES

The system configuration we have recommended can be implemented on a number of different computers. The scope of this study did not include the selection of the specific computer hardware sufficient for adequate performance at the lowest cost. It is possible, however, to estimate the hardware costs based on one reasonable set of hardware, the Honeywell DDP-516. (Previous BBN studies of various information storage and retrieval systems resulted in the selection of this computer as the most effective for systems approximately the same size as that required by BSL. For this reason, we have produced a rough cost estimate based on the use of the DDP-516.) We must emphasize, however, that this estimate is not to be construed as a recommendation that the BSL system be implemented on this computer, since a comprehensive study of the several alternative computers has not yet been made.

The computer system costs, exclusive of terminals and the terminal interface, are estimated as follows:

- 2 Central Processor Units @ $15,800
- 2 Computer Memory Units of 16,384 words @ $32,000
- 2 Consoles @ $3,900
- 1 Disk Controller (including dual CPU interface) @ $17,300
- 4 Disk Drives @ $24,600
- 1 Tape Controller @ $10,130
- 3 Tape Drives (36 ips, 200/556 bpi) @ $13,225
- 1 Line Printer (300 lines/minute) @ $24,000
- 1 Card Reader (200 cards/minute) @ $8,900
- 1 Wire Service Interface @ $3,525

In addition, approximately \$20,000 will be required for the addition of "small" items such as clocks, interrupt channels, data transfer channels, etc.

Other equipment that might be desirable includes the following:

1 Card Punch — no price is available but we estimate the maximum possible cost to be less than \$15,000
1 Dual CPU Interface for Tape Controller @ \$5,900
1 Additional Tape Drive @ \$13,225

Costs for the input/output terminals and the terminal interface are estimated as follows:

12 Entry Room Terminals @ \$2,000
10 Laboratory Terminals @ \$3,000
5 Terminals for the office and other locations @ \$3,000
1 Terminal Interface for 27 terminals @ \$1,000 per line

In order to compile the total operating cost for the computer system, we have listed below all the non-personnel, non-development costs on a per-month basis. The per-month rate for the hardware equipment is based on an industry-average of 1/40 of the purchase price. However, it should be noted that some of the equipment (e.g., the terminals) may only be available on a purchase basis. Also, because it is expected that BSL will keep the system for considerably longer than 40 months, it may prove economically wise to purchase, or lease-purchase, the major portion of the hardware. If the purchased equipment is amortized over a longer period of time, the per-month costs would be considerably lower than those listed below. For example, five-year amortization is one-third lower in per-month cost than rental at the 1/40th rate.

Item	Monthly Cost
Computer Hardware	$7,625
Additional "small" items	500
Terminals and interface	2,400
Disk Packs (total of 18)	225
Tapes (2 per month for long-term storage)	100
Labels (60,000 per month)	540
Terminal paper (for estimated total typing of 30 lines per test)	210
TOTAL	$11,600

We have also attempted to estimate the manpower requirements for operation of this type of system. First, as we have noted in our discussion of the entry room, the addition of the equivalent of seven full-time employees will almost certainly be required. A single computer operator will be required at all times that the system is in operation; this probably amounts to a staff of approximately five full-time operators. The implications of the system on the office staff are not clear, but probably no significant change should be expected. The keypunch staff, however, can be almost completely eliminated, since there should be a requirement for at most one keypuncher.

It is more difficult to assess the requirements for additional clerical personnel in the individual laboratories. Certainly the Thyroid and Automation laboratories will require substantial clerical time for such activities as result posting; but it is not clear that this will require additional staffing, since clerical personnel are already assigned to these laboratories. It is not unreasonable, however, to assume that one or two more clerks will be required for these two laboratories. The other laboratories, with significantly lower work loads, are much less likely to require additional personnel since a clerk is already assigned to each of them. Thus it seems reasonable to predict a maximum of five additional clerical personnel required for laboratory operations. Therefore, we conclude that the total manpower required for the operation of the real time system is somewhat less than the total manpower required for the current system; our preliminary estimates indicate a personnel saving of at least four or five individuals.

10. THE NATURE OF THE SYSTEMS EFFORT

Now that we have been involved with this systems activity for several months, it seems appropriate to make some comments on the general nature of the effort. Some systems development efforts are concerned with the construction of a very well-specified facility that performs certain well-defined functions. In such cases, several similar systems have usually already been built and the detailed requirements are clearly known and can be spelled out in detail.

We have discovered that the BSL system is not at all this way. Rather, it incorporates a wide variety of functions, any of which can be automated in various ways to various degrees. Furthermore, many individuals at BSL will have opinions about specific small parts of the new system. For example, each of the work sheet specifications will have to be designed in conjunction with the appropriate laboratory personnel. Considerable interaction will be required with many different persons in the management of BSL. Thus, *it will not be possible to specify in advance the exact nature of all the jobs to be performed.*

In fact, even during our initial, relatively small, and flexible Phase I activity, it has not been possible to define the limits of our activities in advance. During the progress of the work, new and appropriate tasks have suggested themselves. We expect that this variable situation will continue and become even more marked during the final design and implementation phases. For example, as individual programs take on their final design or even after they have been implemented, BSL personnel, as well as our own staff, will see areas for refinement and improvement. Thus, there will be a general iterative type of interaction during the final design and implementation phases. This iteration is both constructive and necessary to achieve a final system that is well-matched to the BSL environment.

In the implementation of computer systems, BBN has contracted with clients in a variety of different fashions. When the problem has been well-defined, it has been convenient to establish a total price for the entire task including both hardware, software, testing, redesign and so forth. In other cases, where the problem has been more diffuse and where it has been obvious that considerable iteration would be required, BBN has adopted other contracting methods. In particular, in projects where such iteration is required, BBN recommends provision of all hardware on a firm fixed price basis, derived from quotes direct from the manufacturer, along with the provision of the software on a more flexible time and materials basis. We have concluded, in fact, that BSL should contract for the implementation of this system in the latter fashion. This technical conclusion is reflected in the arrangements outlined in our forthcoming proposal. We firmly believe that such arrangements will be beneficial to our working relationship, will result in an efficient expenditure of BSL's time and money, and will produce a system that closely matches BSL's requirements.