Device Photolithography:

The Mask Shop Information System

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The Mask Shop Information System (MSIS) is a set of computer tasks which exist in a specially designed multi-programming environment within a PDP-9 computer, and which control the flow of jobs through the new mask-making facility. The main functions of MSIS are to accept job descriptions and to assign tasks and pass data to the various shop facilities so that these jobs can be efficiently processed. In addition, MSIS keeps statistics on the progress and problems of the shop and issues reports both periodically and upon demand.

I. INTRODUCTION

A computer-based information and control system, referred to as the Mask Shop Information System (MSIS), assists in running the Bell Telephone Laboratories mask-making facilities at Murray Hill, New Jersey, and Allentown, Pennsylvania. In the planning stage for the new mask-making facility, it was realized that the scheduling and processing information required for efficient control of the flow of jobs would be too complicated to handle with paper work. Furthermore, keeping track of the large number of glass plates passing through the facility would be a problem. Thus, it was decided to develop MSIS. Briefly, MSIS controls the entire mask-making facility and serves as a repository of information on the status of each job, the location of each plate, and the performance of the overall facility. The equipment that makes up the new facilities has been discussed elsewhere.[1–3]

The first part of this paper will deal with the functions performed by MSIS and how the system appears to the user; the second part will describe the organization of computer programs and data required to implement MSIS.

II. MSIS FUNCTIONS

The significance of MSIS can best be grasped by reviewing the various functions that are performed.

2.1 *Scheduling*

MSIS schedules each process step required to complete a mask. This scheduling is done on-line and allows for the inclusion of jobs of varying priority. As each task is completed by either a human operator or a machine, such as the primary pattern generator (PPG), MSIS determines the highest-priority task waiting and assigns it to the operator or machine that is idle.

2.2 *Control Information*

MSIS transmits control information over wide-band data links to the two control computers attached to the PPG and the step-and-repeat camera. For the PPG, this information indicates the magnetic tape reel number and the file number within that reel that contains the information describing the artwork to be generated next. For the step-and-repeat camera, the identification of the specific reticles needed to make a particular mask as well as the step-and-repeat array information is transmitted from MSIS to the control computer. Other control information is transmitted directly to human operators via special displays and teletypewriters.

2.3 *Information Storage*

MSIS maintains an extensive disc file containing information such as

(*i*) the status of every job in process,
(*ii*) performance statistics covering each process step as well as the overall mask-making facility,
(*iii*) inspection information required to define special mask features that should be inspected in detail, and
(*iv*) the step-and-repeat array information necessary to define a complete mask for silicon circuits.

2.4 *Glass-Plate Handling*

To avoid the confusion of human operators sorting through a mountain of glass plates to find a specific reticle, piece of artwork, or mask, MSIS assigns each piece of glass to a numbered slot within a numbered carrier. The location of each piece of glass is remembered so that when it is needed as the input to another process step, its exact location can be supplied to the operator.

2.5 *Inquiries and Reports*

MSIS will allow certain on-line inquiries to be made from a teletypewriter terminal. Some on-line inquiries might be:

(*i*) What is the status of my job?
(*ii*) What is the backlog of work for the reduction cameras?
(*iii*) How many pieces of artwork have been generated this shift?

In addition to these short on-line inquiries, more detailed management reports will be generated by MSIS on a daily, weekly, monthly, or quarterly basis. Certain of these management reports will also be available on demand.

III. USER/COMPUTER INTERFACE

There are two sets of users that must interface with MSIS. The first user is the engineer or designer who wishes to request that a particular set of masks be manufactured. The other is the mask-shop operator who must exchange information with the computer system while completing his job.

The engineer or designer will communicate his needs to MSIS by a set of instructions on punched cards that can be included in his XYMASK input deck or can be submitted separately with the post-processed XYMASK tape that is required. Figure 1 shows an example of these instructions for a typical set of masks for a silicon circuit. Both tantalum- and silicon-circuit masks can be handled with equal ease; but a silicon circuit is used in this example because in general it requires that more information be supplied.

The first two cards contain standard identifying information; an engineer might have a number of these cards duplicated to have when

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                JOB DESCRIPTION

ENGINEER   MH, 1112, B65420, J.H. GILMØRE X5023

CASE       39500-20

DEVICE     A1502, BEAM LEAD GATE

MASK       B850122-1-4, 2135, ARRAY-L2
         PATTERN  B413622-1-2, ART
         PATTERN  L100600-1-3
         PATTERN  L200501-1-2

MASK
 •
 •
 •
END
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Fig. 1—Job-description information.

needed. The third card identifies the circuit and is used primarily on reports for ease of identifying the jobs. A MASK card is included for each mask of the complete job. This MASK card contains the drawing-level-issue number of the particular mask and an optional process number. The process number will be imaged by the step-and-repeat camera onto the final mask for use during circuit fabrication. The final field on the MASK card indicates, in this case, that a prestored step-and-repeat array (L2) is to be used in making the mask. It is hoped that most masks can be specified using one of a number of prestored array definitions. For those masks that require special arrays, a means is provided for defining the array along with the job description. In the example of Fig. 1, assume that three patterns are required to complete the desired mask, that is, the primary pattern for which artwork must be generated and two standard test patterns (L100600-1-3 and L200501-1-2) for which reticles already exist. Similarly, for each mask that makes up the job a MASK and three PATTERN cards would be required.

3.1 *Inspection Data*

If special features on a mask are to receive specific inspection, a series of cards, as shown in Fig. 2, can be included. These cards indicate

- (*i*) the coordinates of a fiducial mark;
- (*ii*) the tolerance, in microns, to be maintained;
- (*iii*) the coordinates of a feature and its desired width;
- (*iv*) the coordinates of a feature and its desired height; or
- (*v*) the coordinates of two vertices of a feature whose edges do not parallel the X and Y axes.

At inspection time, MSIS scales this information appropriately, depending on the inspection being carried out, and presents the scaled information to the inspector.

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                INSPECTION DATA

MARK  -100, 0

TOLERANCE  .5

INSPECT  100, -200, W, 52

INSPECT   -500, -150, H, 10

INSPECT  -40, 100, -50, 200
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Fig. 2—Mask-inspection information.

3.2 *Operator Interface*

Operator-to-computer communications is carried out by two different means. Operators involved with the reduction cameras, contact printing, chrome etching, and the step-and-repeat camera will communicate with the system via a combination of cathode-ray-tube displays and keyboards. Administrative information and inspection data is communicated via standard KSR35 Teletypewriters.

3.3 *Secondary Information Strip*

Another medium for conveying information required by both the users and the computer is the secondary information strip. Figure 3 shows the relationship of this strip to the primary artwork as it comes from the PPG (not drawn to scale). Two items of information are placed in the strip in both human- and machine-readable form. These are, the drawing number (for example, B123456-4-3) and the magnification that was used in drawing the artwork (for example, 35). The human-readable portion is intended to allow the operators to verify visually that they have the proper piece of glass or are using the proper reduction camera. The machine-readable representation is repeated twice as a series of coded clear and opaque spots. One set of coded information can be read by an array of photo-diodes mounted in the reduction camera. The other set is imaged onto the reticle produced by the reduction process and can be read by photo-diodes in the step-and-repeat camera. In both cases, MSIS uses the machine-readable information to insure that the proper artwork, or reticle, is mounted in the proper device before allowing a job step to proceed.

Across the top of the artwork is another piece of encoded information. This represents the particular PPG on which the artwork was manufactured, and a sequential serial number. The MSIS does not make use of this latter information.

IV. EQUIPMENT CONFIGURATION

Figure 4 shows the overall equipment configuration for the mask shop. In the center of Fig. 4 is the MSIS main computer, a Digital Equipment Corporation PDP-9. The characteristics of this machine and its associated hardware are shown in Table I. The MSIS computer is interfaced via high-speed data links directly to the control computers associated with the PPG (PDP-9) and the step-and-repeat camera (PDP-8). Two model 35 KSR Teletypewriters are connected to the system. One is for administrative purposes and the other for

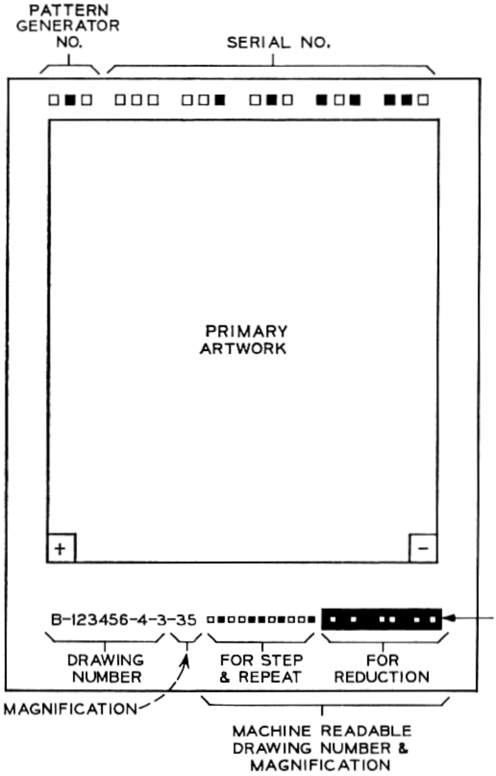

Fig. 3—Secondary information strip.

use by the inspectors. Three keyboard display positions are also connected to the system. Each position consists of a Tectronix 611 Storage Display and a 16-position keyboard. These are used to communicate with operators in the reduction, contact-printing, and chrome-etching areas. Additional keyboards and displays are connected to the two control computers.

V. A TYPICAL JOB

To help understand the functioning of the MSIS, it would be instructive to trace a typical mask as it flows through the system. A silicon-circuit mask will be used as the example (although the system is designed to handle both silicon- and thin-film-circuit masks)

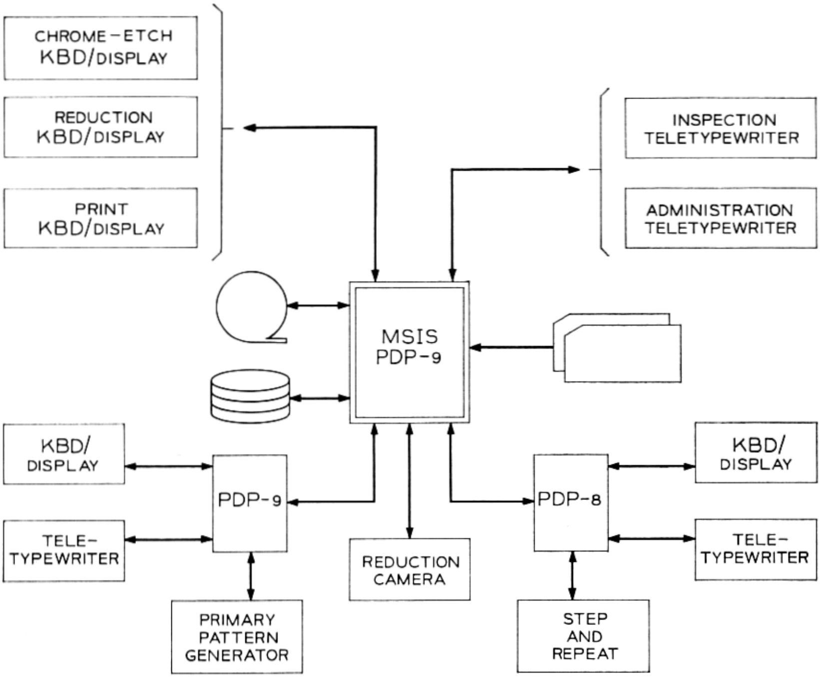

Fig. 4—System configuration.

since it uses more facets of the system. Figure 5 shows the flow of the mask through the system.

When an engineer feels he has adequately debugged his circuit masks using XYMASK, he will add the job description cards described earlier to his XYMASK deck and make a final computer run to generate a computer tape for use by the PPG. This tape will also

TABLE I—MSIS/PDP-9 HARDWARE CHARACTERISTICS

Devices	Characteristics
Core Memory	$8K$ words, 18 bits, 1-μs cycle time
Disk Memory	1 million words, 17-ms average access time
Magnetic Tape	9 track, IBM compatible, $30K$-character/second
Paper Tape	8 level, 300-characters/second reader, 60-characters/second punch

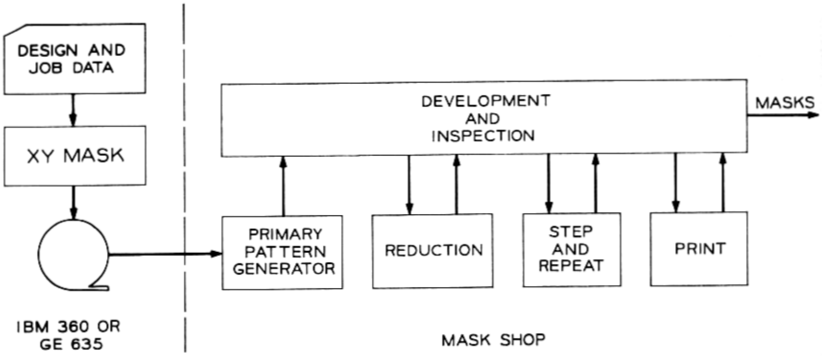

Fig. 5—Trace of a typical mask as it flows through MSIS.

contain the job-description information. The reel of magnetic tape is submitted to the mask shop and is mounted on the magnetic-tape unit attached to the MSIS. The job-description information is read by the MSIS and an instruction is given to save the reel in a particular numbered bin. The designations of the desired masks are placed in a queue awaiting the PPG. Their position in the queue is based on the priority assigned to the job.

When the mask in question reaches the top of the PPG queue, a message is sent from the MSIS to the PPG control computer indicating the reel number, bin, and file within the reel where the XYMASK data can be found for the desired mask. When the artwork has been completed, the PPG control computer transmits an appropriate message to the MSIS. The mask designation will be removed from the PPG queue and assigned to a table of those masks undergoing photographic development.

No attempt is made to schedule or control the work as it passes through the photographic development area. After completing photographic development, the artwork is passed to inspection and it is "logged in" at a teletypewriter. The MSIS instructs the operator to place the artwork in a particular numbered slot of a numbered carrier. At the same time the mask designation is placed on the inspection queue. When it reaches the top of the queue, the inspector is told by the MSIS where to locate the artwork and what unique features should be inspected.

Assuming the artwork passes inspection, the operator signals MSIS via the teletypewriter and the mask designation is placed on the reduction queue. Again the artwork is assigned to a unique slot. When the mask again reaches the top of the queue, a message is displayed to the reduction camera operator to mount the artwork in a particular reduction camera. The MSIS checks to insure that the proper artwork is mounted in the proper camera by scanning the secondary information strip. If it is properly mounted, the MSIS initiates exposure. The exposed reticle is then passed to photographic development.

The development-and-inspection cycle is repeated again, and the reticle is passed to the step-and-repeat camera. When the mask designation reaches the top of the step-and-repeat queue, the MSIS transmits all the step-and-repeat array information, including all reticles required, to the step-and-repeat control computer. Again at each stage of the step-and-repeat process the secondary information strip is checked to insure that the proper reticle has been mounted in the camera.

Upon completion of the step-and-repeat process, another development-and-inspection cycle occurs with the mask being passed to the print area. At the proper time, the number and type of prints required are displayed to the operator. After the prints have been made, a final development-and-inspection cycle occurs and the finished masks are available.

VI. MSIS SYSTEM PROGRAM STRUCTURE

During the early design stage of MSIS, it became obvious that:

(*i*) To keep and continually update the data required to process jobs in the shop, such a large number of disk-memory accesses would be required that the system performance would be limited by the ability to read from disk memory.

(*ii*) MSIS would be continually receiving requests for service either directly or indirectly from about 12-15 shop operators and would have to answer within reasonable human-response times. Furthermore, due to the difference in characteristics of the shop facilities, some of this communication could be handled via speedy interfaces such as data links while other input/output would have to be handled at relatively slow teletypewriter speeds.

(*iii*) To allow demand and periodic reports on shop progress and periodic checks of data to prevent potential problems, there would have to be some programs with long processing times included in the system.

It was decided that the best computer system for solving these problems would be a multi-programming system with a task-priority scheme. Since such an operating system did not exist for the PDP-9, the programming of a monitor had to be included in the MSIS project.

With the present MSIS multi-programming monitor, execution of one program can go on simultaneously with block transfers of data to and from disk for another program. Furthermore, by keeping those programs that have long processing times or that use slow input/output devices in separate execution areas from faster running programs, it is possible to provide quick operator responses and still run lengthy programs. Using a task-priority scheme, those tasks* which must provide quick response can be given high priority and thus processed much more quickly than the slower report and data-checking programs.

With only 8K words of core memory, the luxury of a complex monitor that allows dynamic allocation of execution areas and relocatable programs cannot be afforded. Thus the core memory is divided into fixed execution areas. Each task is assigned to an execution area according to its characteristics. Another restriction used to simplify the monitor is that swapping of tasks in the midst of execution is not permitted. That is, once a task is in execution in an execution area, no other task that requires the same area can be executed until the present task is completed.

The layout of the PDP-9 core memory is illustrated in Fig. 6. The first 3300 words are taken up by the monitor. Approximately the same amount of space is divided into 6 execution areas for task processing. The remainder of core memory is used as a "common" area to provide communication of data between the tasks.

6.1 *Monitor*

The monitor comprises three main modules: the task sequencer, interrupt handler and input/output control:

The heart of the monitor is the task sequencer; its basic function is to determine the sequence in which the tasks should be executed. The relative priority of the various tasks that make up the MSIS is determined by their relative order as they appear in the task list.

Whenever it is necessary to determine which task is to be executed next, the task sequencer scans the task list from the beginning. It searches for the first task which is activated, which belongs to an

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* Throughout this paper "task" is used to indicate a collection of computer subroutines that perform a particular function. These tasks are usually stored on disk memory and brought into core memory only when needed.

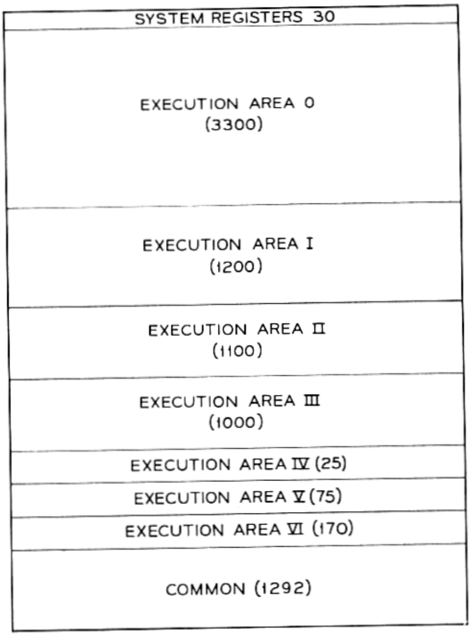

Fig. 6—MSIS PDP-9 core memory layout.

execution area that is not already in use by another task, and which is not still waiting for the completion of an I/O transfer. If the chosen task has already started execution, the task sequencer restores the registers, and returns to the place where it was interrupted. If the selected task is ready to start from the beginning and in core, the task sequencer transfers to its starting location. If the task has yet to be read in from disk, the sequencer calls I/O control to perform the disk transfer and continues its search.

The interrupt handler executes whenever an interrupt occurs as the result of the completion of an I/O transfer or an overflow of the real-time clock. The interrupt handler immediately saves the registers for the program in execution, and then decides what caused the interrupt. If the interrupt was caused by a special keyboard, a reduction-camera signal, a data link, or a request for attention (carriage-return) from one of the teletypewriters, the interrupt handler sets up some common data words and activates the task required to handle the input.

If the interrupt was one of a series of interrupts that occur in the process of completing an I/O transfer (such as the transfer of one character of a teletypewriter message), the interrupt handler stores the data and/or sets up transfer of the next data, and updates some common words to keep track of the status of the overall message. If the interrupt marks the end of a transfer (such as the last column of a card), the interrupt handler sets up the appropriate common words and activates the I/O control program. When all interrupts have been handled, control is given to the task sequencer.

The purpose of the I/O control program is to make I/O transfers via the card reader, magnetic tape, disk, paper tape, and both teletypewriters appear to the application tasks as fully buffered operations that can be handled immediately through subroutine calls. Actually, fully buffered I/O occurs only with the magnetic tape and disk. And when I/O control is called by an application task, it simulates an interrupt and locks the task from execution so that the task sequencer will allow other tasks to execute while the data transfer is taking place. Input/output requests for busy devices are queued and initiated as soon as the device is free. Five retries are made when disk-and-tape parity errors occur. For all other errors, an error is returned to the application task.

6.2 *Execution Areas*

There are six execution areas for the MSIS application tasks. Their size and arrangement are illustrated in Fig. 6.

Execution area I contains the highest-priority disk tasks. These are tasks which lower-priority tasks activate to accomplish activities requiring an update of shared data blocks that are stored on disk. Since all tasks that are allowed to update these shared data blocks at crucial times are included in execution area I, they can never be in execution simultaneously and thus no updates can be lost due to "race" conditions between two tasks. The scheduler task, which handles all queue manipulations, plate carrier assignments and job-status updates, is located in execution area I. The allocate task, which dynamically allocates and restores disk space, is also located in execution area I.

All low-priority disk tasks use execution area II. These are tasks which can afford to wait for their execution area to be free without appreciably slowing up the processing of tasks. There are 25 tasks presently assigned to this area whose functions include the following: entering and deleting jobs from the system, initializing tables at the beginning of a shift, asking for plate carriers to be moved between facilities, listing the contents of a plate carrier upon request, asking for shop output to be delivered to the engineer, and reporting on shop progress and shop problems.

Disk tasks which have medium priority use execution area III. A medium-priority task is one which, in general, doesn't have another task waiting for its completion, but which does have an operator waiting for a response. The tasks which use this execution area include those which control the task assignments for the PPG, reduction cameras, step-and-repeat camera, and inspectors.

Execution areas V, VI, and VII contain small, high-priority in-core tasks. One of these tasks provides a check against the failure of an I/O device to respond, which would cause a tie-up in the system. The other two tasks accept requests from the two teletypewriters and decode the messages to decide what disk task should be activated to handle the request.

6.3 *Common*

As has already been pointed out, most of the common data area is used to pass data between tasks. Another use for this common data area is to allow a task to save crucial data from one execution time to another without requiring the data to be stored on disk. For instance, the scheduling task saves the top of each of its facility queues in core so that it can perform most queue manipulations without taking the time to access disk. Also, the facility control tasks save the description of the mask presently in process in core because the control task is usually activated several times before passing one mask through the facility.

VII. MSIS DATA STRUCTURE

The bulk of the MSIS data is kept on disk in data sets called description blocks. While a particular description block is part of MSIS, its location on disk remains constant so that a "pointer" to its location on disk is a unique and unchanging number. These disk pointers are used to set up a structure of rings and linked lists that unite the data for one job even though the data is not in one contiguous area. In this way, disk segments (64 words) can be allocated in a random fashion, avoiding the problem of collecting a contiguous data area large enough for a particular job. The disk pointers are used in tables that correlate the data with names that have meaning to the shop operators so that teletypewriter requests for specific data can be made.

7.1 *Description Blocks*

There are five kinds of description blocks: job-description block (JDB), mask description block (MDB), pattern description block (PDB), inspection description blocks and step-and-repeat-array description blocks. The job, mask, and pattern description blocks have a fixed length of one segment. The inspection and step-and-repeat-array description blocks can be any number of linked segments.

When a job is entered in the MSIS, its processing data is split into description blocks. As the job is processed, additional data is added to these blocks and this data can be retrieved at any time.

The data common to all masks of a job, such as the engineer's name and the circuit code, are kept in a JDB. The data common to all patterns of a mask, such as the mask-identification number and the present status of the mask, are kept in an MDB. The data particular to one pattern of a mask, such as the pattern-identification number and the current location of the glass plate, are kept in a PDB.

As explained in Section 3.1 of this paper, the engineer may specify particular features of a mask that he wants inspected. All the inspection information for one mask or pattern is kept in an inspection description block.

A description of the array of patterns to be used in making a mask is kept in a step-and-repeat-array description block. The placements of each pattern in terms of X and Y coordinates are given in micron dimensions. The pattern names may be given in general form according to the order of the PDB. In this way, one step-and-repeat-array description block can be used by many masks as mentioned in Section III of this paper.

7.2 *Job-Data Structure*

All the data for one job are linked together by a ring and linked list structure. The ring structure is used to unite the job, mask, and pattern description blocks as illustrated in Fig. 7. An inspection description block consists of a linked list of segments; the pointer to the first of these segments is placed in the description block of the mask or pattern described by the inspection data. The step-and-repeat-array description block is also a linked list of segments; the pointer to the first of these segments is placed in all MDBs using this array description.

With this data structure, data for one job may be scattered in random fashion over the disk and yet one pointer to any one of these segments can lead to all the data for the job. Using this arrangement, data can be easily added to or deleted from a job description. Furthermore, no data structure rules cause limitations to be placed on the number of masks in a job, the number of patterns in a mask, the

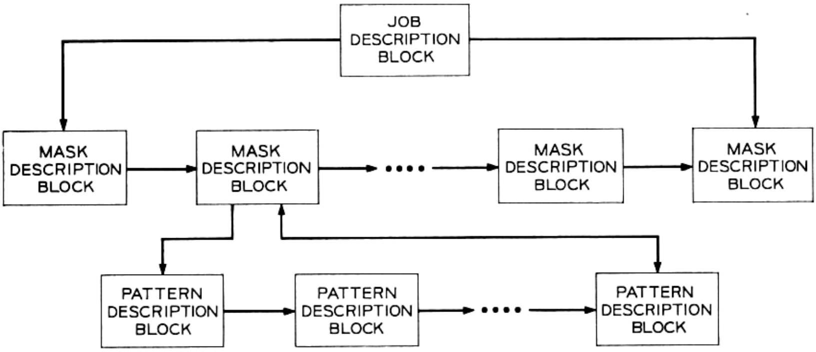

Fig. 7—Description block ring structure.

number of critical features to be inspected, or the complexity of an array description.

7.3 *System-Data Structure*

MSIS uses a table structure to connect the external world with its data. MSIS can retrieve all information about a particular job (if the request for the data includes the job number) by referencing a table which correlates the job number with the JDB pointer. Furthermore, the status and location of any glass plate in the shop, whether it be a piece of artwork, a reticle, a master mask, or a working copy can be obtained through a table which correlates plate identification numbers with the appropriate description block.

Also, the facility queues need contain only a one-word description block pointer for each entry on the queue because all the data needed when an operator or a facility requests a new assignment can be obtained with the use of that pointer.

Shop statistics are kept in status tables on permanent disk segments. The figures in these tables are continually updated by the application tasks. Thus when system statistics, such as the number of jobs in process, or the average time to get a job through the shop, are requested by a demand report, the answer is immediately available.

VIII. SIMULATION

Concurrent with the design of MSIS, a program which simulates the flow of jobs through the new mask-making facility was written using the IBM General Purpose System Simulator. The predictions made with this simulator were used to set upper limits on table lengths, to design the scheduling algorithm, and to design the MSIS—inspector interface.

With a fairly good knowledge of the processing times at each facility and the number and type of jobs that would pass through the shop on an average day, it was possible to set up a reasonably accurate simulation of the shop. However, two items were particularly hard to describe: the length of time required to inspect a plate and the rejection rate for inspected plates. Based on an earlier generation mask shop which existed at Allentown, some figures were obtained. However, two of the main purposes of the new shop were to provide more reliable making of plates and a better inspection facility. Thus these figures were considered worst-case values. An educated guess was used to establish a more likely set of numbers. Using both sets of inputs and varying the load on the shop, a large number of simulation runs were made. The results of the simulation for a load of 25 masks/shift are summarized in Table II.

8.1 *Table Lengths*

With a million-word disk, it was possible to be safe and allow extra space for table lengths. Nevertheless, some numbers were needed to decide just what "safe" meant. Here the simulation was invaluable. By having numbers for the maximum number of jobs in process and the total number of plate carriers used, it was possible to define an upper limit for the plate and carrier tables.

8.2 *Scheduling Algorithm*

The scheduling algorithm maintains a queue of masks that are awaiting processing by each of the facilities that make up the mask shop (e.g., PPG, reduction camera, etc.). One problem in designing the scheduling algorithm was the setting of a limit on the size of a facility queue. If a facility queue was allowed to be indefinitely long, the scheduling program would be cumbersome. Even if the queue lengths were set at a large number, the queues would have to be located on disk and the number of disk accesses involved in the continual queue manipulations would be too time-consuming. However, the possibility of a facility breakdown and a queue build-up prevented the placing of a tight restriction on queue length.

Thus it was decided to have a set of in-core facility queues that would be large enough for use during normal shop operation and queue

TABLE II—INSPECTION RESULTS

	Long Inspection Times—High Rejection Rates	Short Inspection Times—Low Rejection Rates
Shop through-put	22 masks/shift	24 masks/shift
Turn-around time (normal)	3 days	1½ days
Turn-around time (priority)	1½ days	1 day
Average length of a queue	8	5
Maximum number of jobs in process	56	40
Total number of carriers used	48	32
Average percent of time 8 inspectors were busy	85%	35%

extensions on disk to be used during abnormal operation. Using the results of the simulation, the number of in-core queue entries was established as ten; with this number, most queue manipulations can take place without disk accesses.

Other decisions that had to be made in designing the scheduling algorithm were whether a first-come, first-served system would be adequate, whether priority jobs should be allowed in shop operation, and, if so, what the number of priority levels should be. The simulation was used to test the possibilities. It was discovered that if the shop is keeping up with the input load (this occurs at a load of 25 masks/shift), most jobs can be completed in a couple days. Also, if two levels of priority are used for jobs entering the shop and the number of high-priority jobs is limited to 5 percent, a high-priority job can be completed in one day. Thus a simple two-level priority scheme is considered adequate, at least for a first version of MSIS.

8.3 *Inspection-Station Design*

For most of the shop facilities, the hardware defines the number of jobs that can be in process at one facility at one time and thus no facility limitation problems were encountered in the design of MSIS. However, the inspection facility is limited only by the number of inspectors and the capacity of the communication device. Considering the length of time required to complete one inspection process, it was realized that one teletypewriter could readily service five to ten inspectors. And, if necessary, another teletypewriter could easily be added to the MSIS hardware.

The number of inspectors allowed was critical to the design of the inspection control task and the allocation of core area for description blocks for masks in process at the inspection facility. Thus the simulation was invaluable again. The results showed that the number of inspectors could be limited to seven without impairing shop efficiency.

IX. MSIS FUTURE

At present, MSIS is controlling the making of masks at Murray Hill in a shop that is using one PPG and two reduction cameras to handle a small load of work. When the contact printing facility becomes available at Murray Hill, MSIS will also assign tasks in this area. The information system will then be installed in the Allentown shop; at this time, the communication with the step-and-repeat camera will be included. Before the end of the year, MSIS will be controlling the operation of both the Murray Hill and Allentown shops.

It is too early to know what problems will be encountered during a long period of shop operation with MSIS. Realistically, it must be assumed that even with the simulation, some unexpected demands on the system will turn up and some additions and changes will be required. However, the monitor is sufficiently general that it is doubtful that it will undergo any major change. And the method of communication between tasks, the description block data arrangement, the handling of queues, the plate-carrier assignments, and the allocation of disk areas are basic enough to remain permanent. Since the coding for these functions has been kept in separate tasks from those dealing directly with the outside world, these tasks can be kept intact even when major shop changes take place. Thus a change in shop operation will probably lead to the rewriting of a task or two, and it will be possible to add the new tasks without causing havoc to the rest of the system.

This modular arrangement of system functions will also work out well when MSIS expands. A study is now underway to see how the adding of a data link between the coordinate measuring machine in the inspection area and the MSIS computer will improve shop operation. It is believed that with a new inspection task added to the MSIS task list and a small addition to the interrupt handler, this improved inspection capability can readily be added to MSIS.

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