The management of a large commercial computer bureau

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This paper is based on the experience of managing the English Electric—LEO–Marconi London Bureau and particular examples are taken from the operation of LEO III, although the principles can be applied to computers for both scientific and commercial work generally.

Introduction

This paper is concerned with the problems of managing a large scale Commercial Computer Bureau. It must be emphasized that this, in particular, relates to experience gained on one of the Company's Service Bureau Centres where the problems are not entirely typical of a general large Commercial Computer Bureau. However, there is much which is in common with other Bureaux and the principal lessons to be learnt can be applied generally. Again the particular reference is to a Commercial Bureau although it is held that this should apply generally to computers which are used for either scientific or commercial work. This is particularly important with the larger and faster computers now available and where computers are being used on a time-sharing basis. In these circumstances rigorous discipline is necessary for the computer to be used to its greatest advantage and for programmers to be able to use a computer with a minimum of restrictions.

Background

It is appropriate that one should see the background around which this paper has been written which is that of the LEO Computer Bureau in London. This refers primarily to the operation of the LEO III computer although the Bureau is combined with four other computers to provide a fully self-contained computing organization. This organization contains Consultancy, Programming, Data Preparation, Job Installation and Operating sections. More is said later about those sections which affect the operation of the Bureau.

The range of jobs processed on the Bureau includes Payroll, Sales Analysis, Invoicing, Stock Control, Production Control, Production Breakdowns, Material Scheduling, Insurance Scheme Valuations, Stock Exchange Accounting for Brokers and Jobbers, Share Registration and a variety of Mathematical and Management Science applications for Customers associated with the Stock Exchange, Banking, Insurance, Building, Steel, Engineering and the Fashion, Food, Fruit, Fur, Motor, Petroleum, Photographic, Printing, Radio, Record and Wine and Spirit Trades.

Apart from the background of the Bureau, experience gained from contact with the Company's Computer Users has also been drawn on.

The Company has been operating a Computer Bureau for over thirteen years, and whilst the equipment has changed radically over this period the fundamental principles involved in the efficient operation of a Computer Bureau remain very much the same although the faster and more powerful equipment makes increased efficiency more necessary and more possible to achieve.

Activities

The Bureau as a whole is broken down into several sections:

(i) Consultancy prepares systems plans, keeps in contact with existing customers and ensures that the customers' best interests are represented.

(ii) Programming specifies and programs jobs and passes them through trials.

(iii) Job Installation is concerned with the special problems of installing jobs on the computer which include the problems of training customers to prepare the data and to interpret the results, operator initiation and, where necessary, special problems concerned with "take-on" and the setting up of initial records.

(iv) Data Preparation is concerned with transcribing data from documents or Kimball Tags to paper tape, punched cards, etc., including the use of the LECTOR Document Reader.

(v) Operating provides an operating service for all users of the computer. In principle no Programmers touch the computer. Work done includes operational service work, trials for service work, trials for computer Customers, operational work for computer customers before the installation of their own computer, trials of software and the training of operators.

Objectives

The main objective is to run the Bureau on a commercial basis and this can be achieved by ensuring that the Customer receives the best possible service. The service is assessed directly by the accuracy and quality of the results and the time when they are received. To receive these results, programs must be prepared and tested to enable Operators to be able to produce the correct results and also, more important, to know when they have not produced the correct results. The Customer must provide the correct data and the Bureau must ensure that the Customer knows how to prepare the data in the form required.

It is also imperative that the Bureau knows as soon as possible that the Customer is not receiving the service he expects, so that appropriate action can be taken.

The key to the successful management of a computer is standardisation of procedures combined with a comprehensive control on performance. With these two points constantly in mind the Bureau Manager will go a long way towards running a highly efficient Computer Bureau.

A further point to bear in mind is that the emphasis of management to make an economic operation of running a Bureau must be concentrated on producing output. An analysis of the cost of running a Bureau for shift working

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shows that only a small proportion of the expense is directly controllable by the Bureau Manager. In general it is a false economy to understaff an installation provided there is sufficient work available to be processed. The emphasis should always be on increasing the yield.

It is difficult to provide a full balanced load for a computer since peaks of activity will occur either weekly (for example Payroll tends to peak at the beginning of the week), or periodically (for example Statements and Statistics in an Invoicing application). Off-peak time can sometimes be filled by offering a cut price rate. The Computer Manager must plan the total work load so that he can cover the peaks and at the same time have work of a non-urgent nature available as a Base Load to fill any spare capacity. Throughout, a contingency must be allowed to cover unexpected eventualities.

Outline of problems

The major problem for the Computer Manager is to ensure that adequate control is maintained on the operation of the Bureau.

Communication is one of the Computer Manager's big headaches. If the computer is running on a 4-shift basis, 24 hours a day, seven days a week, the Computer Manager is likely only to be in contact with his operators for 25% of the operational time of the computer. Furthermore, there are the problems of one shift handing over the control of the computer to the following shift. The second Shift Leader, in turn, hands over to the third, and consequently there is no direct first-hand link between shifts. This of course means that careful steps must be taken to ensure that everyone knows what work is to be done, that the work done is fully documented, that a new shift is fully aware of any outstanding work and that the Computer Manager can easily get a clear understanding of the situation which has ensued during the previous period when he was away. All this requires careful documentation and training for the operators to work together as a team.

At the same time it is important that an accurate analysis is made so that the Computer Manager can see precisely how the computer is being used by the operators. The basic data on LEO III for producing this analysis is the computer log which is produced automatically on a logging printer. To provide the operators with a stimulus for improving their own performance each Shift Leader, before he goes home at the end of his shift, analyses the overall performance of the computer during his particular shift and provides data which is subsequently used by a program to analyse the log in detail. This is summarized for each 24-hour period for the Computer Manager to see, and summarized each week for the Bureau Manager and other interested parties to see. One week's performance in itself is not necessarily very indicative but it is important to watch for the trend to ensure that the overall operating performance of the computer is not declining. At the same time the Computer Manager can arrange for specific studies or more detailed analyses to be taken on certain aspects where increased time has been taken.

Analysis of operating performance is only one aspect of control which the Computer Manager requires. One further aspect is that of data preparation where it has been shown that careful analysis can help in many directions both to improve the performance of individual teams, to highlight teams which need further training and to highlight particular data forms which present difficulties in respect of slow perforating rate or, alternatively, high error rate. Situations have arisen where a redesign of forms has led to a reduced error rate and an improved perforating rate. The matter of data preparation analysis is also important when data is not being produced under the control of the Bureau Manager. It is often only when data, especially when produced as a by-product operation, reaches the computer that the punching can be checked. The computer is then used to indicate whether the equipment is punching tape capable of being accurately read by the computer. The computer can indicate machines which may need adjustment, maintenance or alternatively machines which have been operated by operators who require further training. It is important that in these circumstances a regular report is made to the Data Preparation Units so that the Unit Supervisors can see the performance of their teams, improve the weak teams and, where appropriate, praise the good ones.

The engineering performance of the computer will normally be analysed by the maintenance engineers. The Computer Manager should study these reports and discuss the details and implications with the engineers.

Standardization of procedures

To achieve the maximum efficiency of work on a Bureau it is desirable to impose a rigid discipline on the operation and types of programs which are processed on the computer.

The Service Programming Section is under the control of the Bureau Manager, but other work is processed for customers who are conducting trials prior to delivery of their own computers and processing operational work for customers who will ultimately be taking their work on to their own computer. Whilst customers are encouraged to follow the regime adopted by the Bureau, their own particular requirements may not make this practical.

If a computer is operated, full time, on one type of job it can be operated with a higher degree of accuracy and efficiency than when many types of jobs are operated. It is therefore desirable to minimize the number of different types of job which are put on to a computer.

It has been found practical to have four basic types of jobs as follows:

(i) *Data Vetting* which reads data from paper tape, or punched cards, edits the data for consistency and carries it forward on magnetic tape. Reports can either be printed "On-Line" or included, as special blocks, on the output tape for subsequent printing.

(ii) *Sorting* which reads in one or more magnetic tapes sequentially and sorts the data to a single order. Where necessary the output may be split on to two or more tapes.

(iii) *File Processing* which reads two magnetic tapes, one containing current data, the other a brought-forward record, updates the record and writes two or three output tapes, one a carry-forward record and the others result tapes.

(iv) *Printing* which is a standard program and prints information from magnetic tape.

At its simplest operators need only to know of these four types of programs, and all programs of each type can, operationally, be made to appear the same.

Each type of program uses only a specified part of the computer's store and input and output equipment. This enables "time-sharable" programs to be scheduled more easily. The division of the computer into parts for processing different types of programs is called "streaming".

In some instances this aim is not achieved or it is sometimes better, overall, to use the whole store for an analysis, say, rather than add a sort as an extra program. In such instances one may adopt the expedient method although there is more to be gained overall by standardization rather than by extreme efficiency on one program.

Standardization must start at the planning stage. Provided one has a standard which is accepted by all concerned (i.e. Programming, Data Preparation and Operating) there is no need for anyone other than programmers to be concerned with the basic planning of a job. Any jobs which cannot be planned on these lines must necessarily be referred to others for approval. In the end it is the service provided to the customer which is the yardstick by which the success or otherwise of a job is measured. Data Preparation and Operating are required to produce these results, and it is important that they are given the opportunity of approving proposals. If a system fails to produce the correct results due to loose control or bad organization, the criticism falls on the computer and its operators.

Programming

This paper is primarily concerned with the problems of operating. However, the preparation of a program must take certain operating requirements into consideration. It is important that the operating system devised for the computer does take full account of these requirements and that the necessary features which the programmers are required to include in their programs are provided with the minimum of inconvenience to the programmer. This is especially true for the scientific programmer who, although primarily a Scientist, may be using the computer to help him calculate results. The scientific programmer, in particular, is not going to be interested in operating conventions, therefore operating requirements and the code which he is asked to obey must be as simple and straightforward as possible.

In LEO III all checks on data and result files, and error recovery routines to overcome trouble caused, for example, by a speck of dirt on magnetic tape, are provided automatically for the programmer. All the programmer writes in his program is "Read" and a block which the computer has checked to have been read correctly is made available to him. Initially he must "Open" the file with a single instruction; at the end of the program he must "Close" the file. All other operating controls are automatically built in for him by the compilers. This is not too much to ask any programmer to provide in his programs. Software routines of this nature should be provided automatically so that the programmer, unconsciously, provides the standard control which the operator requires.

For a job to be installed and maintained successfully on a computer it is necessary to have a full specification which sets out, in detail, what the job is required to do. The specification must be agreed by the customer as being a statement of what he requires to be done, and can be used by the programmer to know what has to be coded into the programs. For the specification to be of value it must be kept up to date at all times, not only during the initial writing of the job but also, possibly years later, when a change is made to the requirements.

The specification is only one of several documents which are required to complete the documentation for a job. Flowcharts, coding sheets and layouts are equally important and again, unless they are kept up to date, they are of little value. The situation commonly arises that whilst a program is undergoing trials the programmer working on the job can retain in his mind the complete details of changes being made; the test comes in six months' time, or more, when he, or more probably a programmer quite new to the job, is asked to make a change to a program; it is then that complete and up to date documentation repays the initial effort expanded in preparing it and keeping it up to date.

A further vital part played by the programmer in the operation of the computer is in the provision of comprehensive trial data to test all aspects and facilities of every program. Equally as important as the data are the pre-calculated results for comparison with the results produced by the computer. Unfortunately it is seldom practical to construct trial data which will test every conceivable combination of data. However, the provision of a comprehensive set of trial data is essential not only to prove the programs initially but, more important, when one is making amendments to operational programs. It is comparatively straightforward to ensure that an amendment has been effected—what is very much more difficult to ensure is that nothing has been changed which should not have been changed. It is in these circumstances that trial data proves its worth.

Trial data must be constantly kept up to date to be of value. The initial set should include both elementary cases and complicated circumstances—one must "torture the data" to test the program. As new complications are revealed and changes are made to the requirements the trial data must be amended to incorporate these additional situations. Whenever a program is amended the test must be run and a full comparison made with the pre-calculated results before the new version of the program is used for operational work.

Job installation

The nature of the jobs put on to a computer some eight to ten years ago was such that the senior programmer in charge of a job could control all aspects of it; he could specify the job, create the specification with the customer, supervise programs, prepare data forms, prepare printed stationery, organise take-on and progress trials, etc. With the advent of magnetic-tape computers it became apparent that the problem of installing a job was very much more complicated and often entailed the preparation of considerable volumes of data to set up customer records, etc. This in itself entailed much training for the completion of data forms and the scrutiny and checking of "take-on" and it was found necessary to have a separate specialist section to deal with this aspect of the work.

At the same time this Job Installation Section was given the task of ensuring that programs are prepared in an "operable state." There is the situation that the Programmer can quite simply write a program which will read five million cards. It is quite impracticable, however, for an Operator to operate such a program and to produce the correct result; it is necessary to have restart points where operators can break off to process other urgent work, or alternatively where they can restart having encountered trouble. It must also be possible to maintain adequate control.

Throughout, the policy is to keep the number of program stoppages to a minimum; there are seldom more than three possible stoppage points in a program.

Only operators operate the computer, although in practice an exception is made for software programmers who conduct their own trials. This has been found necessary due to the time when trials are done, often overnight, and an experienced operator is required to operate the computer to achieve any

degree of efficiency. The potential danger of this approach is, of course, that programmers are insufficiently aware of operating practice and to overcome this it is necessary to have a code of practice which can be followed to provide this practical balance.

The Job Installation Section is responsible for ensuring:

(i) That all jobs have adequate inter-program control.
(ii) That comprehensive reconciliation accounts are included.
(iii) That adequate steps are provided for re-submitting rejected data.
(iv) That adequate restart facilities are provided.
(v) That provision is made for the programs to be operated to a practical schedule.
(vi) That operating instructions are prepared.

The section also ensures that the customer understands what data he is expected to prepare, and the significance of controls. Whilst the customer will understand the main results from a job there is the danger that the exception reports, which often require careful attention and can cause significant inaccuracies if they are ignored, tend to be overlooked. It is considered most important that close attention should be paid to this aspect, especially during the initial runs, since a critical investigation of the reports can reveal weaknesses in the system which, by appropriate action, can be overcome.

It has been said that programmers do not operate the machine and operators only operate standard types of programs. Program trials are processed on the computer although programmers prepare the initial control sheets for the operators which give file details and post mortem requirements. Later on in the preparation of a suite when trials are taking place to check the linking together of programs, the Job Installation Section pay particular attention to possible operational snags and participate closely with the customer in the preparation of the data and in the interpretation and checking of the results.

After the initial runs when a system has settled in, it is appropriate to review the situation. Inevitably a scheme planned in abstract can be improved when practical experience has been gained.

During the formative stages of a job it is necessary to have periodic progress meetings when all interested parties meet together to review the situation. Job Installation tends to be at the head of these activities, although the Bureau Manager conducts the meetings. A standard agenda for these progress meetings is given in Fig. 1.

1. *Deadlines* What undertakings have been given, what plans have been made for take-on, parallel running and live running?	Programming
2. *State of the Programs* A report on the state of each program—charted, coded, checked, trial data prepared, under trial, working on trial data, linked trials?	Programming
3. *Job Installation* Organization of job, operating instructions, data preparation instructions, training of customer, stationery design and ordering?	Job Installation
4. *Operating* Organization of job turn-round schedules, state of data, operability of job, scrutiny of results?	Operating

(An organization chart should be available, preferably drawn on a blackboard.)

Fig. 1.—Standard agenda for job progress meetings

Data vetting

The first operation on reading data into the computer is to vet it for consistency. The object of this operation is to ensure that only data which the job has been specified to process is accepted. Any data which fails the data vetting tests must be rejected and a report printed to enable an investigation to show what information was submitted to the computer, to locate the document that the information comes from, to establish and resubmit the correct information and to analyse the reason for the rejection.

This ensures that in subsequent programs which may use the data no stoppages need occur, although in practice the data may later be rejected (for example, an item valid within the item number range may in fact not be in the catalogue).

The Bureau has adopted a general solution to data vetting, which is based on three basic types of forms, with standard reporting procedures and facilities for re-submitting corrected data. With these facilities there are additional benefits to be derived from the data vetting process, namely:

(i) Random data can be formed up for presentation to a standard sort program.
(ii) Corrections can be submitted before the main run without re-reading all the data.
(iii) The data vetting load can be split into conveniently sized runs to provide a steady flow of work.

Data preparation

The results produced will be no more accurate than the data. It is therefore imperative to take great care over the preparation of data. In a large Bureau there is likely to be a great volume of data and it is necessary to ensure that adequate control is maintained so that all data is read once and only once.

LEO III uses a system of *control sentinels* which uniquely and positively identify the start and finish of each reel or set of data. The data for a run to be fed on one channel is referred to as a *file* and the data for a particular run is uniquely identified by the Program Number, File Number and Run Serial Number. This identity is associated with the Heading Sentinel of each reel which also contains a Reel Serial Number. The End Sentinel either specifies the end of file or that a continuation reel exists. The Control Program automatically reads and checks the sequence of reels from the sentinel blocks and thereby ensures that all data is read once and only once. This sentinel control is carried out quite independently of the program which is reading the data.

Sentinels are provided with the data by completing special data forms which are attached, by the customer, to the front and back of each set of data. In this way data is received into the Bureau already batched and with sentinels; control is thereby automatically maintained on the data.

Operating structure

Functions of the Operating Section can be divided into:

(i) Those tasks which must be performed by the computer operator and
(ii) those tasks which can be performed for him.

Any action taken by the operator is potentially a loss of computing time since any human action is slow compared with the speed of the computer. Operator intervention must be reduced to a minimum to obtain the maximum efficient use of the computer. The basis on which the operating system is founded is therefore to distinguish between "On-Line" tasks which must be performed by the computer operator and "off-line" tasks. The object is to reduce, to simplify and to standardize all tasks as much as possible.

The main functions of the Operating Section are:

(i) To prepare jobs for the computer, gathering together data and information required for each computer run; this is known as Job Assembly and is performed off-line.
(ii) To determine the order in which jobs are submitted to the computer; this is known as Scheduling and is performed off-line normally by the Operator in Charge.
(iii) To process data and produce results on the computer; this is the on-line work.
(iv) To check that the computer run has taken the expected course, to investigate the circumstances by which runs have not been completed and to up-date records for use in future runs; this is known as Job Disassembly and is performed off-line.
(v) To check and dispatch results and maintain records required by management for the control and analysis of performance; this is performed off-line.

The number of operators required to operate on this basis will vary considerably according to the size of the computer and the volume and type of work being processed. A minimum would be two operators, an On-Line Controller and Off-Line Controller; a maximum can involve twelve Operators where multiple time-sharing is in operation.

Computer layout

There are several factors which need to be taken into consideration when planning the layout of a computer site. Provision must be made for the computer room which constitutes the On-Line Area, for the Off-Line Area and for a Maintenance Area. The Off-Line Area should be convenient for the receipt of data and for the dispatch of results. The need for adequate space to be set aside for the Off-Line Area cannot be over-emphasized, and the facilities provided in this area can add much to the efficient operation of the computer.

The actual layout of the equipment on the computer floor needs to fulfil certain requirements for ease of operation. The computer is normally operated from the control desk and the operator, whilst sitting at the control desk, should be able to see the various items of peripheral equipment in operation. This means that he should have all items of peripheral equipment, magnetic-tape decks, tape readers, printers, etc., within his line of vision. The input equipment should be adjacent to the Off-Line Area so that the data can be conveniently transferred on to the computer floor. Likewise the printer should be adjacent to the Off-Line Area so that results can be immediately carried off the computer floor. The magnetic-tape library which may either be in the computer room or in a separate room should be convenient to the magnetic-tape decks. Adequate space is required for working surfaces to simplify operation. Throughout there should be adequate space left for possible expansion even when no extra equipment is envisaged within the near future.

Work flow

To see how the operational work flows through the Bureau it is appropriate to consider the different stages in the production of a computer run. At each of these stages time can be lost and mistakes can occur.

(i) The data arrives from the customer and is booked into the Bureau to a scheduled time, and if the data has to be prepared before input to the computer it is important that sufficient time is allowed in the schedule. This applies particularly when the volume may fluctuate; it is most helpful to the Data Preparation Section if details of any abnormal data volumes are communicated to them as soon as possible so that work schedules can be adjusted accordingly.
(ii) *Data Preparation* which has already been discussed.
(iii) *Job Assembly* in the Off-Line Area of the computer room includes the receipt of data, obtaining brought-forward file details from the library records, the provision of preprinted stationery for results, obtaining relevant operating instructions and preparing control sheets and data for the use of the on-line operators. Job Assembly must be arranged so that a convenient head of data is constantly available for the on-line operators and at the same time sufficient time must be provided for the job to be completed and checked, with a margin allowed for the correction of any errors, before the scheduled deadline.
(iv) *The On-Line Operation* of the computer is controlled by the On-Line Controller who directs the loading of programs, data and stationery. He sits at the operating console and deals with any abnormalities which are revealed during the run. The On-Line Operators' prime responsibility is to keep work flowing through the computer. Any circumstances which cause the computer to stop processing the job will lead to the operator immediately abandoning the computer run for off-line investigation and correction. The computer will continue processing with the next job assembled ready for operation.
(v) *Job Disassembly.* When a run has been completed and unloaded all data and results are taken off-line and checked for completeness. All the results must be scrutinized for such things as clarity of printout, particular reports which require the attention of operators, and completeness of results. Manual records for magnetic-tape files must be updated, and the results are then ready for dispatch.
(vi) *Results Dispatch.* With the operation of the computer on a round the clock basis the Shift Leaders must be responsible for the dispatch of results produced during their shift. It is not practical for operators to know everything about all jobs and it is consequently necessary for clear and precise operating instructions to be provided for them so that they can know a job has been completed correctly and know what they are required to do with the results produced.

The flow of work through the Bureau is shown diagrammatically in Fig. 2.

Scheduling

For a computer to be operated efficiently work must be carefully scheduled. Scheduling is planning in detail the loading of the computer from the overall work list of jobs which are required to be processed. The amount of work

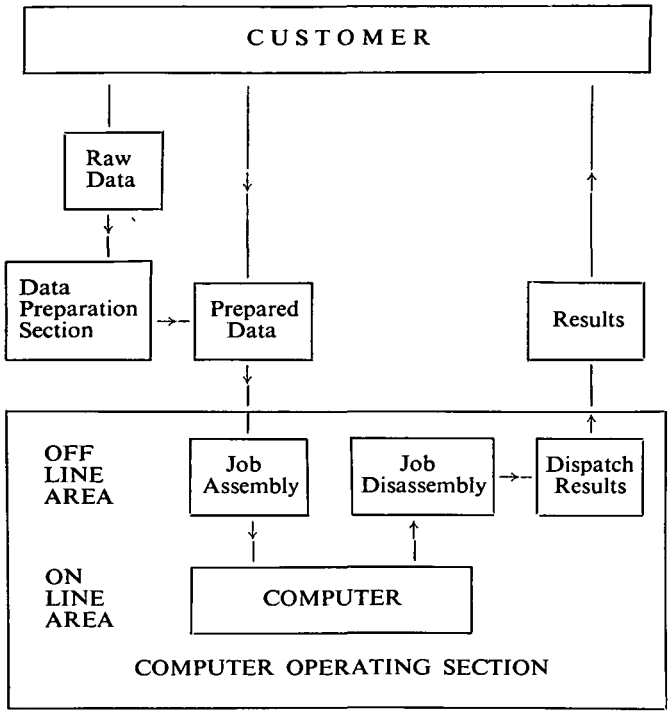

Fig. 2.—Flow of work through the Bureau

involved in scheduling will vary considerably from one installation to another. On an installation with a small number of jobs available at any one time there may be little more to do than to expand the work list into a list of programs to be run. On an installation with a large number of jobs considerable saving in time can be achieved by planning the order of the work with proper consideration for time-sharing and the use of equipment to reduce job change-over times. The computer can be utilized more efficiently and scheduling made very much easier if a policy of "streaming" is adopted.

The main point which needs to be considered when preparing an operating schedule is the deadline time by which results must be ready for dispatch to the customers. The work list should show the time each job will take and a list of priorities indicating the importance of different jobs in case, for any reason, not all results can be produced by their required time. It is often convenient between the different program runs of a suite to check rejection reports and if necessary to make resubmissions before continuing with processing. Such considerations must be taken into account when preparing the schedule so that where there is an interruption in one suite, if necessary, alternative runs can be fitted in to make full use of the computer's facilities. The schedule requires to take account of items of peripheral equipment which are taken out of or put back into service so that the schedule can be rearranged to take account of all the equipment which is available. The expected running time of each program should be taken into consideration so that, particularly when time-sharing, the order of allocation of programs can be included in the plan.

Each program to be run can be placed in one of the following categories:

(i) *Processing to a "Deadline"* for work done on a regular basis, the data being supplied and the results being required at agreed times. Much of the routine commercial work will fall into this category. Also in this category are programs which, although run on an irregular basis, must be processed to produce results a specified time after the arrival of the data.

(ii) *Priority Processing* for work which must be done immediately the data is available. For this type of work the Computer Manager cannot make detailed arrangements until the data actually arrives.

(iii) *Base Load Processing* for work processed on a regular or irregular basis for which there is no critical deadline for the production of results. Program trials are included in this category.

It is common for an installation to commence work with a planned load of fixed regular work, probably of the "deadline" type. The Computer Manager can plan in advance the arrival of data and the intermediate steps necessary to complete the results on deadline. In addition it is likely that new programs will also be under test. The initial schedule will have to provide for the addition of future operational programs and for a base load of program trials.

As new programs are submitted for trials it is important that an efficient service is provided for the programmers. The assignment of a priority code by the person responsible for controlling trials can ensure that programs are automatically processed in the correct order of importance.

A whole series of operational runs and programs for testing have to be processed each day. "Deadline" work must be loaded on to the computer by a certain time if the results deadline is to be met. It has been found that the best way to handle these requirements is to schedule work in periods of about 40 minutes' computer time. A list of the programs to be run together with the corresponding control sheets, data and magnetic-tape lists for a period are assembled and passed on-line in one batch. Whilst one work period is being processed there should be a buffer of a further work period on-line and yet another being assembled. It is imperative that, once on-line, a work period is not altered otherwise considerable wasted time and confusion can result.

The order in which programs are run within a work period is decided off-line. On non-time-sharing computers there is little choice although time can be saved by considering the sequence of programs to reduce the number of magnetic tape changes and enable magnetic tape decks to be preloaded. On time-sharing computers the problems are more complex.

Jobs which require priority processing present special difficulties. It is clear that any program run which requires access to the computer as soon as data arrives is liable to disrupt a routine schedule. Jobs of this nature can best be dealt with by scheduling them as separate work periods which can be processed at the end of the current work period, or, when necessary, immediately by abandoning the current work period; this can be rescheduled whilst the priority work is being processed. On time-sharing computers and when the time of arrival is known at least 40 minutes in advance, sufficient store space and peripheral equipment can be set aside for the priority job throughout the whole work period and the priority job can be processed immediately the data arrives. This type of work inevitably leads, overall, to a loss in output.

The problem of scheduling is an ever changing one and the operator compiling the schedule must be prepared continually to adapt it to changing conditions.

Analysis of performance

With any operation connected with the computer it is important that the performance is controlled and assessed. If performance is to be improved, or even maintained, it is essential that all levels of Management and Staff alike are made aware of the quality of their work. If these steps are not taken the standard of performance will inevitably drop.

Performance analysis is required for:

(i) the submission of data
(ii) the preparation of data
(iii) the operation of the computer.

The processing of work cannot commence until the data has been received in the Bureau. It must be recognized that data can be late for a number of reasons. It is necessary to keep a record of the time when data is received, and this can be done as part of the booking-in process. This record must be analysed on a regular basis so that action can be taken to recognize data which persistently arrives late. An investigation can be made into the circumstances and, if necessary, the schedule changed.

An analysis should be made of all data preparation errors so that the incidence of them is recognized and adequate steps can be taken to improve the position. Data errors can be caused by one, or more, of four reasons:

(i) Malfunctioning of the data preparation equipment which will require the attention of a mechanic.
(ii) Misoperation by the operator who may require more control or training.
(iii) Malfunctioning of the computer reading equipment which may require the attention of an engineer.
(iv) Badly designed data forms or illegible writing.

It is important that the significance of each of these troubles is fully appreciated and that corrective action is taken as soon as possible. The details of all errors should be recorded on Data Fault Report Sheets which are analysed weekly.

As part of the control of the Data Preparation Section it is necessary to record for each job:

(i) The volume of data.
(ii) The time taken.
(iii) The operators concerned.
(iv) The actual machines used.
(v) The number of errors found on scrutiny.

This information is used to assess the Operator's performance, equipment performance, perforation rates and to assist in tracing errors to their source.

The analysis of the operating performance of the computer must take account of:

(i) Effective operational time, showing the time taken for each job.
(ii) Ineffective Time, i.e. operating time lost by:
  (*a*) Data faults.
  (*b*) On-line operating faults.
  (*c*) Off-line operating faults.
  (*d*) Program errors.
  (*e*) Computer faults.
  (*f*) Miscellaneous.
(iii) Unproductive time, i.e. time made available for:
  (*a*) Maintenance.
  (*b*) Training.
  (*c*) Scheduled idle time.

During operation, records must be kept which can be used to prepare these analyses. On LEO III the logging printer under the control of the Master program produces the main information; alternatively a manual log must be kept. In addition Fault Report Slips must be made out and give details of any unscheduled occurrences which can subsequently be used to assist in tracing the source of an error.

At any one time it is only practical to prepare the analysis under a limited number of heads. The actual description of the heads should be varied according to circumstances. Where a large amount of time is being logged under any one head it is necessary to split the headings into two or more parts to concentrate attention on specific causes.

It has been said that one week's analysis in itself is not necessarily indicative but the important thing to watch for is the trend. To some extent an experienced Computer Manager can anticipate changes in the analysis: with new operators the incidence of operating faults is likely to rise; similarly, in spite of all precautions, a new job will cause an increase in the time lost due to data faults and program errors.

These analyses should be produced at least each week for the benefit of the Computer and Bureau Managers.

It can also be of advantage if a simple weekly report is sent to each customer to show difficulties with the data, and if at the same time the customer reports on the quality of results received. It has been found that routine reporting of this nature invariably leads to a better service and a clearer understanding of each other's problems.

An analysis is also required for the performance of the individual jobs although it may be more practical to make this activity the responsibility of the customer rather than the Computer Manager since corrective action is very much in the hands of the customer. This analysis should show the significant volumes of data forms submitted, results produced and a breakdown of all reports. From this analysis the customer can see whether certain types of data forms are prone to being miscoded or whether specific action is necessary, possibly resulting in an amendment to the specification, to improve the performance.

Conclusion

This paper has shown some of the steps which can be taken to simplify the problems of managing a large Computer Bureau and how, with the adoption of standard procedures and a comprehensive analysis of performance, a Bureau can maintain an efficient service for its customers.

In many organizations a similar structure exists where the Computer Department provides a service for User Departments and the points covered can be generally applied to all computer installations whether the work is of a scientific or commercial nature.