THE STL INTEGRATED COMPUTER OPERATING SYSTEM

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Abstract

The separation of conventional unit record input/output processing from a large general purpose computer system has been and still is a common and accepted practice among many large-scale computer installations. This kind of processing has been called off-line or peripheral processing and seeks to reduce costs by removing the relatively slow I/O functions such as card reading, card punching, and printing from the large computer and having them performed on smaller less expensive computers. This practice is not without its inherent penalties, all of which tend to reduce the operational efficiency of the system by introducing large throughput times and equivalently large setup times.

This paper describes a general-purpose computer system currently implemented at STL that returns the conventional data input/output functions to on-line processes. The paper not only includes a general description of the hardware and software employed but also makes comparisons with prior systems, describes simulation experiments performed, and evaluates current performance.

1. Introduction

This paper describes the transformation of a conventional computer installation with off-line processing into an on-line or "integrated" data processing facility by employing very large random access disk storage devices that are shared in common by the main processor and the I/O processor.

2. Former Computer Operating System

Prior to March 1963, STL had in operation a computing center consisting of a data processing equipment configuration shown in Figure 1. The main processors were twin IBM 7090's, each employing 16 magnetic tapes on two channels. The peripheral processors consisted of six assorted IBM 1401's which were assigned to perform the unique I/O functions of card-to-tape, tape-to-printer, and tape-to-punch. The basic flow of information is shown in Figure 2.

a) Programs and data in the form of cards and tapes were processed by the 1401 to produce a peripheral input tape. The 1401 also utilized cards submitted with each program deck to produce a "batch sheet" giving the characteristics of each job which were of concern to the 7090 and 1401 operators. This batch sheet included a description of all tapes to be used and the physical drives on which they were to be mounted. It was the 1401 card-to-tape operator's responsibility to order jobs within the confines of the priority system and work on hand so as to minimize tape mounting time on the 7090 when the batch was run.

b) The input tape generated was then removed from the 1401 and carried to the 7090 area along with its associated batch sheet. In turn, these input tapes were mounted on the 7090 and the jobs executed in a serial fashion, producing a tape reel of print output and a tape reel of punch output. The 1401-generated batch sheet was used by the operator to set up tapes as required.

c) The print and punch tapes produced by the 7090 execution of the batch were then removed and carried back to the 1401 area where they were eventually printed and punched. Again, each tape was processed in a serial fashion.

Thus, the operation was much the same as in any other installation running in a peripheral mode.

2.1 Performance Analysis. Between 350 and 400 jobs were normally processed each day in this peripheral system, with throughput time averaging 4.1 hours. (Throughput time is the interval between the time when the job was first submitted and the time when its last line or card was output.) Job times for 7090 execution ranged from less than a minute to almost one hour, with an average time of 3.6 minutes and with 80 percent of the jobs running less than 5 minutes. Although the work was generally classified as scientific, it was found that most jobs required tapes for their execution and, in fact, that the average job required 2.7 tapes (not including the normal peripheral tapes). Although a 4.1 hour throughput time was considered fairly good compared to other computer installations with similar workload capacities, it was felt that it could be improved upon. In addition, if

the unnecessary delays due mostly to operator action and tape handling could be reduced, it would not only reduce throughput time, but would in turn reduce the overall computing period and thus result in savings on both computer rental and machine operator costs.

2.1.1 Data Collection. Before definitive recommendations could be made, detailed operational data had to be researched and analyzed. This task involved the monitoring of the work flow at various stages in the processing cycle. Major data items were collected over a period of a month. They consisted of:

a) Job submission time
b) Number of cards in job
c) Start time on the 7090
d) Elapsed time on the 7090
e) Number of cards punched
f) Number of lines printed
g) Time when last card punched
h) Time when last line was printed

This information comprised the data for a performance analysis program that produced the following items (Figure 3).

a) Backlog sheet (Figure 3a)
This gives a time history of the volumes entering into and generated by the system. For example, at 10: 29 a.m., Job No. 3193 entered the system with 985 cards input. This increased the input balance by the same amount. At 12: 57 p.m., Job No. 3193 finished processing on the 7090, generating 978 cards and 10,689 lines of output, thus increasing the print and punch balances by the same amount; at the same time, the input balance was depleted by 985 cards. At 1: 43, the 978 cards generated by the 7090 had been punched, thus depleting the punch balance by that amount. At 2: 18, the 10,689 lines generated by the 7090 had been printed, thus depleting the print balance by that amount. The last transaction for Job. No. 3193 occurred at 2: 18; hence the throughput time for that job was 3 hours 49 minutes.

b) Backlog summary (Figure 3b)
This gives the summary on total and average volumes and throughput times.

c) Backlog Distribution (Figure 3c)
This shows how the backlog was distributed through the day. In particular, it pointed out the periods of maximum backlog and the rate of depletion.

In addition to backlog information, other system usage information as shown in Figure 4, was added to the data base. This consisted of the performance of the main processor in terms of both hardware and software. However, the important additional items were:

a) Setup time
b) Idle time
c) Down time
d) Periods of no work

The data collected showed that three major areas could be improved upon:

a) Program running time on the 7090
b) Non-productive time on the 7090
c) Overall throughput time for jobs

All these contributed in some degree to operational costs which, in a 2 1/2 shift operation, were quite high. Reduction of throughput time by reducing non-productive time of each major item of equipment in the configuration, tends to reduce the operations interval and the effective rental period. Since the emphasis was placed upon improving the throughput time, this particular area was investigated first.

2.1.2 Pre-Analysis. The data collected revealed large segments of time during the computing day when jobs needed to be processed and yet the equipment was idle. In addition, a large percentage of the throughput time consisted of setup--tape mounting and dismounting, forms changing, etc. Most of the reasons for this were due entirely to the effect of manual operations on the machines--in other words, a man-machine interaction problem existed.

While it was generally agreed that reductions in throughput time and setup time were desirable goals, the possibility of achieving any dramatic results seemed fairly remote. After all, peripheral operation had been around for a long time and the then current procedures were the product of a lengthy evolution at STL.

It was the announcement of a large capacity disk file capable of being shared with another computer that stimulated further study in the twin areas of:

a) Elimination of inefficient operator action and replacement by relatively inexpensive hardware.
b) Elimination of inefficient computer operation and replacement by more sophisticated software.

This new hardware appeared to permit two significant advantages:

a) Automatic data transmission
The shared disk file meant that it would be possible to process a job from beginning to end with little or no operator intervention. A smaller computer would serve as the peripheral device and place programs and data in the disk for execution by the larger computer. Similarly, print and punch output from execution on the larger machine could be placed on the disk for printing and punching by the smaller machine. Thus, delays resulting from movement of peripheral tapes from one computer to another, and the mounting and dismounting of these tapes would no longer exist.

b) Process Scheduling
The fact that large amounts of data could be stored on the disk file meant that perhaps all unfinished work could be stored there. Since such work was equally accessible to the sharing computers, it would be possible to select the "best" job or sub-job to do, rather than just the "next." The ability to have the computers schedule work offered definite promise that throughput time and equipment idle time could be significantly reduce.

It was necessary to verify these assumptions and also to determine the hardware requirements of such a method of operation. In addition, a quantitative measure was needed that would indicate the improvement in service which could be expected from a system utilizing the new hardware. Thus a simulator program for the IBM 7090 was written to be used in place of experimentation with actual hardware. The simulator was completed in November 1961 and was employed soon after.

2.2 Computer Simulation. The basic elementary system to be simulated is shown in Figure 6. The main steps or processes are:

a) Job submission storage
b) Card input process
c) Input storage
d) Main process (program execution)
e) Output storage
f) Card punching
g) Line printing
h) Job completed storage

The job submission and job completed storages are not connected electronically to the system but, instead, represent racks, shelves, and tables. The operation of the basic system then consists of the following steps:

a) The job in the form of cards is submitted for processing on the computer system.
b) The job remains inactive until an operator actually places the cards in the card reader.
c) When the card reader becomes available it reads the cards and stores their information on the disk.
d) When the main processor becomes available, it reads the card information from disk and executes the associated program. The output from this program is stored back on the disk in the form of line and card information.
e) When the printer becomes available it reads the line information from the disk, prints it, and stores the resulting printout in the job completed storage.
f) When the punch becomes available it reads the card information from the disk, punches it, and stores the resulting card output in the job completed storage.

The basic system can be varied not only by changing the number of reservoirs and processes, but also by varying their corresponding volumes and rates of processing. Figure 7 shows an expanded system where reservoirs are shared by many processes. The major underlying philosophy of the simulation program pertained to the ability for any process to select its next job based upon throughput time and equipment efficiency considerations. Other assumptions stated that the job profile of the old system was the same in the simulated system and that some manual operations performed in the old system (tape mounting, forms changing, etc.) would still be present. Thus the job profiles became the basic inputs to the simulator. This profile consisted of the same data that was collected in the backlog procedure described earlier and the items remaining constant were:

a) Job submission time
b) Number of input cards
c) Number of output cards
d) Number of output lines

When these profiles were entered into the simulator, the following data was generated which usually differed considerably from that produced during operation of the old system:

a) Input start time
b) Input stop time
c) Delay of job due to reader
d) Delay of reader due to job
e) Main processor start time
f) Main processor stop time
g) Delay of job due to main processor
h) Delay of main processor due to job
i) Printer start time
j) Printer stop time
k) Delay of job due to printer
l) Delay of printer due to job
m) Punch start
n) Punch stop
o) Delay of job due to punch
p) Delay of punch due to job

The two kinds of delays can be described as job wait times and process idle times, and both must be minimized to increase efficiency. When the job profile, shown earlier, was input to the system it produced the output shown in Figure 8. A sample comparison for say Job No. 3193 in the old and new simulated mode, shows the following:

Events	Old	New
Submitted	10.49	10.49
Delay	N/A	0
Reader start	N/A	10.49
Reader stop	N/A	10.51
Delay for main process	N/A	0.75
Main process start	12.88	11.26
Main process stop	12.95	11.33
Delay for printing	1.05	0
Printing start	14.00	11.33
Printing stop	14.30	11.68
Delay for punching	.70	0
Punching start	13.65	11.33

Events	Old	New
Punch stop	13.72	11.41
Throughput time	3.81	1.19

In this particular case, the system being simulated is shown in Figure 9.

The other item that was produced by the simulation was the volume of backlogged data that needed to be retained on the disks. Samples of this backlog are shown by the graphs of Figures 10 and 11. Both give an indication as to the amount of volume generated in the disks, the peak volumes and the rates of depletion. For example, the simulation showed over many sample cases that the maximum backlog on the disk would not exceed 2,400,000 words. This figure played a major role in determining the size of the disk that would be required. By changing the components and their corresponding rates of processing, the schematic configuration shown in Figure 12 was derived. The actual hardware system corresponding to it is shown in Figure 13.

Some of the items not simulated, but reflected in the new system, concern the replacement of some of the tape functions by disk operations. These include:

a) Systems residence on disk
b) Systems scratch
c) Programmer's scratch
d) Subroutine storage
e) Utility storage

Their replacement on disk would free six tape units from each system and would not only help offset equipment costs, but would actually speed up operations in some cases. The punch was also completely eliminated from the main processor. The additional 1410 system which was not part of the simulation was postulated as a backup computer in case the on-line systems were down and had redundant interface equipment that would tie it to the disks.

3. Detailed Actual Implementation

The operation of the STL Integrated Computer Operating System includes the following steps within the job processing cycle.

3.1 Job Submission. As a job enters the computing center, it is given a sequence number and placed in the card reader of the 1410 computer. The 1410 reads the input deck, formats the card images as required, and places the total deck in the common input/output area of the 1301 disk file. An additional responsibility of the 1410 during this input phase is to form a Job Information Block from the set of descriptive parameters supplied with the deck by means of administrative cards. Information supplied by these administrative cards includes the programmer's name, problem number, job sequence number, priority classification, maximum 7094 time required, limits on the amounts of print and punch to be generated, and definition of any tapes which will be needed by the object program during its execution upon the 7094. Standard values have been established for many of these parameters so that the programmer need submit administrative cards only for those values which are non-standard. This Job Information Block is also utilized to record the current status of the job and to locate job input and output within the Common Input/Output area of the disk. Thus, completion of the 1410 input phase of processing will result in the location of such input being entered in the Job Information Block and the status of the job being set to indicate that the input phase has indeed been concluded.

3.2 Job Scheduling and Setup. A job becomes available for execution upon the 7094 once its input processing has been finished. The manner in which work is selected, or scheduled, for 7094 execution is simple in theory and has worked well in practice. The procedure consists of maintaining an ordered set, or queue, of jobs to be executed. The length of the queue is long enough to give the computer operator sufficient lead time for setting up the job and short enough to permit rapid response to higher priority work which may subsequently enter the system. The latter requirement results from the fact that job queues are not interrupted, nor are individual jobs, since such interruptions would materially increase the nonproductive computer setup time. Minimum lead time is fifteen minutes or, failing this, five jobs. Maximum queue time may be as much as the time involved in processing the longest job (seldom more than one hour). The scheduling process involves reading the Job Information Blocks from the disk and selecting the jobs available for 7094 execution. Those jobs selected are then ordered by considerations of their priority class, sequence number, 7094 running time, and output volumes. In practice, a weighted sum of these parameters is computed for each job when it first becomes available for 7094 processing, with the ordering being done on these sums. Although the weighting factors have varied somewhat, the intent has been to strongly favor high over low priority work; to run in sequence number order (which is equivalent to submission order); to run short jobs before long jobs; and to favor jobs with low expected output volumes. This preliminary job ordering is then tested to determine the degree of compatibility existing between adjacent jobs relative to their tape requirements. The optimum condition is that in which one job is having tapes mounted while the immediately preceding job is being executed. This condition can be met only if a sufficient number of tape drives are not required by the job presently being executed. If the preliminary ordering does not result in a smooth meshing of tape usage, the jobs will be permuted to a limited degree, so as to arrive at a more compatible ordering. The number of jobs actually added to the queue is subject to the constraints mentioned previously, for the length of the queue. The examination of tape usage also results in the scheduling program assigning the actual physical tape drives which are used by each job. This tape assignment is possible because object programs and administrative cards refer to tapes in a purely symbolic manner, and it is the scheduler then which equates these symbols to the physical devices to be used for a given run. The updated queue,

which contains the tape assignments and updated Job Information Blocks are returned to the disk once scheduling is completed.

The results of the scheduling process are made available to the 7094 operator on a job sheet printed on the 7094 printer at the time each job is added to the queue (Figure 14). To permit proper identification of the run, this job sheet contains the sequence number, programmer's name, and problem number. It also contains the results of the tape assignments made and thus describes any tape reels which the job requires, and informs the operator upon which drives they are to be mounted. The operator may expect to have 15 minutes after this job sheet is printed in which to fetch reels from the tape library before the job will come up for execution. The job sheet also contains certain standardized items utilized by the operator in reporting to the programmer the manner in which the job ran; e.g., no apparent trouble, illegal stop, program looping, too much time, etc. A copy of this job sheet is returned to the programmer with the operator's comments. A second copy of this form is used to control the further processing of any tapes produced by the run. This further processing may be nothing more than saving a tape or it may involve plotting the tape, printing it, etc.

3.3 Job Execution on the 7094. The execution of the individual jobs upon the 7094 is quite straightforward. As a job arrives at the front of the queue, the information in the Job Information Block along with the tape assignments previously made are used to establish a table, or nucleus, which describes the job and reflects the assignment of machine resources committed to this job by the scheduler. Therefore, this nucleus contains not only job identification and tape assignments, but also contains the location in the Common Input/Output area at which the job input starts, the set of tracks in the Common Input/Output area upon which output is to be written, limits upon the amount of print and punch output permitted, the amount of time allowed for 7094 execution, and the results of other system assignments. Then the input is read and operated upon as directed by the control cards submitted with the input deck. What has been accomplished is subordination of two previously independent systems to one scheduling monitor. These two systems are a machine language SOS-like system developed at Space Technology Laboratories, and IBM's IBJOB system which includes COBOL and FORTRAN IV compilers. These systems have been modified to become subservient to our higher level control program and, where possible and justifiable, the various processors within these systems have been further modified to permit operation with disk input and output. This latter modification has proved to be a formidable task and is not yet completed in full. Thus, in some cases, it is unfortunately necessary to transcribe data from the disk to produce a peripheral input tape and after processing this tape to transcribe, print, and punch output back to the disk from tape. Further work is being performed in this area upon both system and object programs. Otherwise, these subsystems operate essentially as before. Completion of 7094 execution results in the Job Information Block being updated to reflect this fact, to record the locations in the Common Input/Output area at which the output print and punch streams may be found, and the amounts of such output.

3.4 1410 Output Processing. Having completed execution, a job becomes eligible for output printing and punching by the 1410. The 1410 program consists of a multiprocessor that performs as many as three simultaneous I/O operations (e.g., card reading and printing on both printers). The selection of work to be processed by the 1410 is done by a scheduling program operating upon that machine. The 1410 scheduler is invoked whenever a printer or the punch becomes available and this scheduler is responsible for choosing the output portion of a job to be processed next. Note that the 1410 does not schedule jobs for output processing, but rather print or punch parts of a job. Considerations in this scheduling are similar to those involved in 7094 job selection. These are priority classification, sequence number, output volume, and form required. In this case, output volumes are true values, whereas for 7094 scheduling, they are estimates. The parameters used in 1410 scheduling are treated in basically the same manner as those used in 7094 scheduling. Completion of an output process for a job results in an updated Job Information Block. A job is considered finished when all of its printing and punching has been concluded.

3.5 Disk Usage. Briefly, the 1301 disk file is used in the following manner. As previously mentioned, it holds the Job Information Blocks, maintains the 7094 job queue, and in addition, contains a Common Input/Output area utilized for the transmission of data between the two sharing computers. Furthermore, the disk holds the programs making up this system, possesses areas used for utility storage, and contains a program file service. The program file service provides a storage facility for program and data decks whereby decks may be extracted by control cards, recognized by the 1410, and effectively inserted into the input stream. Although the use of most areas of the disk is constant, utilization of the disk tracks constituting the Common Input/Output area is constantly changing. The various records making up an input or an output stream are linked together so that each record contains the location of its successor. The starting points of these strings are kept in the Job Information Blocks. In turn, a track is maintained on the disk which reflects the availability or unavailability of the tracks making up the Common Input/Output area. This track, of course, is updated by both of the sharing computer systems whenever a change of status takes place.

3.6 System Inquiry. Since all job information is maintained on disk, it becomes a simple matter to retrieve data about jobs or about the system itself. With an inquiry console

(typewriter) on the 1410, information can be entered as well as displayed. Figure 15a shows some of the requests (underlined) that can be made:

QTRACKS gives the percentage of disk space available.
QSTATUS gives the status or "location" of a particular job in the system.
QJIB gives the status of all incompleted jobs still in the system (see Figure 15b).
QJOBS gives an accounting of all jobs that have entered the system (see Figures 15c).
SADD and SREMOVE indicate to the system that components have been added to or removed from the system.
JPRIORITY is used to change the priority of a job.

3.7 Summary of Operations. The 1410 reads the input deck and places it upon the disk while at the same time constructing an abbreviated description of the job known as the Job Information Block. The 7094 programs scan the disk and select and order the jobs to be run with the jobs being processed in a conventional manner except that input cards are read from the disk and output for print and punch is written back on the disk. The 1410 completes the cycle by processing the output on the disk and printing or punching it. Each computer schedules its own tasks with the various concurrent processing steps although upon different jobs.

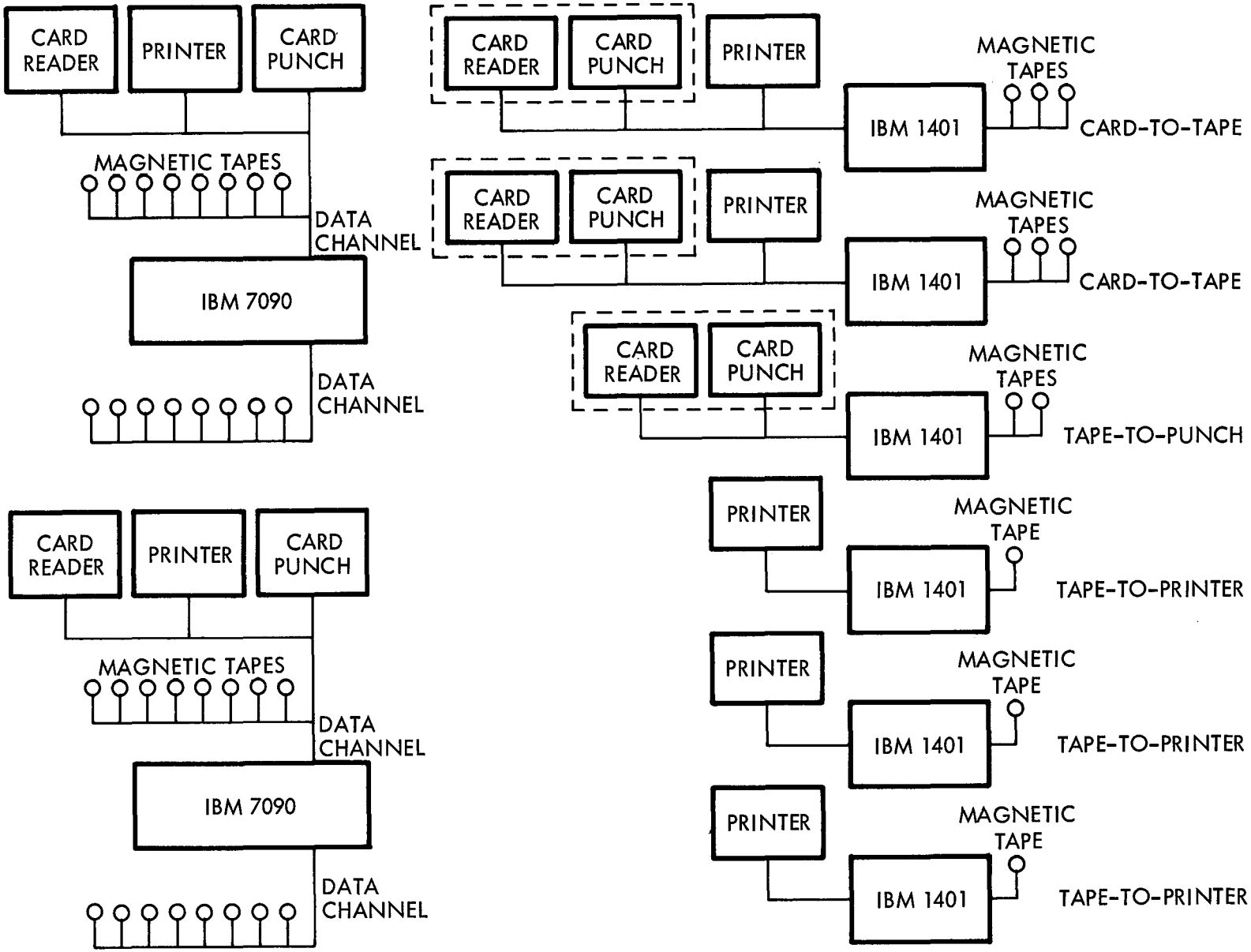
4. Conclusions

4.1 Current Mode. The system has performed successfully since its inception in March 1963. As was expected, the setup time for jobs at all stages of processing has been reduced considerably--namely, from 1.3 minutes to .5 minutes per job. This reduction in setup has led to a corresponding reduction in throughput time; namely, from 4.1 to 1.6 hours per job. In addition, by appropriate scheduling, a substantial reduction in machine idle time has resulted. The equipment costs of the new system are approximately the same as those of the equivalent old system, but the number of work shifts has been reduced even though the workload has remained constant.

4.2 Future Considerations. Simulations that include a faster main processor have been made and show that a single main processor system communicating with two unit record processors, could easily replace the two independent systems currently in use without increase in throughput or operation time.

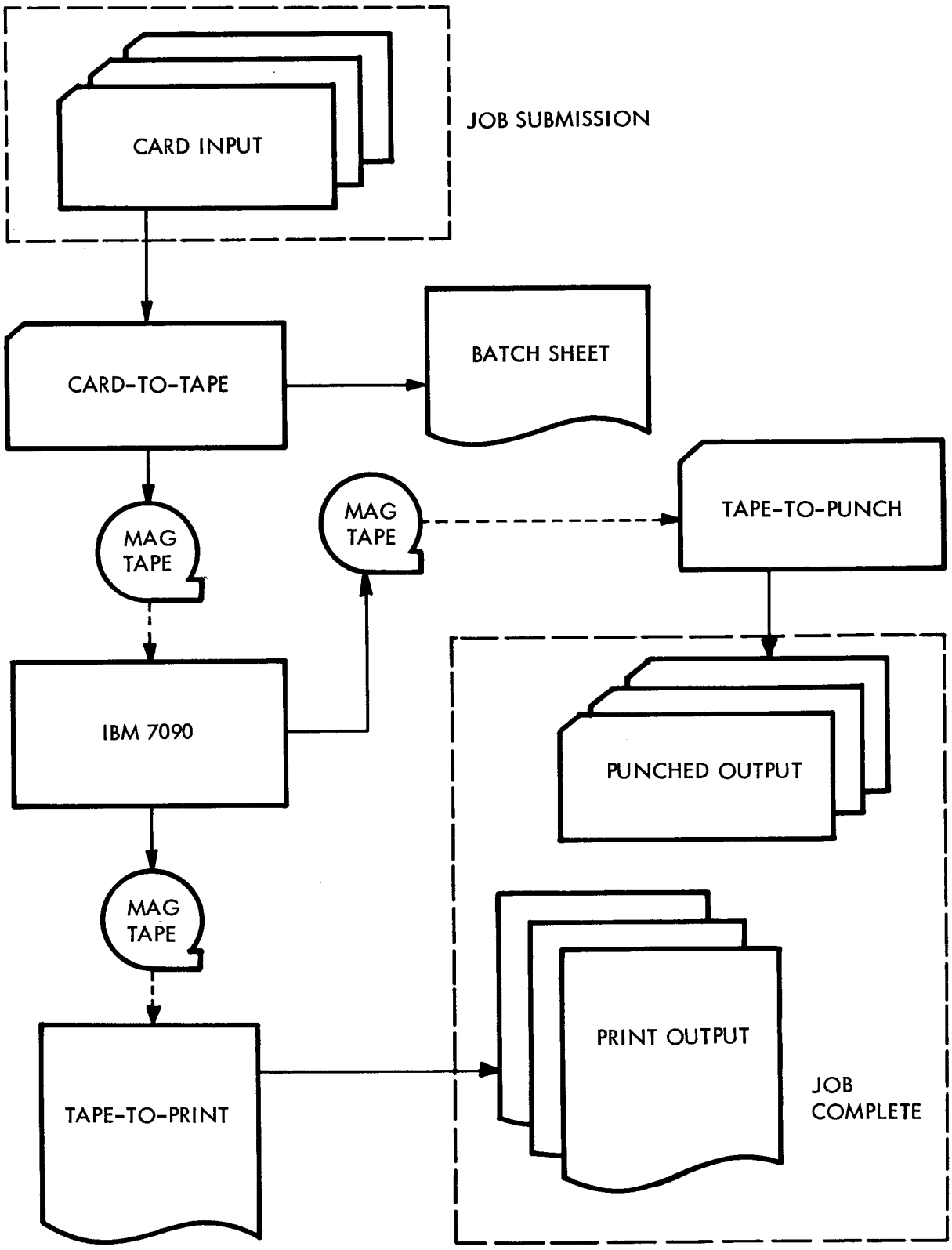
Other simulation experiments related to the improvement of the scheduling algorithm have been and will continue to be performed. The purpose here is to arrive at an optimal yet practical system that considers not only the operational efficiency of the equipment, but also the urgent needs of programmers for very fast throughput times.

4.3 Summary. The return to an on-line mode of operation has proven successful at least in the case just described. Variations on this basic notion are currently being implemented or considered by other computer installations, especially those that operate under a production line mode involving many jobs per day. This trend appears to be quite general and until manufacturers provide for truly integrated and efficient I/O unit record processing within a single machine, multi-computer on-line systems will continue to be pursued.



Computer Configuration Prior to March 1963

Figure 1



Basic Information Flow Prior to March 1963

Figure 2

INPUT/OUTPUT BACKLOG SHEET

DATE COLLECTED 20/20/61

TIME HR/MIN.	SEQ. NO.	CARDS INPUT	CARDS PROC.	GENERATED CARDS	GENERATED LINES	LINES PRINTED	CARDS PUNCHED	BALANCE INPUT	BALANCE PRINT	BALANCE PUNCH	CUMULATIVE TOTALS INPUT	CUMULATIVE TOTALS PRINT	CUMULATIVE TOTALS PUNCH
10.27 AM	3122		650		317			42,515	460	0	52,115	26,811	720
10.27 AM	3192	615						43,130	460	0	52,730	26,811	720
10.29 AM	3193	985						44,115	460	0	53,715	26,811	720
10.30 AM	3187					143		44,115	317	0	53,715	26,811	720*
10.30 AM	3116		775	125	897			43,340	1,214	125	53,715	27,708	845
10.31 AM	2895		1,850		120			41,490	1,334	125	53,715	27,828	845
12.52 PM	3203		375		1,417			44,930	64,912	0	89,105	162,168	1,586
12.52 PM	3181		15		4,171			44,915	69,083	0	89,105	166,339	1,586
12.57 PM	3193		985	978	10,689			43,930	79,772	978	89,105	177,028	2,564
12.57 PM	3212		260		2,677			43,670	82,449	978	89,105	179,705	2,564
12.58 PM	3173					11,850		43,670	70,599	978	89,105	179,705	2,564
12.58 PM	3234					1,931		43,670	68,668	978	89,105	179,705	2,564
1.42 PM	3301	200						43,150	71,356	4,813	99,630	223,135	6,630
1.43 PM	3102					15		43,150	71,341	4,813	99,630	223,135	6,630
1.43 PM	3193						978	43,150	71,341	3,835	99,630	223,135	6,630
1.45 PM	3302	1,325						44,475	71,341	3,835	100,955	223,135	6,630
1.45 PM	3303	1,300						45,775	71,341	3,835	102,255	223,135	6,630
1.46 PM	3245					831		45,775	70,510	3,835	102,255	223,135	6,630
2.16 PM	3263		2,950		5,520			40,435	55,930	1,190	108,005	249,709	6,729
2.17 PM	3240		75		208			40,360	56,138	1,190	108,005	249,917	6,729
2.18 PM	3193					10,689		40,360	45,449	1,190	108,005	249,917	6,729
2.20 PM	3264		400		15,140			39,960	60,589	1,190	108,005	265,057	6,729
2.21 PM	3110		1,100		3,717			38,860	64,306	1,190	108,005	268,774	6,729
2.22 PM	3212					2,677		38,860	61,629	1,190	108,005	268,774	6,729

Input/Output Backlog Sheet
Figure 3a

I N P U T / O U T P U T B A C K L O G S H E E T

DATE COLLECTED 10/20/61 ***FINAL SUMMARIES*** PAGE 034

TOTAL NUMBER OF JOBS PROCESSED = 335
TOTAL NUMBER OF CARDS INPUT = 243,138
TOTAL NUMBER OF LINES PRINTED = 1,052,876
TOTAL NUMBER OF CARDS PUNCHED = 26,462

MINIMUM TURNAROUND TIME = .37 HOURS
MAXIMUM TURNAROUND TIME = 14.72 HOURS

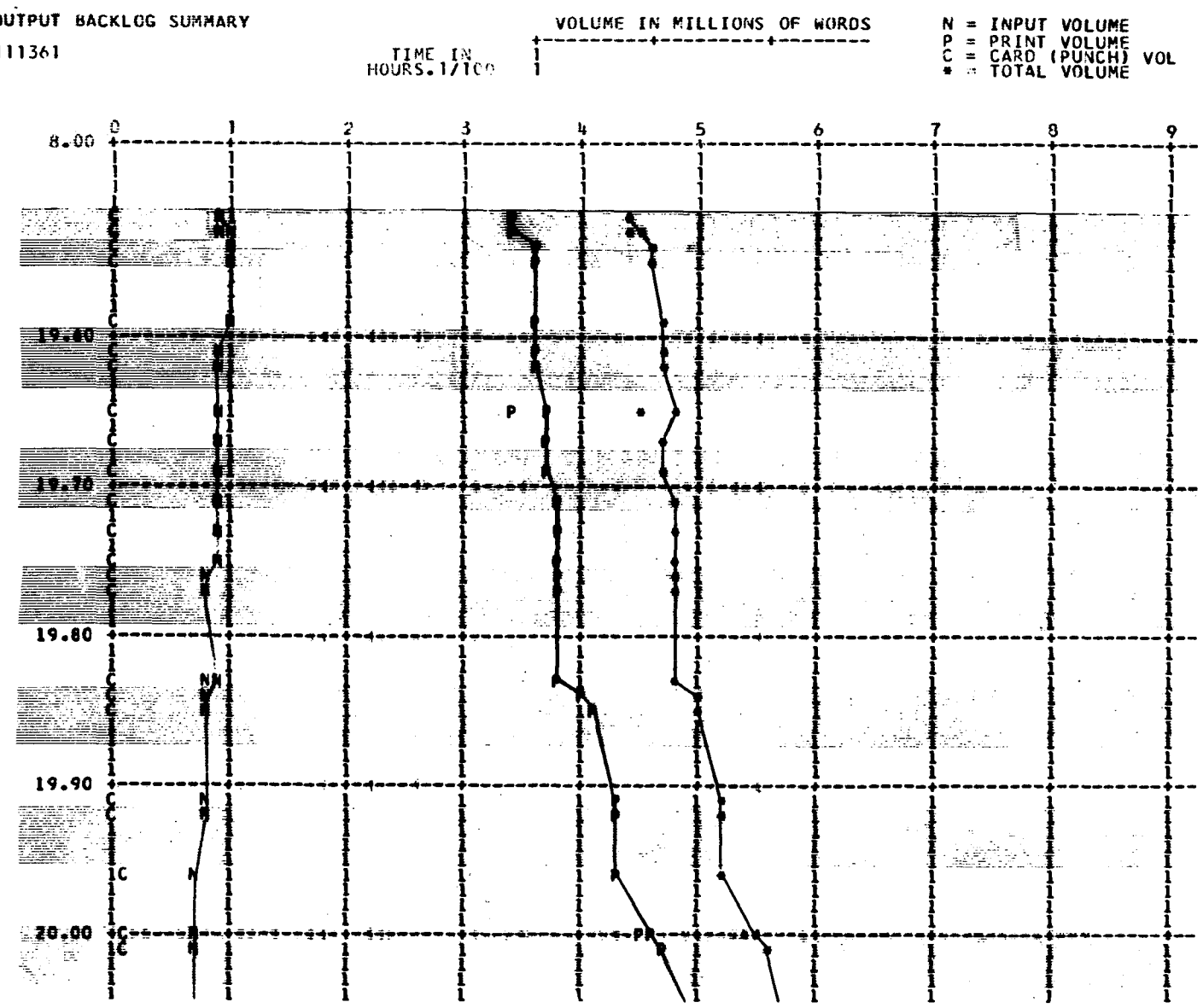
AVERAGE NO. OF CARDS INPUT/JOB = 725.785
AVERAGE NO. OF CARDS PUNCHED/JOB = 78.991
AVERAGE NO. OF LINES PRINTED/JOB = 3,142.913
AVERAGE TURNAROUND TIME/JOB = 4.90038 HOURS

MAXIMUM INPUT BALANCE WAS 82,595 CARDS (OR) 1,651,900 WORDS AT 6.09 PM
MAXIMUM PUNCH BALANCE WAS 10,742 CARDS (OR) 214,840 WORDS AT 7.47 PM
MAXIMUM PRINT BALANCE WAS 229,914 LINES (OR) 4,598,280 WORDS AT 8.21 PM

MAXIMUM TOTAL BALANCE WAS 46,391 CARDS AND 229,693 LINES (OR) 5,521,680 WORDS AT 8.21 PM

Input/Output Backlog Sheet Final Summaries

Figure 3b



Input/Output Backlog Summary

Figure 3c

SYSTEM USAGE SUMMARIES. 7090-2. 103061 THROUGH 103161 (7.00 A.M.)

MAJOR SYSTEM

SYSA	SYSB	FORTRAN	8-10(UTIL)	NONSYS
.645	8.352	2.951	.209	3.381

TRANSLATION TYPES

ABS	CPL	CPLPA	LS	ML	PA	PEST	POS	PS	PSPA	FCOMP	FAP	SMASHT
.078	.064	.000	.457	.876	.000	.000	.000	.108	.000	.322	.006	.358

SPECIAL TYPES

COMPAT	9AP	SIMUL
.060	.000	.000

COMPUTATIONAL PHASE

TRANSLATION	EXECUTION	DEBUGGING
2.519	12.184	.835

NON-PRODUCTIVE SUMMARIES

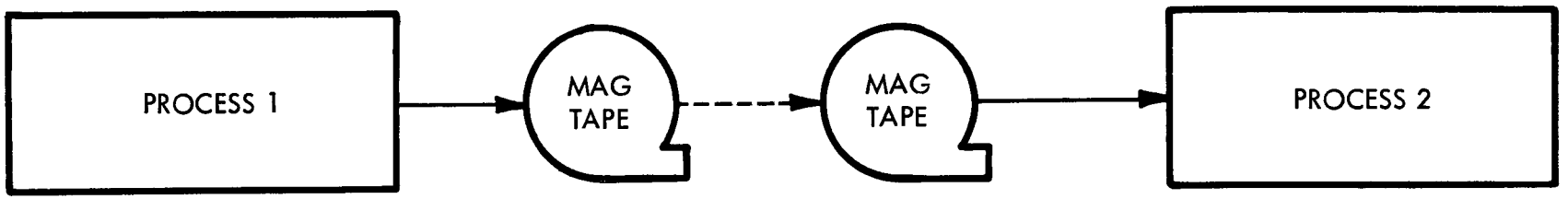
SETUP	IDLE	PM	SYSTST	EXTPM	IBTEST	DOWN	NOWORK	OTHER
4.449	2.645	.000	.000	.000	.368	.000	1.000	.000

SPECIAL USAGE

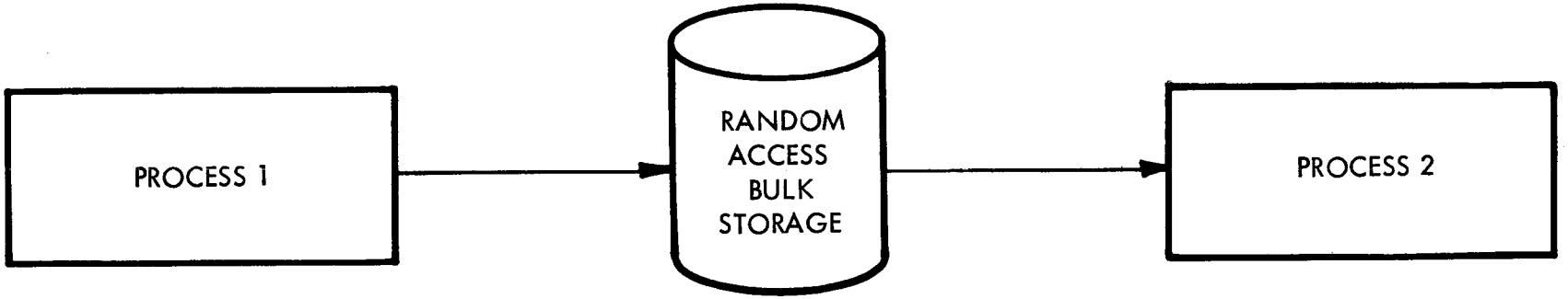
DEMONSTRATION	EXTERNAL USE	ENGR. CHANGES	SALES CHANGES	POWER FAILURE	AIR COND. FAILURE
.000	.000	.000	.000	.000	.000

System Usage Summaries

Figure 4

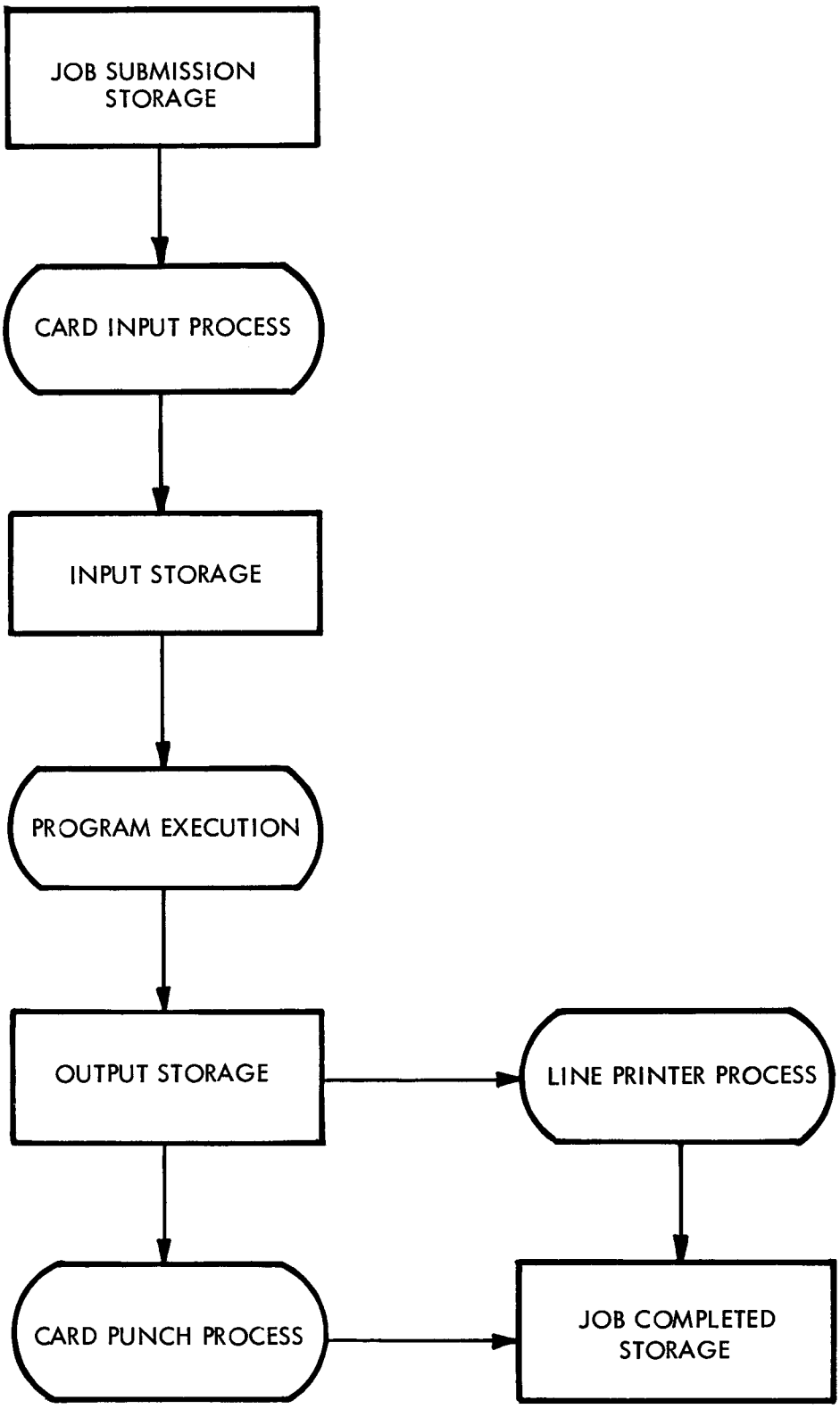


PERIPHERAL OPERATION



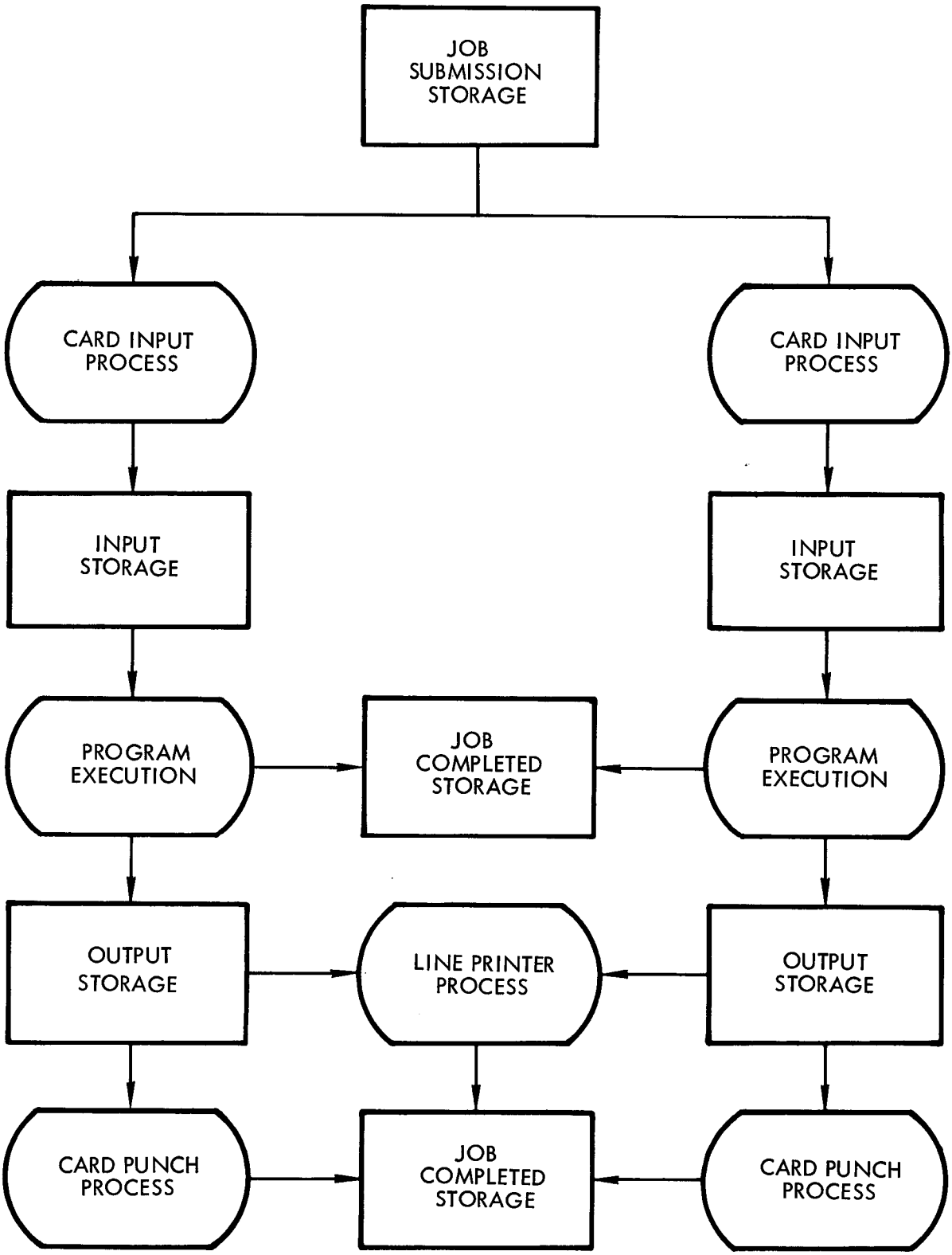
Comparison of Peripheral and Direct Operations

Figure 5



Basic Elementary System to be Simulated

Figure 6



Expanded System To Be Simulated

Figure 7

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SYSTEM SIMULATION PROGRAM - DETAIL JOB PROCESSING

SEQ	SUBM. TIME	NO. CARDS	READER START	ELAPS. TIME	7090 START	ELAPS. TIME	NO. LINES	PRINT START	ELAPS. TIME	NO. CARDS	PUNCH START	ELAPS. TIME	TURNOVER TIME
3176	10.150	03075	10.150	0.076	10.794	0.024	00011	10.833	0.000	00000	10.818	0.000	00.683
3174	10.160	01100	10.160	0.027	10.818	0.065	03464	10.883	0.114	00000	10.883	0.000	00.837
3177	10.170	00110	10.188	0.002	10.905	0.028	00847	10.949	0.027	00217	10.933	0.018	00.806
3179	10.190	00085	10.191	0.002	10.955	0.007	00019	10.977	0.000	00000	10.962	0.000	00.787
3180	10.200	00115	10.200	0.002	10.984	0.058	00757	11.042	0.024	00000	11.042	0.000	00.866
3181	10.260	00015	10.260	0.000	11.064	0.010	04171	11.074	0.137	00000	11.074	0.000	00.951
3182	10.260	00150	10.260	0.003	10.840	0.023	01975	10.863	0.065	00000	10.863	0.000	00.668
3186	10.340	00755	10.340	0.018	11.096	0.081	03201	11.177	0.105	00257	11.177	0.021	00.942
3188	10.410	00400	10.410	0.009	10.885	0.648	00000	11.533	0.000	00000	11.533	0.000	01.123
3191	10.420	00225	10.420	0.005	11.199	0.041	00049	11.240	0.001	00000	11.240	0.000	00.821
3192	10.460	00615	10.460	0.015	11.555	0.096	00000	11.651	0.000	00000	11.651	0.000	01.191
3193	10.490	00985	10.490	0.024	11.262	0.062	10689	11.324	0.352	00978	11.324	0.081	01.186
3196	10.550	00750	10.550	0.018	11.673	0.059	01941	11.732	0.064	00000	11.732	0.000	01.246
3185	10.610	02450	10.610	0.061	11.346	0.066	09826	11.412	0.324	00000	11.412	0.000	01.126
3211	10.830	00280	10.830	0.006	11.754	1.044	02586	12.798	0.085	00000	12.798	0.000	02.053
3209	11.000	00470	11.000	0.011	11.434	0.003	00455	11.677	0.015	00000	11.437	0.000	00.692

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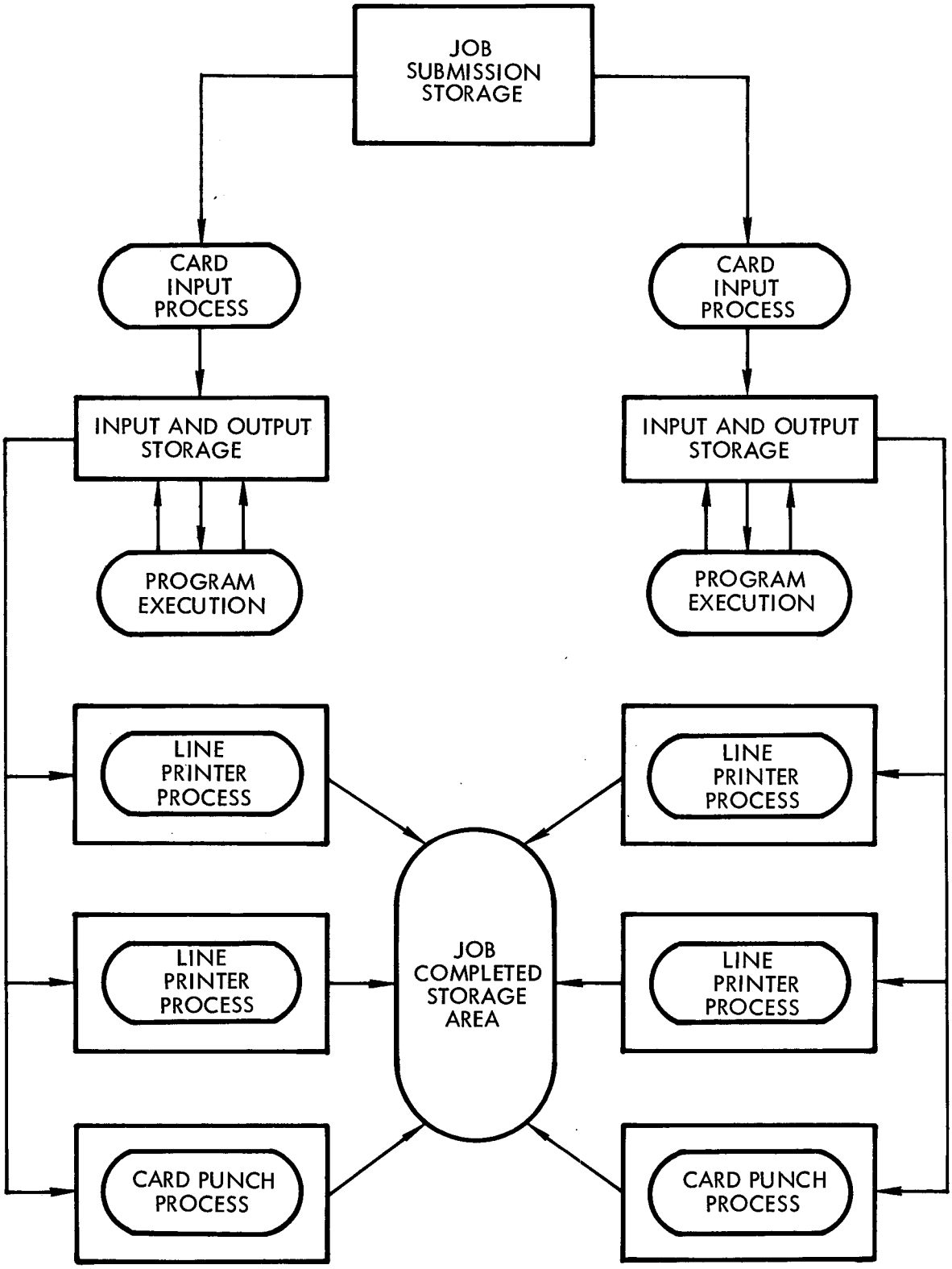
SYSTEM SIMULATION PROGRAM - DETAIL JOB PROCESSING

SEQ	SUBM. TIME	NO. CARDS	READER START	ELAPS. TIME	7090 START	ELAPS. TIME	NO. LINES	PRINT START	ELAPS. TIME	NO. CARDS	PUNCH START	ELAPS. TIME	TURNOVER TIME

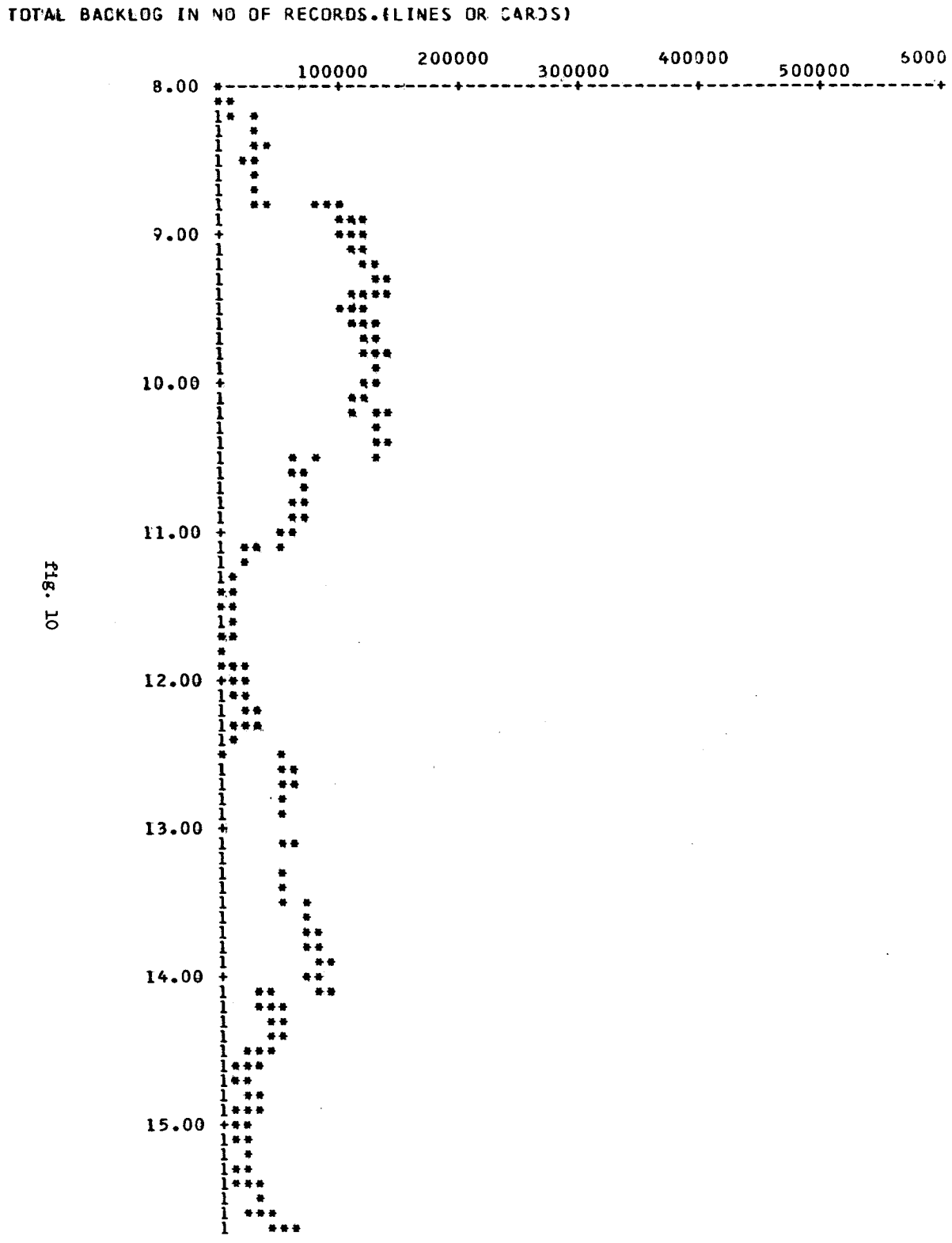
	READER			7090			PRINTER			PUNCH			AVE TURN	UTIL.	TUR
DELAY	SETUP	USAGE	DELAY	SETUP	USAGE	DELAY	SETUP	USAGE	DELAY	SETUP	USAGE	TIME/JOB	RATIO	MAX
24.970	00.105	05.874	02.243	06.890	28.116	40.953	00.140	34.588	35.069	00.020	02.163	01.036	.204	06.60

System Simulation Program-Detail Job Processing

Figure 8

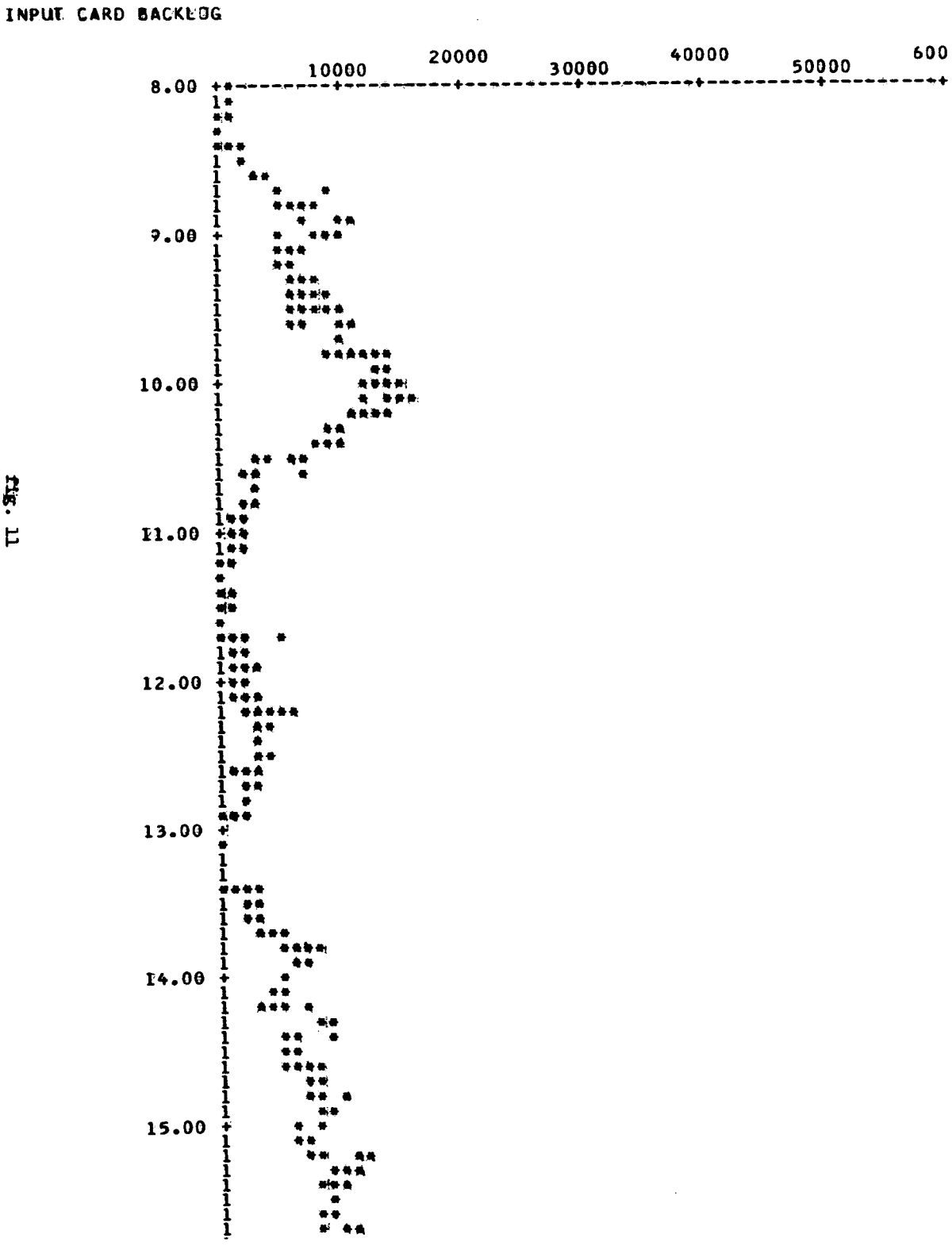


Sample System Under Simulation
Figure 9

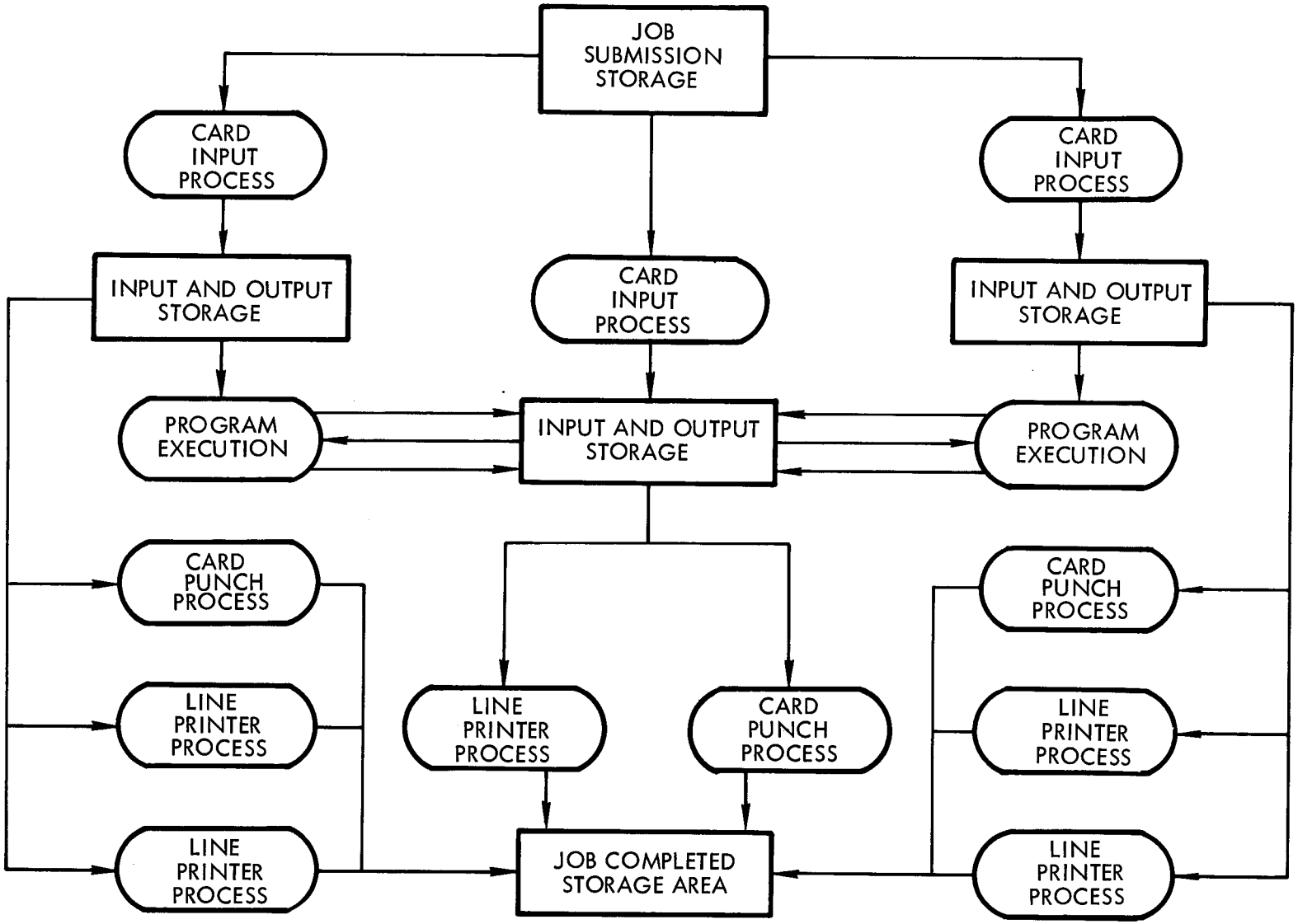


Total Backlog in Number of Records

Figure 10

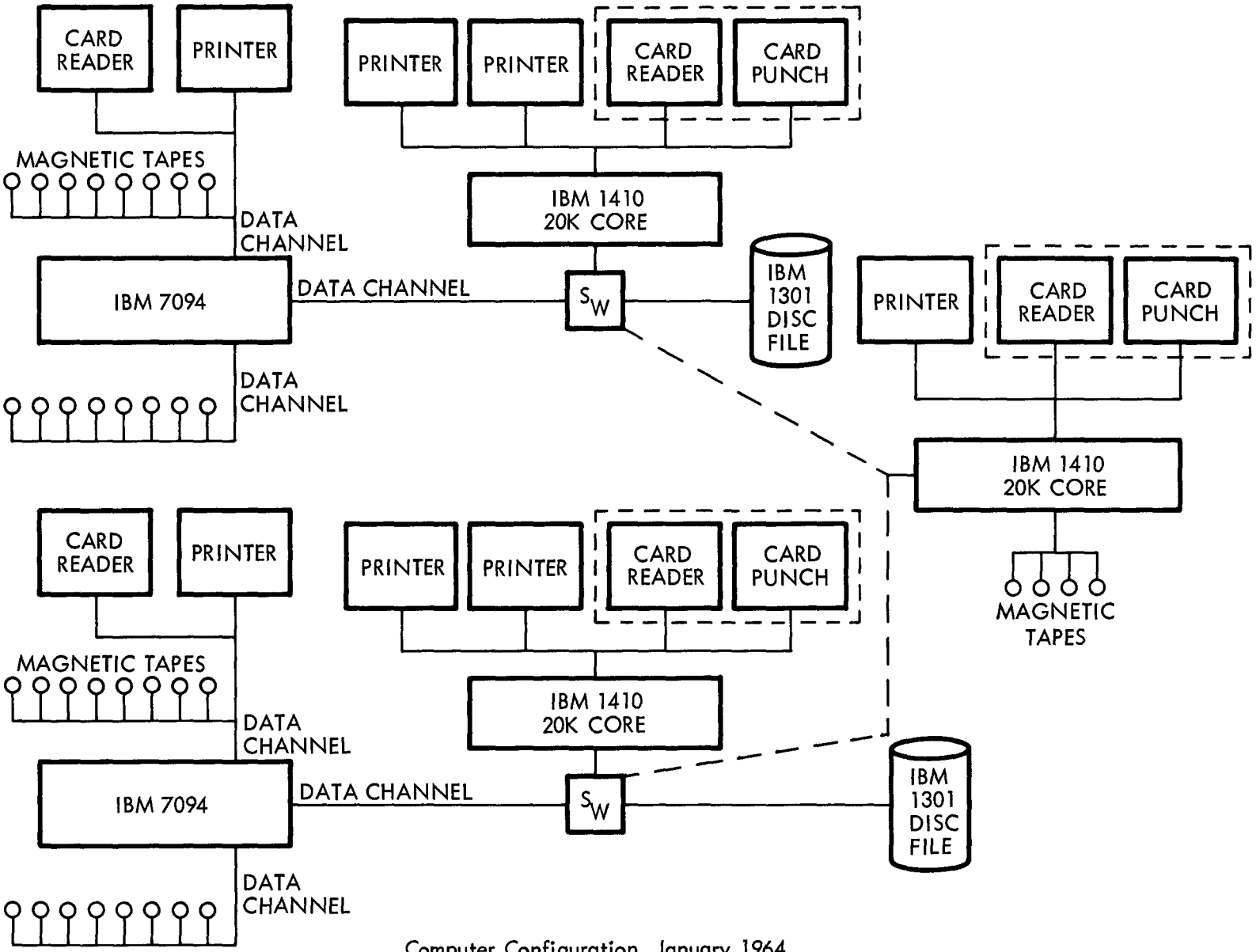


Input Card Backlog
Figure 11



Simulation Schematic of Current Configuration

Figure 12



Computer Configuration January 1964

Figure 13

```
SEQUENCE NUMBER 3840        LAZAAR,N.......        PROBLEM NUMBER A62d-01
PRIORITY 3  MAXIMUM TIMES TRANS. AND EXEC.   4.0 DEBUG        TOTAL   4.0
TAPE  TYPE    NUMBER PROCESS      FORMAT    PASSES FORM IMPRINT SYMBOL
A1  RING OUT   130                                              05
A4  RING OUT  2655                                              06
A5  UTILITY                                                     13
A7  RING OUT  2308                                              08
A8  RING OUT  4393                                              07
B4  UTILITY                                                     14
B5  UTILITY                                                     04
B6  UTILITY                                                     11
OPERATOR REPORT   NO APPARENT TROUBLE   PROGRAM STOP   READ/WRITE SELECT
                    STR 0 EXECUTED     MAXIMUM TIME      STR 0 NO GO
                 INSTRUCTION COUNTER       LOOP            SKIPPED
SEQUENCE NUMBER 3994        HOMER,S........        PROBLEM NUMBER A097-01
PRIORITY 1  MAXIMUM TIMES TRANS. AND EXEC.  15.0 DEBUG        TOTAL  15.0
TAPE  TYPE    NUMBER PROCESS      FORMAT    PASSES FORM IMPRINT SYMBOL
A1    SAVE          CALCOMP  NO. 00 BLACK    1     A           A1
A4    SAVE          CALCOMP  NO. 00 BLACK    1     A           A2
B6  RING OUT  6202                                              B1
OPERATOR REPORT   NO APPARENT TROUBLE   PROGRAM STOP   READ/WRITE SELECT
                    STR 0 EXECUTED     MAXIMUM TIME      STR 0 NO GO
                 INSTRUCTION COUNTER       LOOP            SKIPPED
```

7094 Job Sheet

Figure 14

```
I QTRACKS
R PERCENT DISK SPACE AVAILABLE =  43
I JPRIORITY59451S
R 5945 CHANGED 1455 Ø22964
I QSTATUS5943
R SEQ NO 5943 7Ø9X SCHEDULED
I SREMOVEP2
R P2 REMOVED 1455 Ø22964
I SADDP2
R P2 ADDED 1455 Ø22964
I SREMOVEP4
R P4 REMOVED 1455 Ø22964
I SADDP4
R P4 ADDED 1455 Ø22964
I QJIB
I QJOBS
```

1410 Inquiry Commands

Figure 15a

JOB INFORMATION BLOCK (JIB)

SYSTEM 1 TIME 1713 DATE 022964

SEQ NO	NAME	PRIORITY	STATUS	ESTIMATED 709X TIME WAITING	STARTED	COMPLETE	OUTPUT WAITING NO LINES	NO CARDS	SEQ NO
5889	L.HEUREUX,O....	2	OUTPUT STARTED	0.	0.	8.0	24744		5889
6010	KINCAID,D.....	7	INPUT COMPLETE	21.0	0.	0.	0	0	6010
5891	SCAIEF,J.....	2	OUTPUT STARTED	0.	0.	6.5	6539		5891
6013	DOOLEY,W.....	2	INPUT COMPLETE	20.5	0.	0.	0	0	6013
5866	KINCAID,D.....	7	INPUT COMPLETE	21.0	0.	0.	0	0	5866
5950	L.HEUREUX,O....	2	OUTPUT STARTED	0.	0.	8.0	24748		5950
5885	MEYER,F.....	7	INPUT COMPLETE	7.0	0.	0.	0	0	5885
5922	DRAKE,S.....	3	OUTPUT STARTED	0.	0.	3.0	6871	129	5922
5937	DOWNS,R.....	3	INPUT COMPLETE	3.0	0.	0.	0	0	5937
5613	JACKSON,D.....	3	OUTPUT STARTED	0.	0.	3.0	1609	218	5613
6009	HARDISTY,J.....	4	INPUT COMPLETE	6.0	0.	0.	0	0	6009
5946	SCANTLIN,L.....	3	INPUT COMPLETE	3.0	0.	0.	0	0	5946
5952	DEALY,J.....	3	INPUT COMPLETE	3.0	0.	0.	0	0	5952
5894	JEPSEN,P.....	4	INPUT COMPLETE	6.0	0.	0.	0	0	5894
5931	SCHLUTER,R.....	3	INPUT COMPLETE	3.0	0.	0.	0	0	5931
5612	JACKSON,D.....	3	OUTPUT STARTED	0.	0.	3.0	1764	214	5612
5692	DOWNS,R.....	4	INPUT COMPLETE	4.0	0.	0.	0	0	5692
5924	SCANTLIN,L.....	4	INPUT COMPLETE	6.0	0.	0.	0	0	5924
5892	SCANTLIN,L.....	4	INPUT COMPLETE	6.0	0.	0.	0	0	5892
5942	TRAWEEK,B.....	4	INPUT COMPLETE	6.0	0.	0.	0	0	5942
5930	SCHLUTER,R.....	4	INPUT COMPLETE	6.0	0.	0.	0	0	5930
5783	SAHS,V.....	3	OUTPUT STARTED	0.	0.	3.0	303		5783
6020	DOWNS,R.....	3	INPUT COMPLETE	3.0	0.	0.	0	0	6020

JIB TOTALS

WAITING STATUS NO JOBS	EST TIME	709X SCHEDULED NO JOBS	EST TIME	OUTPUT STATUS NO JOBS	NO LINES	NO JOBS	NO CARDS
16	124.5			7	66578	3	561

Job Information Block
Figure15b

ACTIVE JOB STATUS

SYSTEM 1 TIME 1713 DATE 022964

SEQ NO	709X PROCESS	PRINTING	PUNCHING	JOB STATUS	SEQ NO
5945				COMPLETE	5945
5963				COMPLETE	5963
5944				COMPLETE	5944
5930	WAITING				5930
5943				COMPLETE	5943
5942	WAITING				5942
5892	WAITING				5892
5924	WAITING				5924
5692	WAITING				5692
5697				COMPLETE	5697
5612	COMPLETE		COMPLETE		5612
5931	WAITING				5931
5894	WAITING				5894
5929				COMPLETE	5929
5613	COMPLETE		COMPLETE		5613
5937	WAITING				5937
5922	COMPLETE	STARTED	COMPLETE		5922
5590				COMPLETE	5590
5441				COMPLETE	5441
5923				COMPLETE	5923
5907				COMPLETE	5907
5442				COMPLETE	5442
6013	WAITING				6013
5866	WAITING				5866
6020	WAITING				6020
5891	COMPLETE	STARTED	COMPLETE		5891
5889	COMPLETE	STARTED	COMPLETE		5889
6010	WAITING				6010
5888				COMPLETE	5888
5885	WAITING				5885
6009	WAITING				6009
5975				COMPLETE	5975
5783	COMPLETE		COMPLETE		5783
5973				COMPLETE	5973
5972				COMPLETE	5972
6007				COMPLETE	6007
5971				COMPLETE	5971
5969				COMPLETE	5969
5913				COMPLETE	5913
5968				COMPLETE	5968
5952	WAITING				5952
5946	WAITING				5946
5770				COMPLETE	5770
5949				COMPLETE	5949
5966				COMPLETE	5966
5950	COMPLETE	STARTED	COMPLETE		5950
5967				COMPLETE	5967
5951				COMPLETE	5951

TOTALS	INPUT COMPLETE	16
	PROCESSING STARTED	
	PROCESSING COMPLETE	7
	JOB COMPLETE	25

Active Job Status
Figure 15c