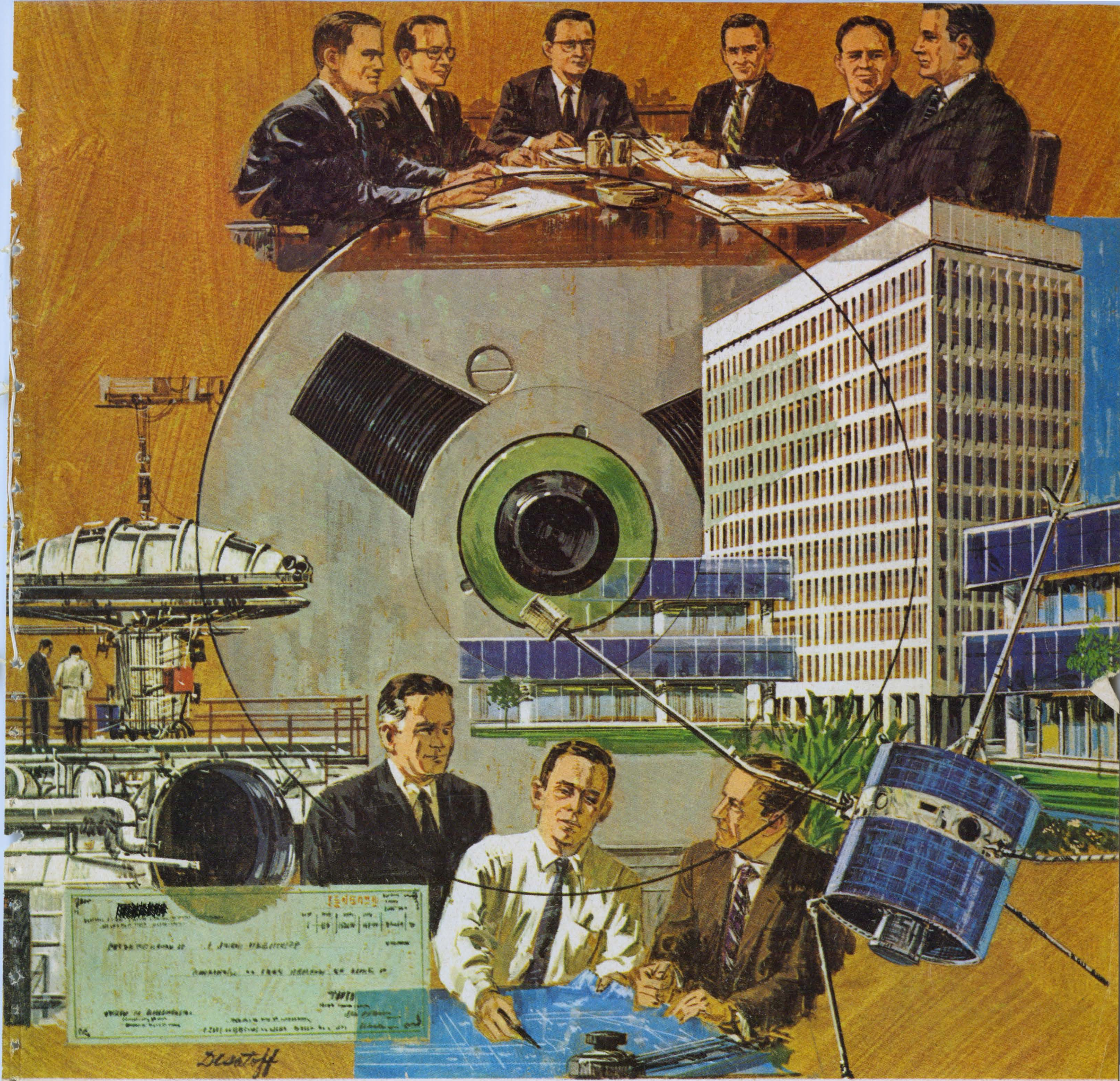

COVER STORY—AEROSPACE PLANNING. SEE PAGE 16

software age

JANUARY 1968

THE MAGAZINE FOR PROGRAMMERS • MATHEMATICIANS • ANALYSTS • EDP MANAGERS

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new installations

The University of Houston has installed a Scientific Data Systems' Sigma 7 in the school's new $400,000 computer center. In the coming year remote terminals will be installed in various classrooms and laboratories allowing time-sharing to become a reality throughout the university. The more routine EDP problems of running a major university will also be handled by the $1,250,000 equipment.

■ ■ ■

Techalloy Company, Inc., producers of rod and strip wire composed of stainless steel and high nickel alloy, has announced the purchase of a UNIVAC 9200 Computer System. When installed in the summer of '68, the new equipment will replace tabulating equipment presently being used for handling accounts receivable and payable and for inventory control and invoicing.

■ ■ ■

Merck Sharp and Dohme, an international manufacturer of pharmaceutical products, has ordered a Series 200 Computer from Honeywell Controls Ltd. Most of the firm's data processing has been handled by a service bureau; however, the Hoddesdon, England firm anticipates converting all order processing, accounting, inventory, sales and marketing functions to the new Honeywell 120 format.

■ ■ ■

Penn Jersy Auto Stores, operators of more than 100 retail outlets in a five state area in the East, has ordered a UNIVAC 9300 Computer System. The system will be used for processing daily order entry operations, stock status reports, sales analysis and complete general accounting and management exception reporting. The equipment will be located in the company's general offices in Philadelphia.

■ ■ ■

Northwest Orient Airlines has given the order for $12 million worth of UNIVAC 494 Computer System hardware. The airline will have invested over $25 million in the system through the next five years. Located at the Twin Cities Airport, the system will incorporate functions of numeric reservations, inventory, message switching, flight planning, revenue accounting, payroll and other related programs. The newest application of the new equipment will be the storage of passenger name records, flight schedule displays and freight control.

■ ■ ■

Fruin-Colnon Contracting Co., a St. Louis based construction and engineering firm, has installed a Honeywell Model 120. Along with the usual applications of payroll, general accounting and fiscal reporting, the firm plans to use the equipment for critical-path reporting and to plan, schedule and control major engineering and construction projects. Fruin-Colnon was instrumental in the development of the Busch Civic Memorial Stadium.

■ ■ ■

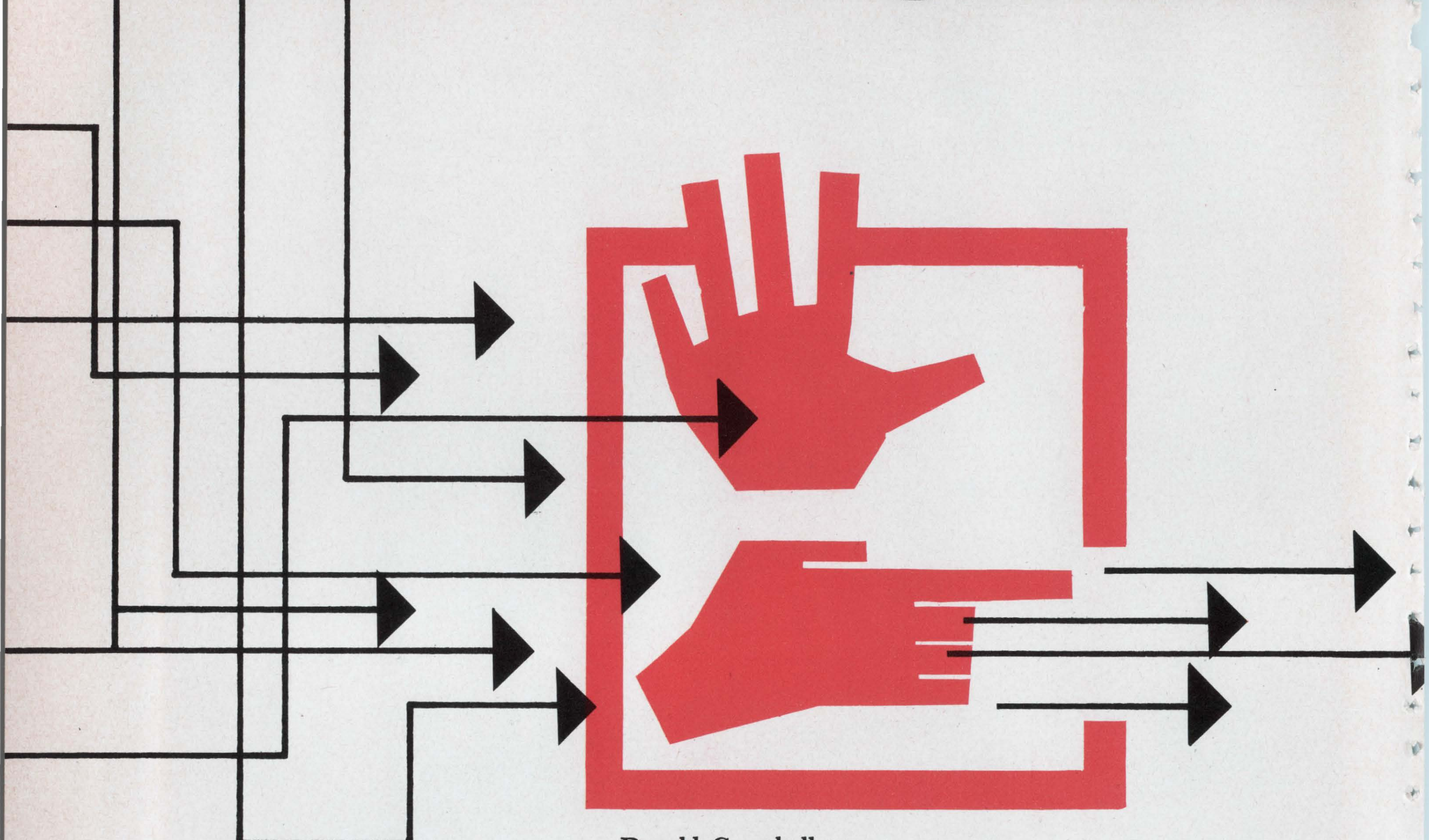
The Alabama Department of Public Health has installed a UNIVAC 9300 Computer System in its division offices in Montgomery. While the department plans to continue using punched cards for the time being, plans are being made to convert to magnetic tape in the future. Along with predictable useage such as statistics of births, deaths and communicable diseases, the new system will also be used for compiling and comparing historical medical information and for budget projection and preparation.

■ ■ ■

EDP Data Centers Ltd., reputably Canada's largest independent computer service bureau, has installed a Honeywell 200 at its Vancouver, B. C. branch office. Previously centering its activities in and around

(Continued on page 22)

GENERAL



Donald Campbell
Walter Cook
William Heffner

■ An advanced operating system announced by General Electric at the recent Fall Joint Computer Conference offers users of large-scale computers the ability to mold their varied data processing and access requirements into a truly integrated system.

General Comprehensive Operating Supervisor III (GECOS III) is a new operating system for General Electric's GE-600 series of large-scale computers. It efficiently integrates requirements for on-line batch, remote batch, and time-sharing into one system, using a common data base. The problems of employing multiple systems, with incompatible programs and files, no longer need exist for large-scale computer users.

The new operating system provides significant improvements in the performance and reliability of the multiprogramming, multiprocessing, and remote processing functions of its predecessor, GECOS II. It also provides concurrent time-sharing capabilities with BASIC* language and text-editing functions.

---

* Jointly developed by Dartmouth College and General Electric Company.

The "heart" of GECOS III is a centralized file system of hierarchical, tree-structured design which provides multiprocessor access to a common data base, full file protection, and access control. Full user program compatibility with GECOS II has been retained, but the internal organization and logic flow of the system is completely new. The ease with which the system may be extended and modified has been enhanced greatly.

Hardware Considerations

A brief introduction to the GE-600 series of computers is necessary as a frame of reference in understanding the operation of GECOS III. GE-600 systems are modular in concept, consisting of memory modules, processor modules, input-output controller (IOC) modules, and associated peripheral devices. From one to four of each type of module may be attached to the system, depending upon the memory, processing, and input-output requirements of a given installation.

The systems are "memory oriented" in that the system controller is associated with the

COMPREHENSIVE OPERATING SUPERVISOR

GECOS III

memory. Processor and IOC operations are coordinated by the system controller. Each memory module may contain from 32K to 128K of 36-bit words. The minimum rational memory size is 64K; the maximum, 256K. One and two microsecond memories are available.

The processor(s) perform a double word instruction fetch from memory, with interpretation overlap of the second instruction. The processor operates in a dual mode, with the operating executive (GECOS) executing in both "master" and "slave" modes, as required, while user programs execute in "slave" mode only. In master mode operation, the full instruction repertoire may be executed; all memory references are absolute; and the full range of memory may be referenced directly. In slave mode operation, memory references are relative to a base address register (BAR) which defines the physical address limits of the executing program; the program cannot access memory locations outside of the BAR setting; the length of program execution time is under the control of a "timer" register; and the program is limited to a sub-set of the instruction repertoire. Control operations such as input-output operations, setting the BAR and timer registers, etc. are prohibited in slave mode.

An important attribute of the BAR is the ability to move user programs in memory without address relocation merely by establishing a new BAR setting.

Sixteen special processing status conditions, termed "faults," cause interruption of sequential instruction execution and transfer of control to one of 16 pre-set fault vector locations, depending on the type of fault which occurred. Faults provide control (e.g., timer run-out, arithmetic overflow); detection (e.g., an attempt to reference outside of memory limits); and communication (master mode entry).

The IOC's perform asynchronous input-output operations on up to 16 peripheral channels per IOC. Communication with the processor is effected through a pre-set group of 256 words of memory (IOC "mailboxes") and through four distinct types of interrupts to one of 32 pre-set interrupt vector locations, depending on the type of interrupt and the IOC on which the interrupt occurred. DATANET-30* data communications processors may be attached to one or more of the peripheral channels of an IOC,

* Registered trademark of the General Electric Co.

adding remote input-output capabilities to the system.

Design Objectives

The myth that system development ends when the system is operating reliably has been exposed repeatedly. It simply is not possible to anticipate the effect of all design decisions and the merging needs of all users during system development.

GECOS II has been in operation for over two years, controlling up to eight batch and remote batch programs in a multiprogramming/multiprocessing mode of operation. It has been in a continual state of development and improvement since its initial release. However, the insight gained from the development of GECOS II and the statistical analysis of its operation, together with the evolving need for new capabilities, indicated an urgent need for a new operating system. The major design objectives of the new system were:

—The system must be immune to user program errors, whether intentional or unintentional.
—The system must be fully user program compatible with GECOS II.
—The internal system structure must be simplified for ease of extension and modification.
—The system must maximize peripheral utilization.
—The file system must provide file protection and access control in a multiprocessor mode of operation.
—Batch, remote batch, and time-sharing must be integrated for effective concurrent operation.
—The system must operate efficiently under an effective memory discipline.
—Self-measurement and feed back techniques must be incorporated to provide data for continued development.

GECOS III consists of three distinct elements, or types of routines:

1. A resident executive (known as the "hard core monitor").
2. A small number of "system programs" (such as the job input processor) which perform services for the *community* of user programs within the system.
3. A library of system subroutines which perform service functions (such as I/O) for *individual* user programs.

Hard Core Monitor

At system initialization, the hard core monitor is loaded into memory, and remains intact throughout GECOS III operation. Its size depends upon the system configuration, but averages about 10K words. It contains:

—System configuration data.
—Interrupt processing routines.
—Fault processing routines.
—The "dispatcher," which allocates the processor(s).
—The most heavily used system service subroutines.

All memory, except the hard core monitor, is occupied by programs from user-submitted jobs and by a few system programs. The system programs include:

—Job input processor.
—Peripheral allocator.
—Core allocator.
—Standard output disperser.

Note that these system programs concern the functions of introduction, preparation for execution, and dispersal of results of a user program. They communicate through the file system and manipulate the file system image of the job as it passes through the system. This filing procedure ensures that a fresh copy of the job always is available for restart if required.

There is only one distinction that the system makes between user programs and system programs. System programs need to reference common data such as the system configuration, held in tables in the hard core monitor; therefore, a special entry point to the hard core monitor is provided to allow such a reference. If a user program attempts to gain entry, that program is aborted.

Programs which are permitted to use this entry point are "privileged" programs. The time-sharing system and the test and diagnostic system also are privileged system programs, and are allowed this privilege in order to achieve high speed I/O interfaces and interior memory protection.

Many advantages are gained by treating system functions like ordinary programs. Since they are subject to the same rules of memory and processor use as any program, while one program is executing, the rest of the system is memory-protected against accidental reference and destruction. Each is organized as a free-

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standing program with a few well-defined interfaces with the file system and with input queues of other system programs, making it easier to understand and maintain. GECOS III does not treat these programs in special ways. There is a single memory space manager, for instance, rather than one for user programs and another for the system.

System programs, like any other user program, may be suspended and swapped out of memory. The important task of accounting for the system resources they use is readily accomplished since they are charged for processor and I/O time just as any user program would be.

Slave Service Area

Memory space reserved for possible system overlays is essentially dead space much of the time, and contributes to a deterioration in effective memory utilization.

There always must be enough room for any required complement of overlays. If the maximum space required is not known, the system may encounter the disastrous situation of having insufficient space in which to load an overlay needed to keep the system going.

In GECOS III, the memory space required for overlays is minimized and strictly disciplined. A fixed amount of space, called the Save Service Area (SSA), is dynamically allocated by program for this purpose. Each program in the system has an SSA, and when a program is brought into memory, all system data pertinent to that program is held in the SSA.

I/O requests by the program are queued in tables in the SSA. The SSA also maintains a push-down stack for defining the state of the program, and as system service function overlays are needed, they are loaded into the SSA for execution.

The SSA is adjacent to and below the zero address of each program. The SSA addresses are –1 through –1024 of the program. The BAR setting protects the SSA from user program access. System overlays brought into the SSA reference data within both the user program and the SSA by addresses relative to the BAR setting, making it unnecessary to relocate any code read into the SSA for execution.

Approximately one-half of the SSA is used for overlay execution. In addition, an automatic push-down and pop-up capability for overlays was developed in the SSA. If one overlay executing in the SSA should call another, the first is written on a push-down file associated with the program. When the corresponding exit is made, the SSA is popped up again. Experience has shown that most system service functions can be accomplished within the SSA without incurring the push-down, pop-up overhead.

Treating system service functions as subroutine overlays of the program requesting the function has resulted in several advantages:

1. Coding and checkout of the routines is simple and straight-forward.
2. Multiple requests for the same function may be executed in parallel by providing each requesting program with its own copy of the routine.
3. In general, a failure in one of these routines results only in removing the associated user program from the system—not in the deterioration of the system itself.
4. The charges for system resources used by the function can be applied directly to the requesting user program.

The amount of memory required by GECOS III is exactly the length of the share core monitor plus 1024 words per program in memory. The system always knows if it has space for another program.

In addition to solving the space discipline problem, the SSA has proved to be the single most important concept in GECOS III. Since the system data for a program is codified by and adjacent to the program, it is much easier to determine the status of a program or to suspend program execution in order to move it in memory or to swap it out to secondary storage. This association of system data and service function overlays with their programs also results in increased multiprocessor effectiveness by avoiding the memory interface problems which are incurred when such data and subroutines are pooled and under a common memory controller.

File System

Basic to the organization of GECOS III is a file system comprised of a permanent on-line data base, with security protection, and access control.

The design of the file system was strongly influenced by considerations of system safety and maintainability. The list-structured physical space definition was discarded, for example, because of the complexity and time required to reconstruct such a base if the list pointers were accidentally destroyed.

Logically, the file system consists of a master catalog which identifies each user known to GECOS. Within the master catalog are pointers to catalogs for every user. The user's catalog may define files, or may in turn name and point to still lower level catalogs. Accounting information for the time-sharing system also is kept in the master catalog.

To identify a file in the system, a string of names is given, beginning with the user name in the master catalog. Each successive name, in turn followed by the file name, defines the file. At any point in this string of catalogs, except for the master catalog, passwords or permissions may be invoked.

Any file or catalog in the file system may be read, written, appended to, or executed. The owner of the file or catalog may specify who may have each of these four types of permissions. In traversing a catalog string, the permissions are checked at each level, and if the interrogator has been denied the permission he seeks, he is not allowed to compete the reference.

When a user asks for a file,he must state what activity he has in mind. Safeguards in the system prohibit a user from asking for one type of permission and then using the file in another manner. The file system allows any number of users to read or execute a file at one time, but will not allow anyone to write or append a file if someone else is referencing it.

Space on each device in the file system is divided into an area for file space, an area for catalogs, and a small area for diagnostic blocks reserved for the exclusive use of the test and diagnostic system. By dividing the space in this manner, it is possible to inventory the available file space on a device simply by reading the catalogs. This may be done without reference to the catalog structure of the file system because of an important restriction in structure: No file space within the file system may be described from more than one string of catalogs.

Although the same space cannot be described twice, users may share a file. A user can traverse the catalog structure of another user and thereby access that user's files, assuming he has appropriate permission and password approval.

Files within the system may be removable devices such as magnetic tapes, or they may be space on disc or drum files. Many discs and/or drums may be known to the file system. If a catalog string passes across devices, however, it must do so at the master catalog level.

For each user in the master catalog, there are entries defining how much space he may use in the file system. The file system will prohibit an attempt to create files exceeding that space limit.

Files in the file system may be accessed in the batch processing, remote batch, and/or time-sharing modes. System service subroutines allow the user to create and/or purge his catalogs and files, and perform miscellaneous functions such as changing permissions and copying.

The operating system itself is contained on files defined within the file system. When the system is established, the installation states the files that contain the various elements of the system. The few special working files needed by GECOS are defined similarly by their file system names. Various versions of the operating system can be held in the file system at one time and called as desired.

I/O Interfaces

GECOS III provides true device independence. The I/O structure is defined so that user-programs reference logical files and need not be concerned with physical device peculiarities. Furthermore, association of logical I/O requests with a specific device only occurs when the physical I/O operation is initiated. Thus, a data file can be moved to a different device whenever

necessary. In the case of a magnetic tape file, a unit swap results in repositioning the tape reel to the same position on the new device.

Within GECOS, each I/O request produces an entry in a threaded list. A list is present for each logical device that is to be known in the system, and the lists are contained in the SSA of each program. In this manner, each I/O request by a program is tabled in the SSA of that program, but the threaded list may wind through various programs within the system.

If a particular device is used heavily, a queue of demands on that device will grow; however, since there is only a fixed amount of space in each SSA, a program bug in one program can not saturate the system with spurious I/O demands.

The most important property of these I/O queues is that they allow the adoption of selection strategies which increase the system's I/O throughput. For instance, the drum commonly used as secondary storage informs the processor of its angular position at I/O terminate. The I/O system selects the particular I/O request in the drum queue which will minimize rotational delay. Tests show that throughput may be more than doubled using this technique.

An interesting feature of the I/O design is the "courtesy call." Any user program I/O request may specify that a courtesy call is to be paid to a given address when the I/O terminates. The operating system interrupts the execution of the program to pay the courtesy call as soon as it has processed the termination of the I/O command. In this way, I/O-bound programs are guaranteed processor time to reinitiate I/O requests as soon as a previous request is finished. Even in a heavily loaded system, I/O is kept running at high speed. The system input and output programs use courtesy calls extensively.

Job Scheduling

Jobs are entered into GECOS III from on-line peripherals, remote terminals, and/or time-sharing terminals.

Gross requirements are checked against limits established by operations through the control console. A job exceeding the assigned limits is set aside and operations is informed.

Next, a priority is calculated for the job—unless a forcing priority is given on the job control card itself. The calculated priority for the job is on the form: $P = \Sigma (R_i * K_i + C_i)$ where:

R_i = the amount of system resources of a given type demanded by the job; i.e., memory, disc, drum, etc.

K_i, C_i = multiplicative and additive constants which may be supplied by the installation.

An installation may change the priority calculation in favor of any type of job. The priority may be set to favor small jobs, for instance, by giving a negative K_i to both time and memory size. Tape jobs may be favored by giving a positive K_i for tapes.

The priority determines the order in which the peripheral allocator attempts to find the peripherals for each job.

Before the peripheral allocator assigns peripherals to a program, it verifies that one of the following conditions is met:

1. There is a contiguous area of memory that is large enough to hold the program.
2. The priority of the program is high enough to force memory compaction or program swap to start the new program.
3. Not more than N-programs already are waiting for memory.

The effect of these rules is that programs are sent to the core allocator until a backlog of programs waiting for core is created. Then no more peripherals are allocated. The peripheral allocator is swapped out of memory, and the space it occupied is used to run the programs it processed.

The core allocator assigns memory to programs after peripheral file allocation is complete. Memory is allocated according to the priority established for that program by the peripheral allocator. If the priority is high enough, the core allocator forces other programs to be suspended and swapped out of memory. For programs of somewhat lower priority, the core allocator compacts memory so that contiguous space is available. For ordinary programs, no special action is taken.

The core allocator gives primary emphasis to jobs with small memory requirements; however, jobs with large memory requirements eventually will be chosen in preference to newer small jobs.

Dispatching

In GECOS III, processors are system resources, allocated to programs for specific time quantums to effect program execution. The allocation of processors to programs is called "dispatching."

The dispatcher gains control in three ways:

1. At each I/O interrupt.
2. When the allocated time quantum for a program in execution is exhausted.
3. By voluntary return of control to await completion of necessary I/O operations.

The dispatcher maintains a queue of programs ready for execution, ordered in the sequence to be dispatched. Programs executing I/O operations are placed at the top of the queue.

By selecting a new program for execution at each interrupt, I/O-limited programs are kept active and maximum throughput is achieved. When there is a heavy I/O load, the system commutes rather rapidly between the programs that are performing I/O and gets to the "proc-

(Continued on page 38)

AEROSPACE PLANNING

■ Practical applications of Operations and Systems Analysis techniques to internal corporate planning in the aerospace industry are being pressed into service to deal with the dynamic growth and forecasting requirements which a multitude of planning activities encompass. The Overall Planning Model recognizes the usefulness of modern systems and computer technology and applies lessons learned from the scientific developments fostered by the industry. Lack of visibility in the business environment and evolving planning activities require rapid analyses to be performed—analyses which have imposed intolerable workloads on existing methods and personnel. The purpose of this article is to describe an extensive planning model and an implementation strategy which represent a practical systems-oriented approach to keep pace with the modern planning requirements of a large aerospace company.

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The data used in developing detailed plans is almost always uncertain. The probability of acquiring major contracts, any of which has a significant impact on total sales, is difficult to estimate with accuracy. The sales forecasts that include these contracts must be analyzed with respect to the support required in manpower, facilities, and capital equipment. In addition, indirect expenses must be allocated among contracts by applying overhead rates negotiated before those costs are incurred. Since overhead is a major cost item, accurate forecasting and planning of indirect expenses becomes critical to the future profits of the company. Finally, the performance of the company must conform with certain overall management criteria, the most important of which are measures of profit performance and investment utilization.

We have been developing a series of analytical planning tools to aid in meeting these requirements. The primary objective of developing these tools was to provide a coordinated overview of the separate and diverse planning activities in the company. The tools would determine not only the local effect of a decision within a certain area, such as indirect expense planning, manpower planning, or facilities planning, but also the interrelated effects of that decision in other planning areas. Detailed planning data are available in the company but do not always reflect the most recent business conditions. Therefore, the design of the system would facilitate quick reaction time. The tools would supplement detailed plans with aggregate forecasts and utilize the outputs of management information systems, while having the flexibility to operate under continual company growth. Secondary objectives were to provide each planning group with working tools to aid in preparing detailed plans, and to facilitate company planning interfaces by reflecting the adequacy and consistency of the data needed to perform the planning functions.

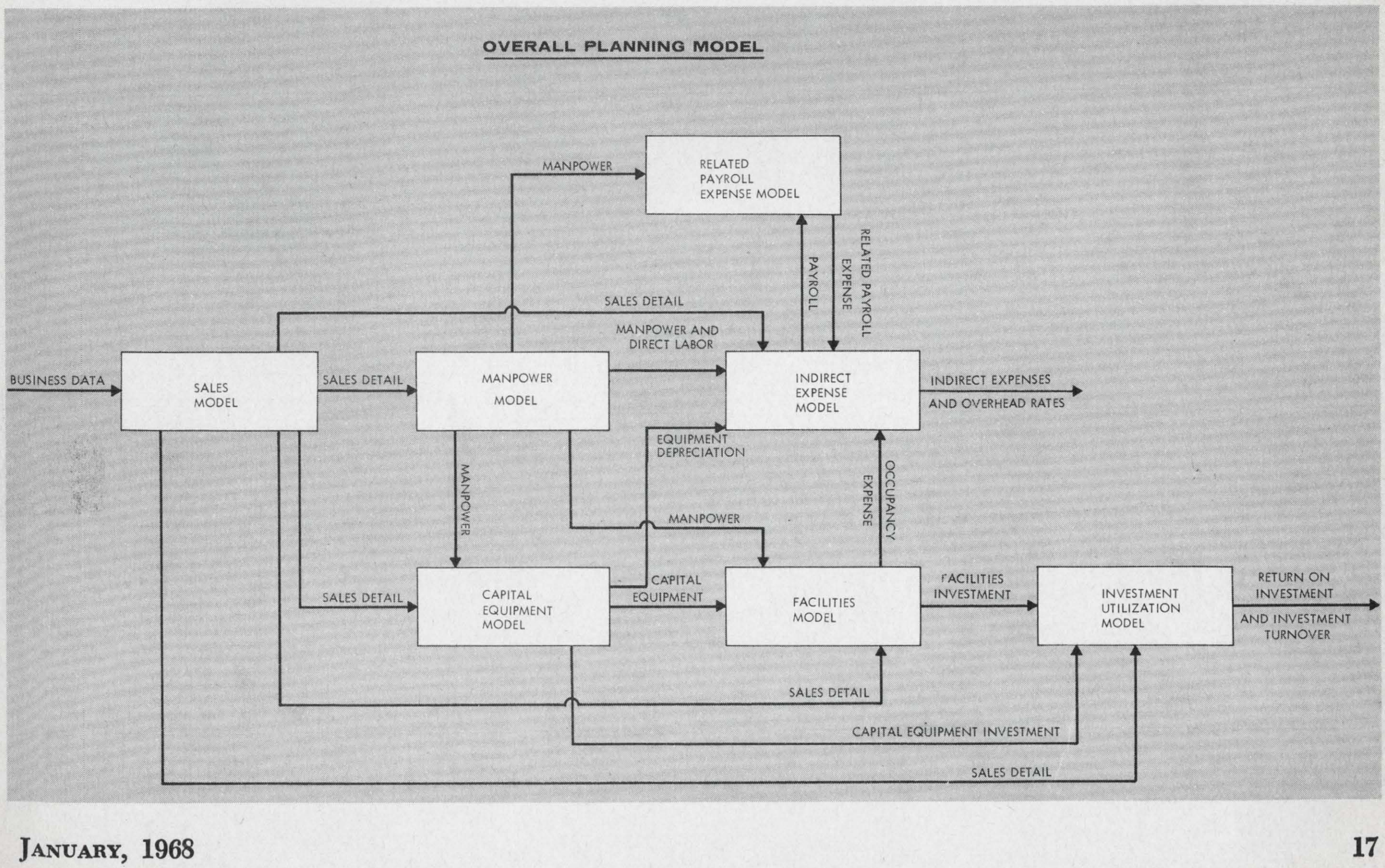
Overall Planning Model

Achieving these objectives required the tools to be integral parts of an overall model of the planning system. The Overall Planning Model consists of modular components, each of which is a model of a specific planning area and has data interfaces with the other models. Each model can be used separately in a given planning area or together with the others to analyze the total system. Basic design characteristics of the Overall Planning Model make it easy to use and help maintain reliability.

The general form of the Model is shown in the diagram, which illustrates how the individual models fit together to provide various types of planning information. This information includes forecasts of manpower, direct labor expenses, indirect expenses, overhead rates, investment requirements, and investment utilization. Only the important flows of information are shown in the diagram.

The Overall Planning Model begins with business data inputs to the Sales Model which include sales backlog, information on major anticipated projects, and other forecast information. The primary output of this model is a detailed breakdown of product line sales, which includes profits, negotiated overhead, direct labor, and other direct costs. The estimate of direct labor is used in the Manpower Model to generate manpower forecasts for each of the operating organizations. Sales and manpower data become the primary inputs to the Capital Equipment Model, Facilities Model, and Related payroll expense. The Indirect Expense Model develops the remaining items of indirect expense and produces a total forecast for each organization. It then uses the direct labor estimates in forecasting overhead rates. The Investment Utilization Model develops measures of return on investment and investment turnover on sales for organizations and product lines.

Numerous feedback flows not shown on the diagram are important in maintaining consistency between the models and improving the reliability of the total system. For example, the negotiated overhead dol-



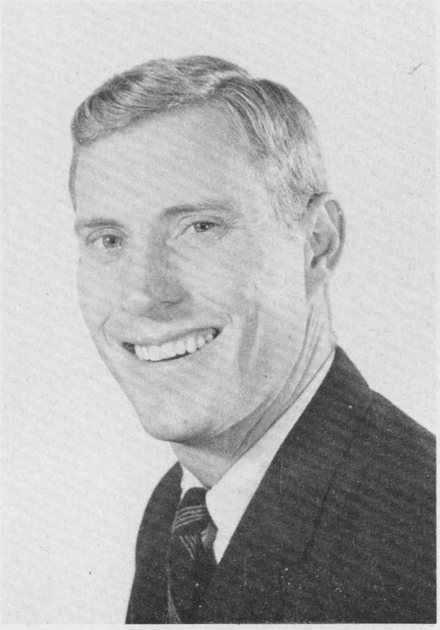
lars in a sales figure must be consistent with the forecast of overhead rates. When these do not agree, consistency can be maintained by adjusting the forecasted indirect expenses, changing the anticipated profits, or renegotiating the overhead rates. Another feedback which affects the sales forecast is a manpower hiring constraint determined in the Manpower Plan Model.

Several characteristics are common to all of the models. Each can serve functional planning areas as a working tool to perform detailed calculations, because the logic and arithmetic processes used in the computer closely parallel existing manual procedures. The models' operation is flexible with regard to the quantity of data inputs required. Data manipulations are performed on a quarterly basis, but optional time-phasing routines are available if the user wishes to supply data on an annual basis. Also, forecasting routines using historical data are available to project the detailed breakdowns of basic planning variables such as the labor categories within total manpower.

The historical data used in the models are stored on magnetic tapes and are updated each quarter as actual figures become available. The forecasts are automatically updated by substituting the most recent actuals into the forecasting equations. The models are configured as a series of subroutines, each of which is called by a central control program according to a sequence that is specified by the user. A multiple run for each model seldom uses more than two minutes of computer time, and the user will often call only one or two of the available subroutines to accomplish a specific task.

The Indirect Expense Model, Related Payroll Expense Model, and the depreciation calculation program in the Capital Equipment Model are currently operational and are being put to use by central planning groups and individual budget planners throughout the company. The design and implementation of these sections was completed in approximately two man years by a group of business-oriented systems analysts. Programming required another one-half man year, and because this was done by another group, the familiarity of the system designers with

Mr. Combest received his BA in Economics from Vanderbilt University in 1964 and his MBA from Stanford in 1966.



Mr. Oates also received his MBA from Stanford 1967 and BA in Psychology from Stanford in 1965.

the language (FORTRAN IV and the equipment (7094–II) was helpful in designing and debugging the programs. Much of this programming time was due to redesign of the models in response to feedback from users who were able to clarify their needs only after using the tools in an actual planning exercise.

Implementation Strategy

Because the Overall Planning Model represented an advanced approach with many concepts new to company personnel, the implementation strategy was as important to the success of the model as the system design. The strategy stressed a modular approach to problem solving, simplicity and clarity of design, and encouragement of participation by potential users in the developmental process.

The modular construction of the system was defined such that the boundaries on individual models corresponded with planning function responsibilities. This organization tended to minimize data interfaces and overlapping functions among the models. Thus, each could be analyzed independently as a separate problem, and quick, tangible results were achieved by applying a concentrated effort to one problem at a time. These results encouraged user confidence and participation in the modeling effort. In addition, the experience gained by the analysts from problems encountered in the development and implementation of one model carried over to the design of subsequent models.

User involvement was also encouraged by the participation of the analysts in the activities of each planning group. This participation led to applications of other planning tools, such as a sorting and tabulation program to summarize manpower planning data, a financial model to determine the profitability of a new product line, and a model for determining optimal bidding strategy. Close lines of communication and good working relationships were instrumental in eliciting the cooperation of the various groups in the company who provided valuable data for use in the models.

The design of the system itself encouraged cooperation and participation. The use of familiar terminology, processes that paralleled existing manual systems, and a gradual introduction of sophisticated techniques achieved simplicity and clarity in the models. This accelerated the assimilation of the system among company personnel by reducing the amount of learning required and by avoiding confusion and possible negative reaction to procedural changes. There was, in fact, very little negative reaction to the modeling activities, probably because the personnel in the company were accustomed to computer applications in scientific problems and rapid technological change.

TRW scientists are deeply involved in planning, designing and manufacturing many types of U. S. spacecraft, space communications and space propulsion systems.

Summary

The design of the Overall Planning Model and the strategy used in its implementation combine to form a practical solution to the problem of financial planning in a rapidly changing environment. Modular construction provides the capability to analyze the limited effects of a decision in one planning area or the broad, interrelated effects of that decision in other areas. Other design characteristics make the model reliable, easy to use, and adaptable to perform routine calculations for individual planning personnel. The implementation strategy was important in stimulating the interest and involvement of potential users, which led to constructive feedback and useful modifications in the models. The success of the Overall Planning Model is most clearly demonstrated, however, by the actual applications it has achieved throughout the company. ■

NEW INSTALLATIONS

(Continued from page 6)

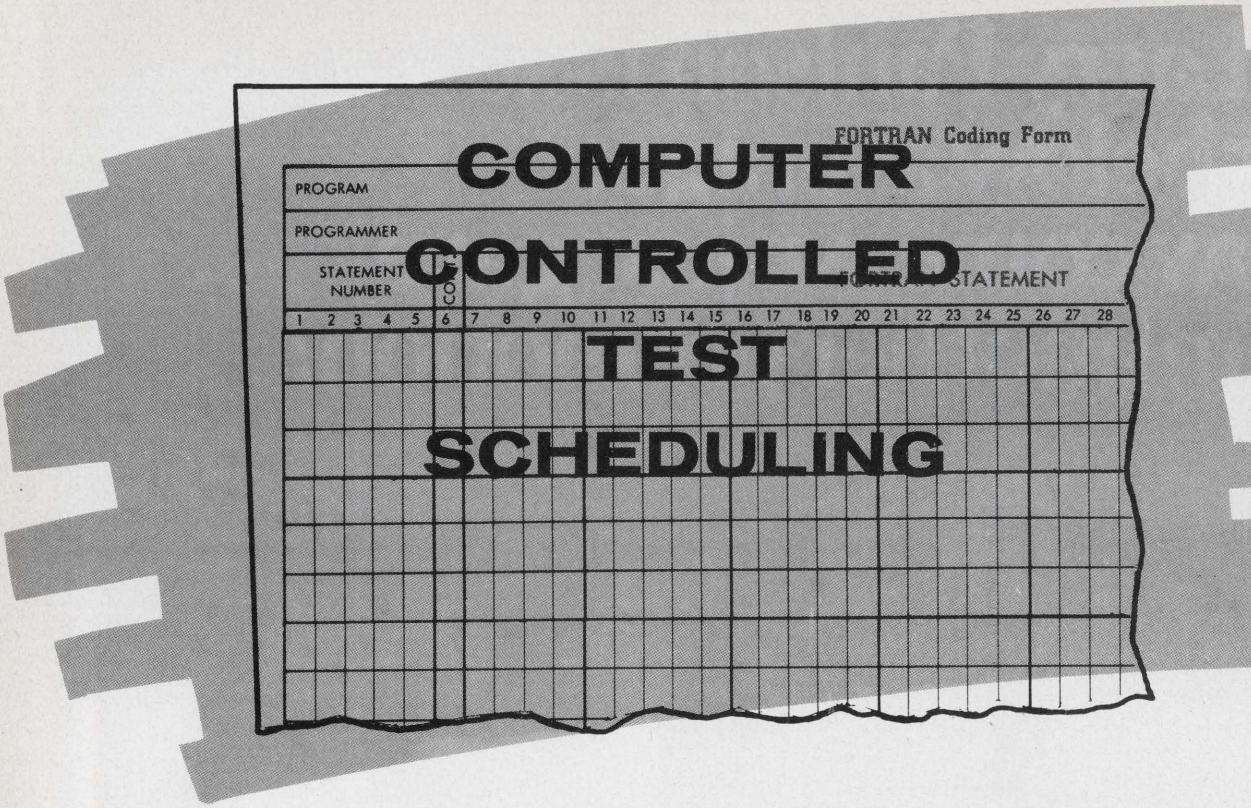
Toronto, the firm announced this as the first of many expansions throughout the area.

■ ■ ■

Ohio Bell Telephone Company is completing the installation of a $2 million UNIVAC 494 Real-Time Computer System. Located in Cleveland, more than 200 teletypes in various operating departments will be connected with the systems. In addition to the central processing unit and its 65,000 word core memory, the system will also include two FH-432 and FH-880 high-speed memory drums, four FASTRAND II mass storage memory units, eight UNISERVO VIII-C magnetic tape units, one UNIVAC 1004 Card Processor and three communications sybsystems. The entire system has been designed to enable customers to obtain immediate information about his account and to provide operating departments with information on telephone equipment inventories held by the various customer accounts.

■ ■ ■

COMPUTER CONTROLLED TEST SCHEDULING



James K. Ryan
Gerald M. McDonough

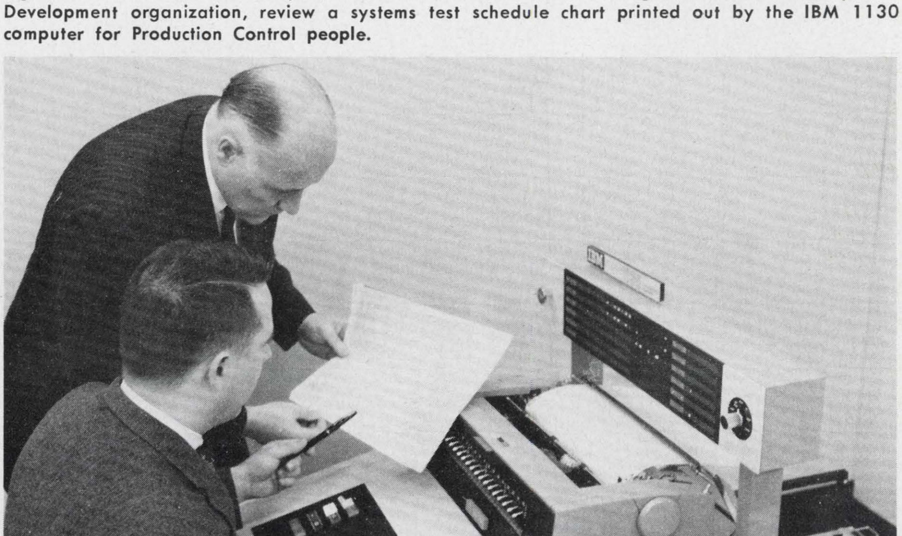
■ Large scale products of IBM's System/360 call for extensive and complex test facilities whose optimum use must be maintained by the Production Control people who schedule these facilities. Each of these IBM computing systems must undergo an exacting series of systems tests before it can be shipped to a customer. However, a system cannot be scheduled for systems test until a test area, designed to accommodate its particular size and complexity, is made available.

Systems test schedule charts, which are Production Control's roadmaps for scheduling the use of multiple test areas, have traditionally been prepared by hand. They were often out of date before they were released to manufacturing managers and they were usually both costly and time-consuming to prepare.

A solution to this problem was developed jointly by the Information Systems Development and Production Control organizations at IBM's Systems Manufacturing Division plant in Kingston, N. Y. Members of this group created computer programs, written in 1130 Fortran IV, which quickly and economically generate a systems test schedule chart using an IBM 1130 computer system (Figure 1).

The system takes bulky flow charts, easel pads, and multi-colored magic markers out of the hands of the Production Control scheduler and places at his disposal one deck

Figure 1.—Co-author James Ryan, left, and a member of IBM Kingston's Information Systems Development organization, review a systems test schedule chart printed out by the IBM 1130 computer for Production Control people.



James K. Ryan is a senior associate systems analyst in Information Systems Development at IBM's Systems Manufacturing Division plant in Kingston, New York.

Gerald M. McDonough is Planning and Scheduling manager in the Materials Planning and Control organization at IBM's Systems Manufacturing Division plant in Kingston, New York.

of IBM cards on which he is able to handle all the required data about the systems and the test areas.

Using the information contained on these cards, the IBM 1130 computing system can generate the following information:

- The systems test schedule chart.
- A weekly or monthly summary for each system type scheduled for test. This summary lists the number of each system type scheduled to start systems test, how many systems are currently in test, and the number of systems scheduled to be shipped.
- A list of schedule changes which supersede specific information carried on the previous chart.
- A legend to explain the symbols used on the test schedule chart (e.g. model type, advance planning, reserved areas, etc.).

Three programs were written by Information Systems Development people so as to provide more efficiency and greater flexibility in developing copies of the test scheduling charts. If a need exists, the user may address each of the programs separately.

Date heading generator program. The Date Heading Generator Program takes one input card containing the beginning and ending dates of the scheduled testing period and develops actual working dates which will be required to generate individual system test cycles. This program contains two tables. The first table displays the possible work days in any month (7 entries). The second, which is maintained by the materials control scheduler, will recognize the proper Table 1 entry for each month—per year—and any holidays which might occur in that month. Presently, this second table will be able to accommodate entries for three years.

The Date Generator Control Card (Figure 2) defines the extent of the schedule period (beginning and end dates) and which of two schedule formats should be prepared by the Date Generator program. The first of these is the current year format. In this format, the first 13 weeks are listed, with each work day identified. This is followed by the remaining nine months of the year, with each Friday identified. The second format provides for a planning period of up to 22 months with each Friday date being indicated.

The system test schedule portion of the program output is developed in multiples of five columns (or positions). A period is inserted in the fifth position of each month containing four Fridays or, whenever a holiday occurs in the daily portion of the current year format.

The Date Heading Generator program is also used to develop a table which identifies the "print" position of each date of the requested chart period. This table, as well as the schedule formats, are used by a Schedule Chart Developer program to either load the data on the "dedicated" IBM 2315 disc cartridge or, at the discretion of the user, keypunch the data on cards.

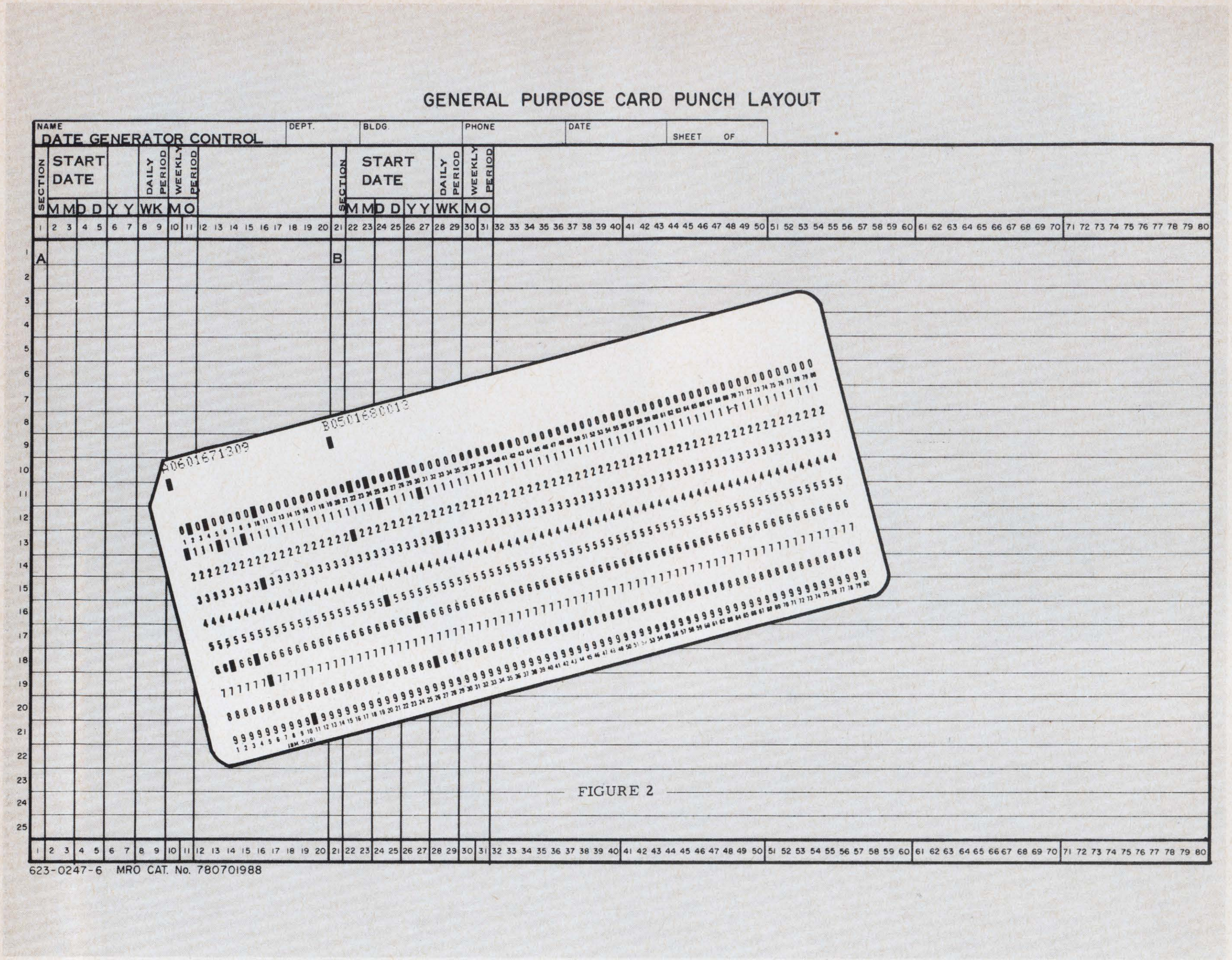


Figure 2.—The Date Generator Control Card defines the extent of the schedule period (beginning and end dates) and which of two schedule formats should be prepared by the Date Generator program.

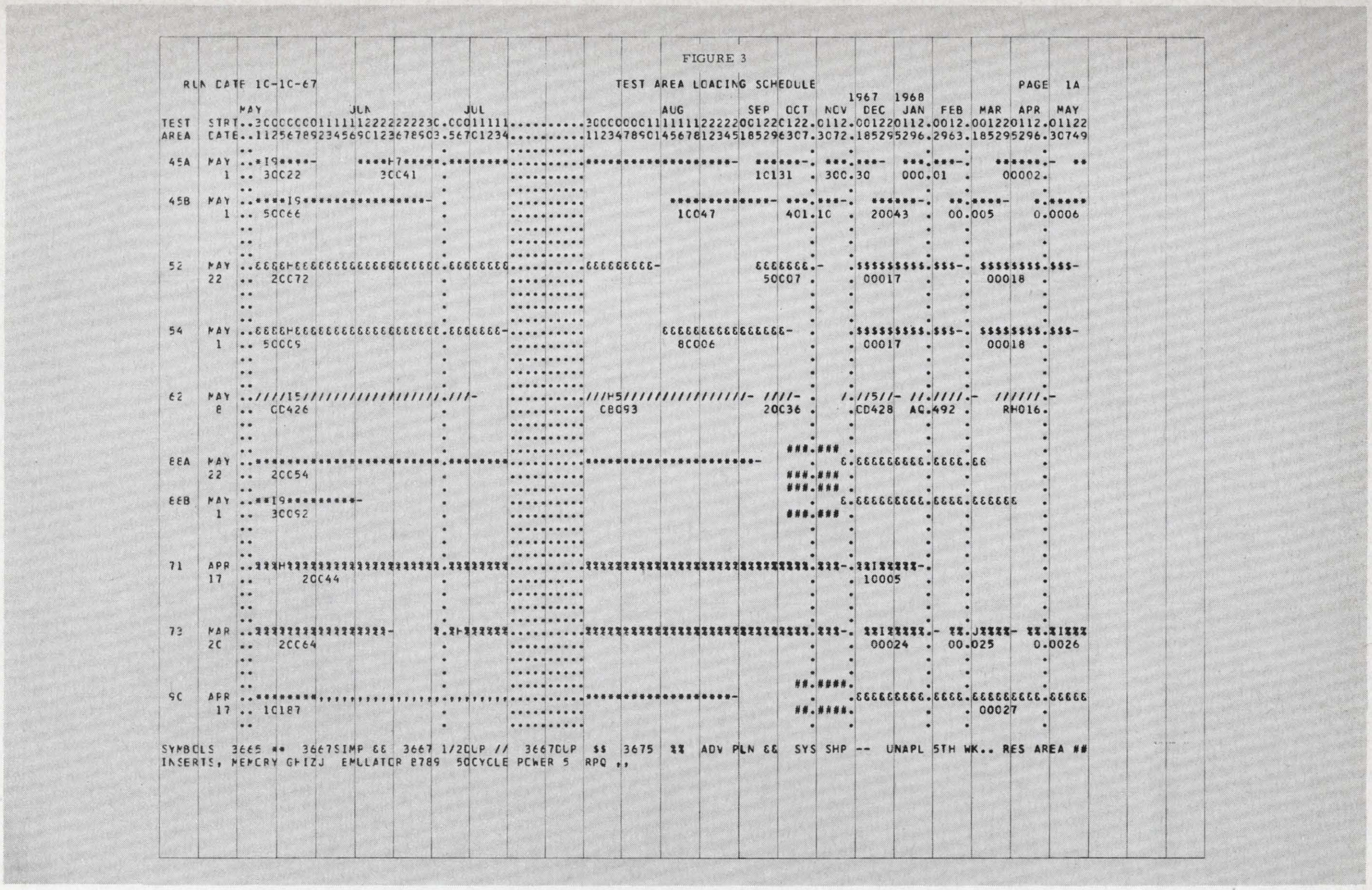
Schedule chart developer program. The Schedule Chart Developer program performs audits to ensure that each of Kingston's computer systems is properly identified for easy recognition, scheduled for test within the proper time period and assigned to a systems test area which can adequately accommodate it. This program uses the selected output of the Date Heading Generator program, plus the system schedule cards to create system test schedule lines and system test identity lines (Figure 3) for each system test area.

A System Schedule card (Figure 4) is created for each computer system scheduled to undergo systems testing. This card contains the identity of the system, the date on which systems testing is to begin, the scheduled shipping date, the memory size and the power required (if other than 60 cycles). The card also carries its own issue date. When this date matches the date of which the Schedule Chart Developer program is run by the IBM 1130 computing system, data contained on the schedule card is added to a change list. This information is loaded on a disc cartridge in a manner similar to the system test schedule lines and system identity lines. When the last test area schedule has been loaded, the program automatically develops a summary report format for each model type of the system being tested.

In the event that some of the audit parameters are exceeded, the specific condition of the parameter and the system involved are noted on the console typewriter of the IBM 1130. The program, if possible, continues by accepting the next system schedule card. Several error conditions can be easily recognized on a single program run. The user can correct conditions which are listed on his console sheet by printing whatever information is available on the disc cartridge.

Once the complete schedule chart has been generated, changes may be made to the data on the disc cartridge by using system schedule cards for only those computer systems being changed or relocated, if the time period for the schedule report remains unchanged.

Schedule chart generator program. The Schedule Chart Genera-



```
                                          FIGURE 3
RUN DATE 1C-1C-67                  TEST AREA LOACING SCHEDULE                          PAGE  1A
                                                                     1967  1968
       MAY          JUN          JUL              AUG        SEP  OCT  NOV  DEC   JAN  FEB  MAR  APR  MAY
TEST  STRT..3CCCCCC01111112222222223C.CCO11111..........3CCCCOOC11111112222200122C122.0112.00122O112.0012.001220112.01122
AREA  CATE..11256789234569C123678903.567C1234..........11234789C14567812345185296307.3072.185295296.2963.185295296.30749

 45A  MAY ..*I9****-     ****H7*****.********..........*******************-  ******-. ***.***-  ***.***-.  ******.-  **
        1 ..  30C22          30C41   .       ..........                      1C131  . 30C.30   000.01  .   00002.

 45B  MAY ..****I9****************-  .       ..........         *************- ***.***-.  ******-.  **.****-  *.*****
        1 ..  5CC66                  .       ..........           1C047       401.1C  .  20043  .  00.005    0.0006

 52   MAY ..&&&&H&&&&&&&&&&&&&&&&&&&&.&&&&&&&&..........&&&&&&&&&-            &&&&&&&.-  .$$$$$$$$$.$$$-. $$$$$$$$.$$$-
       22 ..  2CC72                  .       ..........                      50C07 .   . 00017   .   .  00018  .

 54   MAY ..&&&&H&&&&&&&&&&&&&&&&&&&&.&&&&&&&-..........          &&&&&&&&&&&&&&&&-  .  .$$$$$$$$$.$$$-. $$$$$$$$.$$$-
        1 ..  5CCC9                  .       ..........           8C006             .  . 00017   .   .  00018  .

 62   MAY ..////I5//////////////////////.///-  ..........///H5/////////////////- ////-  .  /.//5//- //.////.-  //////.-
        8 ..  CD426                  .       ..........  C8093              20C36 .  .CD428  AQ.492 .     RH016.

                                                                          ###.### .
 88A  MAY ..************************.********..........**********************-     .  &.&&&&&&&&&.&&&&.&&          .
       22 ..  2CC54                  .       ..........                    ###.### .
                                                                          ###.### .
 88B  MAY ..**I9**********-                  ..........                           .  &.&&&&&&&&&.&&&&.&&&&&&      .
        1 ..  3CC92                  .       ..........                    ###.### .

 71   APR ..%%%H%%%%%%%%%%%%%%%%%%%%%.%%%%%%%%..........%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%.%%%-.%%I%%%%%-.
       17 ..       2CC44             .       ..........                           . 10005    .

 73   MAR ..%%%%%%%%%%%%%%%%%-      %.%H%%%%%%..........%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%.%%%-. %%I%%%%%.- %%.J%%%%- %%.%I%%%
       2C ..    2CC64               .       ..........                           .  00024  .  00.025    0.0026

                                                                          ##.####.
 9C   APR ..********,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,******************-        .&&&&&&&&&.&&&&.&&&&&&&&&.&&&&&
       17 .. 1C187                  .       ..........                    ##.####.          . 00027   .

SYMBOLS  3665 **  3667SIMP &&  3667 1/2DUP //  3667DUP  $$  3675  %%  ADV PLN &&  SYS SHP --  UNAPL 5TH WK.. RES AREA ##
INSERTS, MEMCRY GHIZJ  EMULATOR 8789  50CYCLE POWER 5  RPQ ,,
```

Figure 3.—The Schedule Cart Developer program uses the selected output of the Date Heading Generator program, the system schedule cards to create test schedule lines and system test identity lines for each system test area.

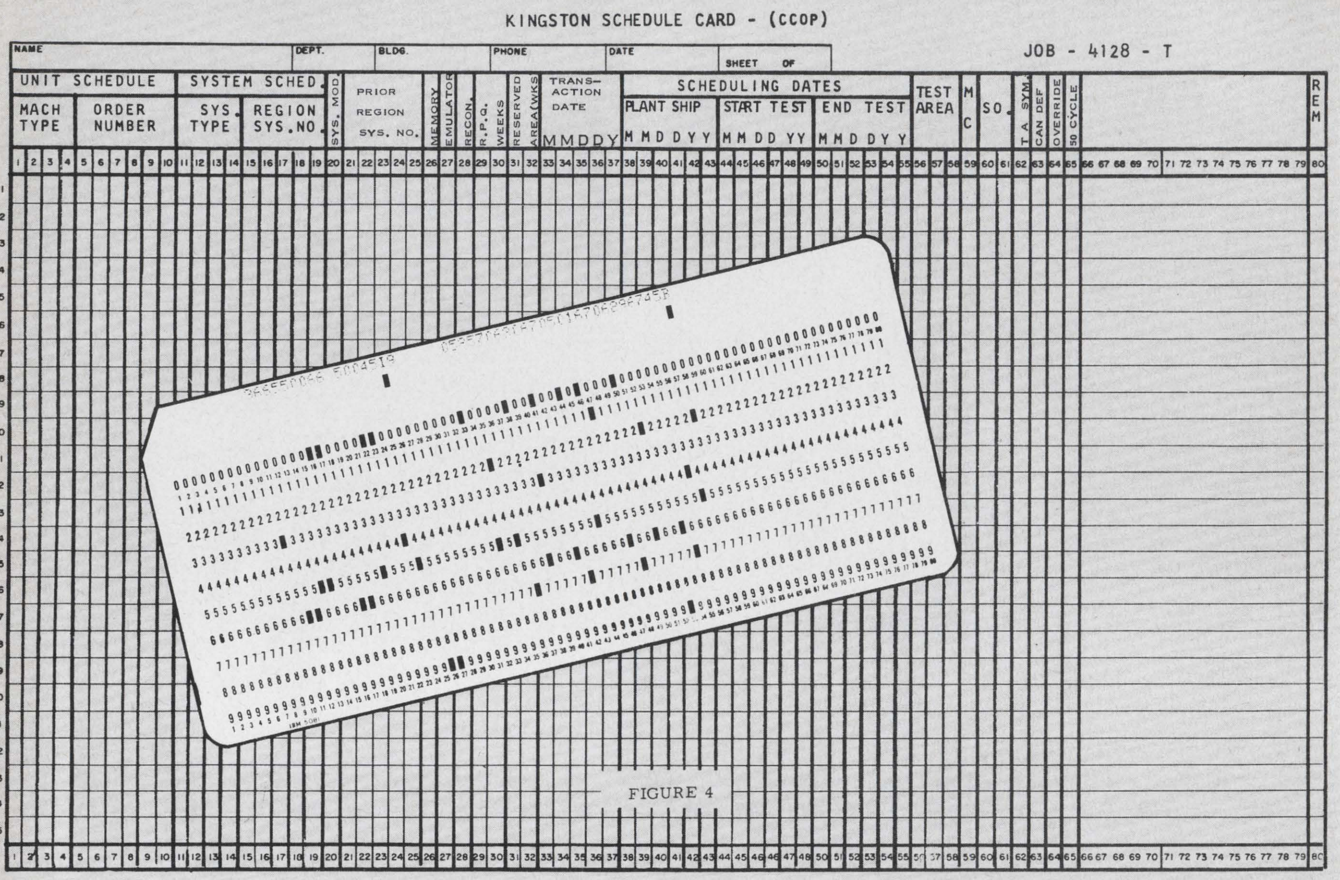
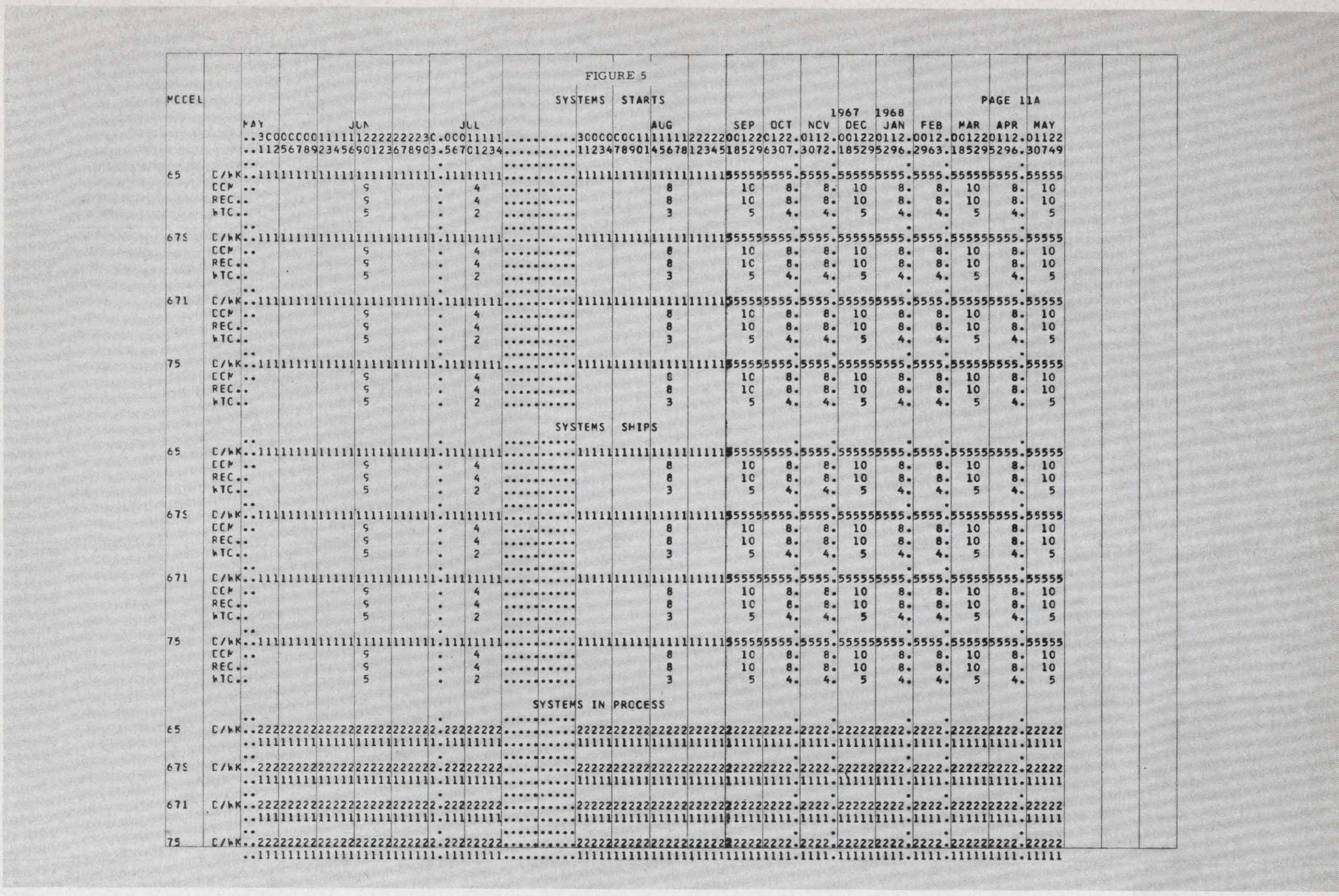


Figure 4.—A System Schedule card is created for each computer system scheduled to undergo systems testing. This card contains the identity of the system, the date on which systems testing is to begin and other information.

tor program will print copies of the systems test schedule format (Figure 3) from the information that has already been loaded on the disc cartridge by the Schedule Developer program. A special two-part paper stock, with a hard carbon insert, is used so that readability of the chart will not be affected by continuous handling. The paper has alternating light green and dark green columns at 10 columns to the inch so that each printed character will center in its own column. Every five columns are separated with a dark line so that each week or month will fall within its own block. Column 76 is designated by still a darker color. This column separates individual weeks from months on the current year format.



```
                                       FIGURE 5
MODEL                             SYSTEMS  STARTS                                       PAGE 11A
                                                                              1967 1968
        MAY        JUN           JUL                    AUG        SEP  OCT  NOV  DEC  JAN  FEB  MAR  APR  MAY
        ..30000000111112222222230.00011111..........300000001111111222220012201 22.0112.001220112.0012.001220112.01122
        ..112567892345690123678903.56701234..........112347890145678123451852963 07.3072.185295296.2963.185295296.30749
        ..                        .        ..........
65      C/WK..1111111111111111111111111.11111111..........11111111111111111111555555555.5555.555555555.5555.555555555.55555
        CCM ..           9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        REC..            9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        WTC..            5            .  2  ..........        3      5   4.   4.   5    4.   4.   5    4.   5
        ..                        .        ..........
67S     C/WK..1111111111111111111111111.11111111..........11111111111111111111555555555.5555.555555555.5555.555555555.55555
        CCM ..           9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        REC..            9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        WTC..            5            .  2  ..........        3      5   4.   4.   5    4.   4.   5    4.   5
        ..                        .        ..........
671     C/WK..1111111111111111111111111.11111111..........11111111111111111111555555555.5555.555555555.5555.555555555.55555
        CCM ..           9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        REC..            9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        WTC..            5            .  2  ..........        3      5   4.   4.   5    4.   4.   5    4.   5
        ..                        .        ..........
75      C/WK..1111111111111111111111111.11111111..........11111111111111111111555555555.5555.555555555.5555.555555555.55555
        CCM ..           9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        REC..            9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        WTC..            5            .  2  ..........        3      5   4.   4.   5    4.   4.   5    4.   5

                                  SYSTEMS  SHIPS
        ..                        .        ..........
65      C/WK..1111111111111111111111111.11111111..........11111111111111111111555555555.5555.555555555.5555.555555555.55555
        CCM ..           9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        REC..            9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        WTC..            5            .  2  ..........        3      5   4.   4.   5    4.   4.   5    4.   5
        ..                        .        ..........
67S     C/WK..1111111111111111111111111.11111111..........11111111111111111111555555555.5555.555555555.5555.555555555.55555
        CCM ..           9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        REC..            9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        WTC..            5            .  2  ..........        3      5   4.   4.   5    4.   4.   5    4.   5
        ..                        .        ..........
671     C/WK..1111111111111111111111111.11111111..........11111111111111111111555555555.5555.555555555.5555.555555555.55555
        CCM ..           9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        REC..            9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        WTC..            5            .  2  ..........        3      5   4.   4.   5    4.   4.   5    4.   5
        ..                        .        ..........
75      C/WK..1111111111111111111111111.11111111..........11111111111111111111555555555.5555.555555555.5555.555555555.55555
        CCM ..           9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        REC..            9            .  4  ..........        8     10   8.   8.  10    8.   8.  10    8.  10
        WTC..            5            .  2  ..........        3      5   4.   4.   5    4.   4.   5    4.   5

                                  SYSTEMS IN PROCESS
        ..                        .        ..........
65      C/WK..2222222222222222222222222.22222222..........22222222222222222222222222222.2222.222222222.2222.222222222.22222
            ..1111111111111111111111111.11111111..........11111111111111111111111111111.1111.111111111.1111.111111111.11111
        ..                        .        ..........
67S     C/WK..2222222222222222222222222.22222222..........22222222222222222222222222222.2222.222222222.2222.222222222.22222
            ..1111111111111111111111111.11111111..........11111111111111111111111111111.1111.111111111.1111.111111111.11111
        ..                        .        ..........
671     C/WK..2222222222222222222222222.22222222..........22222222222222222222222222222.2222.222222222.2222.222222222.22222
            ..1111111111111111111111111.11111111..........11111111111111111111111111111.1111.111111111.1111.111111111.11111
        ..                        .        ..........
75      C/WK..2222222222222222222222222.22222222..........22222222222222222222222222222.2222.222222222.2222.222222222.22222
            ..1111111111111111111111111.11111111..........11111111111111111111111111111.1111.111111111.1111.111111111.11111
```

Figure 5.—A Summary Report is printed on the page which follows the last test area to be scheduled for use.

The date heading and page number are printed at the top of each systems test schedule chart, followed by the number of the test areas which can be accommodated on a page. A symbol legend is located at the bottom of each schedule page.

A Summary Report (Figure 5) is printed on the page which follows the last test area to be scheduled for use. This report, in turn, is followed on a succeeding page by the change list. This list permits the user to easily identify any system which may have test data which is different from the information listed on a prior schedule chart run.

The computer generated systems test schedule chart has significantly reduced the time it takes to obtain systems test information. It has helped IBM manufacturing managers to maintain more efficient and effective use of its systems test areas. ■

SCHEDULING

This article discusses two scheduling methods which can provide maximal computer throughput in a multiprogramming fixed partition size environment. The scheduling problem is expressed as a linear or nonlinear programming model dependent on the type of scheduling control desired. The models are developed for a two partition system, but can be extended to any number of partitions. The solutions can also be used to reflect specified or optimal partition sizes.

Guy L. Curry
Allen C. Schuermann, Jr.

■ Multiprogramming is a concept which attempts to utilize the computer's capabilities by making them available to two or more programs simultaneously. In this environment, the program ordering and partition assignment influence the computer throughput. This article is concerned with optimal scheduling policies for a specific multiprogramming technique. For the technique considered, the available core is segmented into n program locations or partitions, which need not be of equal size. The CPU (Central Processing Unit) can be utilized by only one partition at a time, and it is therefore necessary to have a priority scheme for the allocation of the CPU time. For the system under consideration, the CPU priority is characteristic to the partition and not the program. Thus, the problem is to assign the work to the various partitions in such a manner that the resultant time to complete the work is minimal.

Multiprogramming

The concept of multiprogramming may be illustrated by the following simplified example:

Consider a two partition system with enough I/O (Input-Output) capacity to handle any I/O requirements without interference. The program run time is then strictly dependent on the availability of CPU cycles. The program in the high CPU priority partition has preemptive power over the other program. Thus, the high CPU priority partition program will complete in its normal singular processing run time. The second program will sometimes be required to wait for CPU cycles and hence will take longer than the normal run time. The amount of extra wait time or degradation factor is dependent on the amount of CPU usage of both programs. The higher the CPU requirement of the first job the longer the second program will take to complete.

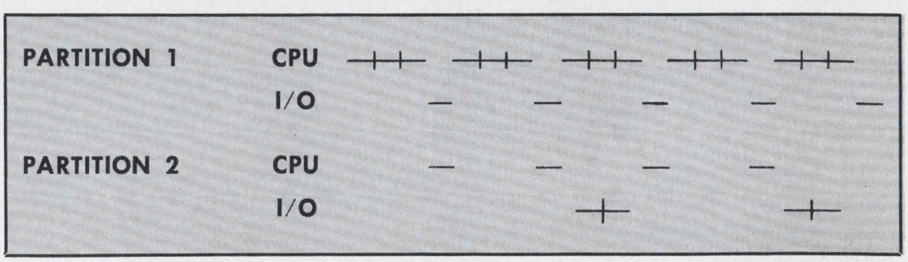
Figure I will illustrate this phenomenon. Let the program in the high priority partition (Partition 1) require three CPU cycles to each I/O cycle and the program in the low priority partition (Partition 2) require two CPU cycles for each two I/O cycles. Assume that these relationships are constant and repetitive.

Scheduling Methods

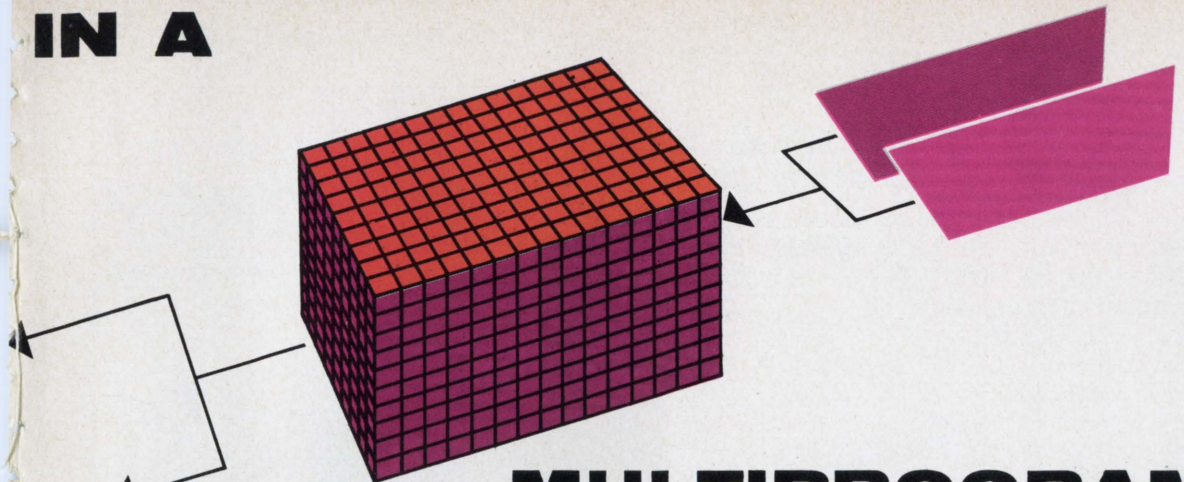
There are two general classes of control in a multiprogramming environment. The first type of control is one in which the order the jobs are processed is immaterial. The type of programs allocated to the high priority partition determine the average run times of the programs assigned to the low priority partitions. Thus, the scheduling problem in this case is to determine which type of programs to assign to each partition to maximize the computer throughput. To insure the success of this approach, a large enough time period is required so that the actual run times are accurately represented by the estimated times. The mathematical representation of this environment is a nonlinear system of equations.

For the second type of control, the order as well as the partitions

FIGURE 1: Cycles of CPU and I/O time allocated to each program



IN A



MULTIPROGRAMMING ENVIRONMENT

in which programs are run is controlled. Under these circumstances, the problem becomes one of specifying the type of programs to be run simultaneously and the assignment of partitions for each program. To implement this type of control, it appears necessary to develop a system's program to monitor the application. The mathematical model representing this control class is a linear system of equations.

Thus, the two general classes of control lead to the development of two scheduling methods which can be used to provide maximal computer throughput.

To employ the scheduling techniques, the following information must be known:

1. Each program must be categorized according to its average percent of CPU usage. Any number of categories may be used.
2. The core requirements for each program.
3. The average high CPU priority partition run time for each program.
4. The average low CPU priority run time for each CPU percentage category relative to each CPU percentage category operating in the high CPU priority partition. That is, the relative increase in the run time in the low priority partition, when a specific usage class is running in the high priority partition. This information can be estimated through the use of a simulation model if it is not readily available. A simulation model was developed by the authors for this purpose using the IBM GPSS/360 language [1]. Through the use of this model, estimates for two and three partition system run times were obtained for three CPU classes.

The scheduling methods will be presented for a two partition system and can easily be extended to any number of partitions.

Nonlinear Model

Let:

- n — the number of usage classes
- R_i — the total run time to be scheduled for the ith usage class
- X_i — the fraction of the ith usage class total run time that is allocated to the high priority partition
- $(1 - X_i)$ — the fraction of the ith usage class run time allocated to the low priority partition
- D_{ij} — the average degradation factor for a program of class i in the low priority partition with a program of class j in the high priority partition.

Then,

- X_iR_i — the total time the ith class will require in the high priority partition
- (1) $\sum_{i=1}^{n} X_iR_i$ — the total run time in the high priority partition
- $\dfrac{X_iR_i}{\sum_{i=1}^{n} X_iR_i}$ — the percent of the time the ith class will be running in the high priority partition.

The average degradation factor for the ith usage class in the low priority partition can be expressed as:

$$\frac{\sum_{j=1}^{n} X_jR_jD_{ij}}{\sum_{k=1}^{n} X_kR_k}$$

The total run time for all work in the low priority partition is:

$$(2)\quad \frac{\sum_{i=1}^{n} (1-X_i)R_i \sum_{j=1}^{n} X_jR_jD_{ij}}{\sum_{k=1}^{n} X_kR_k}$$

The X_i's must be between 0 and 1; in addition, if only 90% of the ith category work can fit in the high priority partition, then $X_i \leqq .9$. Also if only 40% of the jth category work can fit in the low priority partition, then $X_j \geqq .6$.

Thus,

$$(3)\quad 0 \leqq a_i \leqq X_i \leqq b_i \leqq 1 \text{ (for all i)}$$

Two observations can be made about the system:

(a) The optimum throughput occurs when both partition run times are equal and as small as possible;

(b) The low priority partition operates like the high priority partition if the high priority partition is empty. Therefore, a restriction must be employed to insure that at least half of the work runs without a degradation factor.

$$(4)\quad \sum_{i=1}^{n} R_i \leqq 2\sum_{i=1}^{n} X_iR_i$$

The maximum computer throughput for the problem defined by (1), (2) (3) and (4) is the minimization of

$$\sum_{i=1}^{n} X_iR_i$$

subject to

$$(a)\quad \sum_{i=1}^{n} (1-X_i)R_i \sum_{j=1}^{n} X_jR_jD_{ij} - \left(\sum_{k=1}^{n} X_kR_k\right)^2 = 0$$

$$(b)\quad 0 \leqq a_i \leqq X_i \leqq b_i \leqq 1 \text{ (for all i)}$$

$$(c)\quad \sum_{i=1}^{n} R_i \leqq 2\sum_{i=1}^{n} X_iR_i$$

Carroll's Response Surface Technique [2] can be used to obtain the optimum solution. However, a parametric approach, a technique in which the variables are systematically varied, is quite useful since a class of near optimal solutions is obtained. This class of solutions may contain more easily controlled solutions near the optimum. For example, if the optimum solution for two variables to be allocated to the high priority partition is 33 and 75 percent, it would be easier to control a solution such as 0 and 100 percent. The parametric solutions are also useful in studying different partition sizes. These solutions can be summarized by partition size and thus result in the optimum solutions for the various partition sizes. Summarization by computer throughput and then by partition size results in groups of partition sizes and solutions which can be used to obtain similar throughput results.

Linear Model

Let n, R_i, D_{ij} be the same as in the nonlinear model definition.

Let:

Y_j — percent of usage class j to be run in the high priority partition

X_{ij} — percent of usage class i to be run in the low priority partition while the jth CPU class is running in the high priority partition.

Then,

$$(1)\ \sum_{j=1}^{n} Y_j R_j \text{ — total run time in the high priority}$$

The total amount of work to be run in the low priority partition while the jth CPU class is in the high priority partition is:

$$(2)\ \sum_{i=1}^{n} X_{ij} R_i D_{ij} \leq Y_j R_j \text{ (for all j)}$$

The total percent of each CPU usage class must be equal to one and each element must be positive, hence:

$$(3)\ \sum_{j=1}^{n} X_{ij} + Y_i = 1 \text{ (for all i)}$$

$$(4)\ X_{ij}, Y_j \geq 0 \text{ (for all i, j)}$$

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SA-1

linear programming [3], where the object is to minimize (1) subject to (2), (3) and (4).

Conclusions

Linear and nonlinear programming techniques appear to be useful in scheduling computer work in a multiprogramming environment. The systems presented can be used to study the optimal number of partitions and their sizes for a given computer in a particular work load environment. ■

REFERENCES

[1] "General Purpose Simulation System/360—User's Manual", IBM Document H20-0326.

[2] Carroll, Charles W., "The Created Response Surface Technique for Optimizing Nonlinear Restrained Systems", Operations Research, Volume 9, No. 2, March–April, 1961.

[3] "Mathematical Programming System/360—User's Manual", IBM Document H20-0290.

GECOS III

(Continued from page 14)

essor burners" (processor-limited programs) only when all the other programs have been serviced. On the other hand, when there is little I/O loading, the systems stays for a longer period in each program, with proportionately less overhead.

GECOS performs all interrupt processing and dispatching in less than 15% of the processor cycles when the system is heavily loaded, and in about 5% of the cycles when only "processor burners" are in memory.

Test and Diagnostic System

Experience has strongly indicated that an operating system for a large-scale computer must include a comprehensive test and diagnostic (T&D) system, particularly for the peripherals.

GECOS III includes special interfaces for the T&D system to allow it to test any peripheral operation. The I/O supervisor simply returns the status without analysis to the T&D program. The T&D system must observe device allocation rules of GECOS.

Operations personnel may request through the control console that any device be tested at any time. Also, at any error condition on a device, a demand may be made to test that device as soon as it is free.

A portion of every shared-access device is reserved for use by the T&D system for recording tests.

Error information accumulated by the operating system or the T&D system is accumulated on an accounting file, allowing for continual measurement of peripheral device performance. Problems can be spotted and corrected before they reach the disaster stage.

Time-Sharing

The GE-600 time-sharing system embodied in GECOS III answers the question, "How can installations provide time-sharing functions without disrupting existing batch processing commitments?"

The GECOS time-sharing system is designed for installations that have a batch commitment and also need time-sharing. The portion of the hardware dedicated to time-sharing is dynamically variable, providing an operating spectrum from full time-sharing through full batch processing, according to the requirements of the installation.

GECOS time-sharing is designed to encourage development by users, following an extension of the present batch mode philosophy in which the manufacturer supplies the operating system, commonly used compilers, edit functions, and a variety of application programs, while the user develops the specific programs required for his business.

The time-sharing executive is a privileged system program within GECOS. Time-sharing occupies a block of memory of variable size, depending on the desired time-sharing/batch ratio. This block contains:

—The SSA.
—The time-sharing executive.
—User status tables and buffers.
—Time-sharing user memory.

To provide fast response for the heavy I/O load imposed by multiple time-sharing users, the SSA includes considerably extended I/O queueing and file definition capabilities.

The time-sharing executive performs the functions of selecting, allocating, dispatching, and swapping time-sharing user programs. Since the time-sharing executive is treated as a single system program by GECOS, it sub-allocates memory and sub-dispatches the processor to individual time-sharing user programs. In the process of sub-dispatching, the time-sharing executive establishes a new BAR setting around the user program to be executed, insuring the integrity of other user programs in memory.

The time-sharing executive also performs variout services for individual programs, including file system I/O, terminals I/O, and creation and modification of files, catalogs, and their security definitions; and it accounts for resources used by the individual time-sharing users.

The user status table and buffers are used to maintain the current status of the programs and to accumulate data generated by terminal I/O.

Time-sharing user memory is allocated to individual user programs for execution. Several programs may occupy portions of this area. A program may be swapped to allow another user of higher priority to be allocated memory space.

One of the major integrating factors in the design of the time-sharing system is the use of the GECOS file system. It is through this common file system that user programs in the batch system and in the time-sharing system communicate with each other.

A straight-forward application of this capability allows a large batch job to generate or update a file (perhaps based on inputs from another file entered from time-sharing terminals) and have the updated file available for inquiry by time-sharing users.

An even more interesting capability allows the time-sharing system to generate a job for the batch system. The user program in the batch system may be too large to process conveniently in the time-sharing mode, or may be an existing program for which modification for direct execution in the time-sharing mode is not desirable. An option exists to allow a time-sharing program to wait for the completion of a batch job. In addition, there can be a direct "conversation" between a batch program and a remote terminal.

The time-sharing system provides an extensive set of commands by which the user communicates his processing requirements to the system. In addition, an interface has been provided to allow the knowledgeable user to specify new commands. Each command consists of a list of primitives.

The commands and their associated sets of primitives are unique to each language. The primitives define sequences of processes that are to be executed when the command is entered. The primitives consist of such functions as loading and execution of programs, conditional transfer of control to other primitives, and initiation of various input and output modes.

Status

GECOS III is now running on several GE-635 systems.

All GECOS II jobs execute under GECOS III without program or control card modification, including extensive test programs collected to quality-assure GECOS II updates and the reliable operation of GE-600 systems prior to shipment. Remote batch and time-sharing programs execute in concurrent operation, demonstrating the integrated operation of the system. ■

new products

Two new products—the UNIVAC 0707 **Card Reader/Communications Terminal** and the UNIVAC 0708 **Card Reader**— were introduced recently.

Typical applications for the equipment would be in general accounting processing, inventory status, and other functions requiring constant updating.

The Model 0707 is capable of interfacing with most communication terminals. It consists of a card reader with an electronics unit, and is interfaced with a teletypewriter plus modem. Line transmission is in American Standard Code Information Interchange (ASCII).

The 0708 unit can be incorporated into other manufacturers' computer systems, automatic control systems, and other applications which require slow speed card reading with the ability to stop and hold on each column of the punched card.

Depending upon requirements, the 0707 and 0708 Card Readers can read column-by-column in the incremental mode at up to 10 cards per minute, or 40 cards per minute in a continuous mode.

Equipped with input and output magazines with a capacity of 500 cards, the Card Reader is 20 inches in width, 12 inches high, and 8 inches in depth. It weighs 25 pounds.

For more information circle No. 80 on the Reader Service Card

* * *

Potter Instrument Company, Inc., has developed a revolutionary, low-cost **adaptive logic circuit attachment**, ADLOGIC. Although no circuit changes are necessary in connecting the ADLOGIC to disk packs, random access memories, high density tape handlers, or any device using phase encoding, ADLOGIC increases effective packing densities by 1.5 to 1.7 times normal densities.

The 50% storage dividend is achieved by Potters' ADLOGIC without imposition of any additional requirement on the recording or playback response of a particular system. Instead, it achieves the increased throughput by means of electronic coding techniques. It is simply connected between the input and output of each disk pack, random access memory, tape handler or phase encoding unit.

The effective density of recording in ADLOGIC is increased by increasing the ratio of information transitions to clocking transitions while still retaining the self-clocking characteristics of phase encoded recording. As recording achieves higher and higher packing densities, the new Potter ADLOGIC system will continue to increase the effective packing densities by 1.5 to 1.7 times over the nominal density.

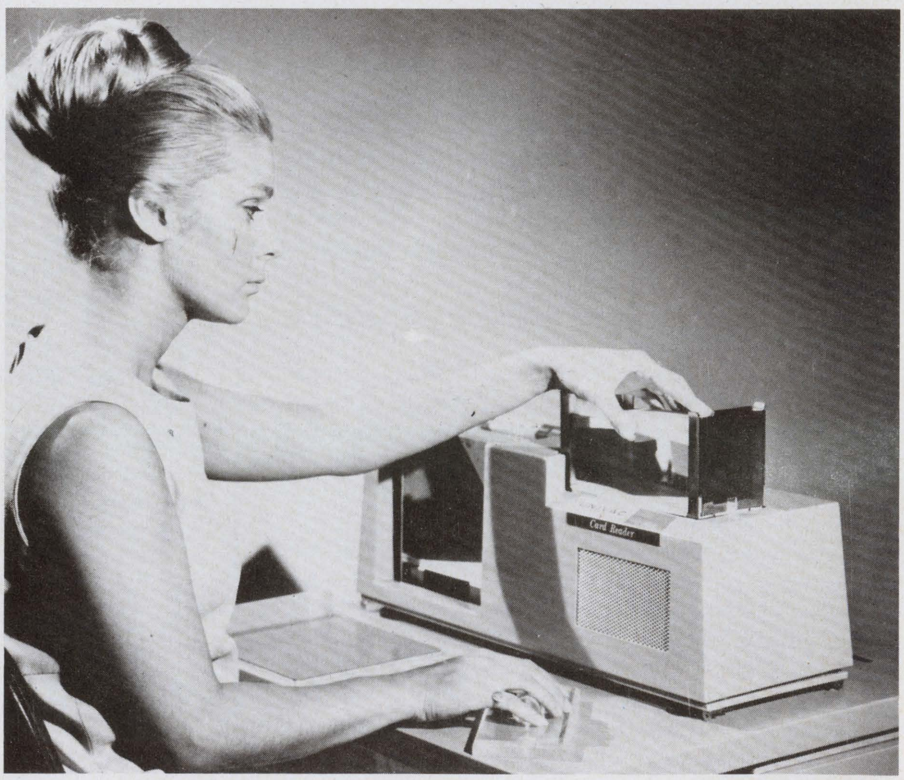
For more information, circle No. 79 on the Reader Service Card

* * *

Now it is possible to display computer information in color with General Electric's Datanet-760 **data display terminals.**

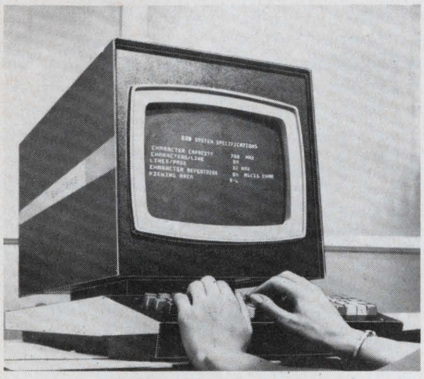
Color information display can be useful, GE said, in indicating out-of-limits conditions in on-line, real-time applications, and in drawing more recognizable contrasts between certain types of data, such as profit and loss, in-stock versus back-ordered inventory, and so on.

The color modified Datanet-760 is ca-



pable of displaying computer-generated information in red and green. Availability is said to be six months.

For more information, circle No. 78 on the Reader Service Card



The new 620 Stand-alone **Data Display System** is now available from Sanders Associates, Inc. It is a completely self-contained system designed to handle retrieval and update applications quickly. I/O, editing, memory, character generation, power supply and other circuitry are all housed in a single terminal unit. A Sanders exclusive is memory save which allows the standard 768 characters to be displayed at any of 2048 positions on the 9½" x 7½" horizontal screen. Memory save permits the user to arrange data in the most useful formats without serious reductions in displayable message length. The standard unit is available for purchase or rental.

For more information, circle No. 79 on the Reader Service Card

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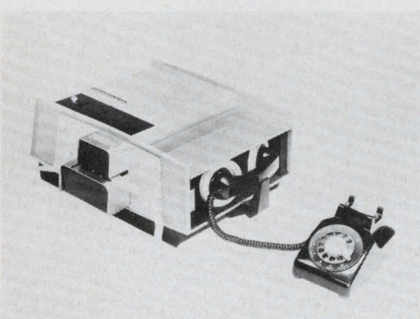

Digitronics Corporation, announced a new line of low-cost **data transmitters** which enable remote locations to transmit data over telephone lines without using data sets.

The new units, called AUDIO-VERTER, convert input data to audio tones and couples these tones, via an acoustic coupler, to a standard telephone for transmission.

Designed for use by remote locations in sending information over the dial telephone network to centralized EDP centers, the AUDIO-VERTER transmitters require no data sets. Most standard telephones can be used to interface the unit to the telephone network. Used with today's modern office machines, such as a cash register which produces a punched paper tape, AUDIO-VERTER transmitters can send a day's total transactions in minutes to the EDP center.

Initial model in the AUDIO-VERTER line is the Model 8050 Paper Tape Transmitter which accommodates any 5, 6, or 8-channel paper tape conforming to EIA standards. Data is transmitted at 30 characters per second (alphanumeric code) or 43 characters per second (numeric code). The transmitter can send data to a Digitronics 523 Magnetic Tape Terminal or 504 Paper Tape Terminal, with data received in form ready for computer input.

For more information, circle No. 76 on the Reader Service Card

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Remex Electronics, a unit of Ex-Cell-O Corporation, is introducing a new **high speed photoelectric punched tape reader** specifically for the computer industry.

The Remex model RRS-302F punched tape reader/spooler features a 300 characters per second reader with a 40 inch per second integral spooler equipped with 5¼ inch diameter reels. The unit is very compact requiring only 7 inches of rack space.

New sensitive motor regulations permits highly accurate tape motion control as demanded by the high speed reader.

Included is electronic noise suppression to a level that virtually eliminates the possibility of interference with the most sensitive integrated circuit computers.

For more information, circle No. 75 on the Reader Service Card

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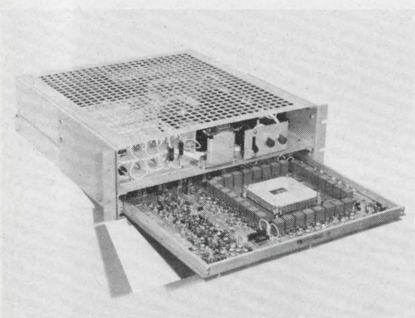

New Ampex **Model RF-4 core memory** is designed to fill such widely varying roles as high-speed buffer memory for data acquisition systems, main-frame memory for small-to-medium computers, and special purpose memory for land-mobile and airborne digital systems. The RF-4, complete on a 17-inch square printed circuit board, offers data access time of 400 nanoseconds and capacity of 80,000 bits.

For more information, circle No. 74 on the Reader Service Card

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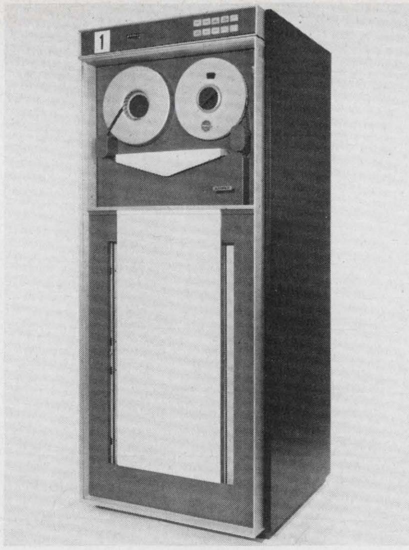
New Ampex Model **TM-16 digital tape transport** is plug-interchangeable with IBM 729 and 2400 units and features straight-line tape path design for maximum operator speed and convenience. The TM-16 also is designed to incorporate phase encoding, the method of doubling maximum data packing density from 800 to 1600 bits per inch. The transport offers tape speeds ranging from 75 to 150 inches per second, and 75 or 112½ ips in the IBM-replaceable version.



For more information, circle No. 73 on the Reader Service Card

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A new **program generator** that vastly simplifies file maintenance programming was announced today by Software Resources Corporation. The generator—called GENCO—accepts shorthand-type input statements and transforms them into a complete modular COBOL file maintenance program.

The generator is fully operational and available for immediately delivery. Among the GENCO features announced by the company are the following: easy to learn system with simple coding sheets provided, complete COBOL source programs generated, modular form of the generated COBOL program permits easy modification to meet special requirements, data processing priority feature allows the user to add, change or delete records or data fields at his convenience, and extensive range of updating, validation and default action is provided.

GENCO operates on an IBM System/360 with 128,000 bytes of storage. The COBOL file maintenance programs produced by GENCO can be compiled on a smaller 32,000 byte 360.

For more information, circle No. 72 on the Reader Service Card

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Allen Hollander Co. announced a new **pressure sensitive label** used to identify cleaned data processing tapes. It specifies that the reel has been cleaned and provides a space for noting the date of the cleaning. The labels tell programmers at a glance which reels can be used again for the processing of new data.

For more information, circle No. 71 on the Reader Service Card

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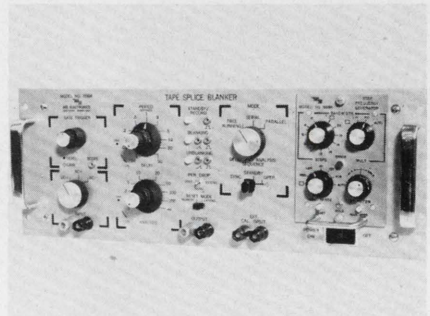
MB Electronics, a Textron company, has announced the Model N904 **Tape Splice Blanker.** The new unit, used when performing spectral, transient, or shock analyses on tape-recorded data, permits analysis of desired data and the rejection of all spurious signals.

The splice blanker can be used with any magnetic tape or signal analysis equipment taking data from a tape loop, and eliminates splice transients which could place a damaging signal on test data. Use of the instrument makes it unnecessary to record a tape loop with multiple reproductions of the single pulse or transient of interest. One pulse or transient on one loop of tape comprises all the data and all the preparation required for a complete and accurate analysis.



The unit provides timing circuits and signals to start and stop the average and integration-smoothing circuits in an analyzer. It eliminates possible tape flaws due to random noise, line transients, or fingerprints.

The Model N904 is of solid-state construction and operates on 105–115 vac 50/60 cps. A two-channel instrument is standard, with 3 to 8-channel units available.

For more information, circle No. 70 on the Reader Service Card

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A new **Multispeed Wide Band FM Modulator/Demodulator System** compatible with all modern wide band instrumentation tape recorders is offered by Data-Control Systems, Inc., Danbury, Connecticut.

Change in tape speeds for time base expansion and contraction is executed through pushbutton control. Electrical command is derived from tape recorder control circuitry and there are no moving parts in modulator/demodulator modules.

Typical applications include record/playback of PDM, PAM and PCM serial wave trains, high frequency analog data, video output signal storage for processing and analysis and other applications requiring DC to video response.

The system is comprised of DCS Model 545 Modulators and DCS Model 532 Demodulators which occupy 3.5″ of vertical rack space.

For more information, circle No. 69 on the Reader Service Card

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IRA Systems Inc. announced the development of a new **data-logging system** for measuring voltage, current and ohms. The entire system is controlled by a general-purpose digital computer.

According to Walter R. Anderson, President, the system incorporates fully-developed measurement software, making it unnecessary for the user to incur programming expense.

The IRA digital voltmeter has a DC accuracy of ±0.01 percent plus 1 digit, an AC accuracy of ±0.1 percent of reading, 4 digits with a 5th digit overrange. Range, function and sampling times are completely controlled by the computer.

The basic IRA system can be augmented to perform other functions as a result of readings derived from the digital voltmeter. Typical computer-controlled applications include: test systems for integrated circuits, circuit board assemblies, transistors and diodes; fabrication systems for non-linear function circuits, impedance matching circuits, and ultra-linear potentiometers; and logging of analog data for process control systems.

For more information, circle No. 68 on the Reader Service Card

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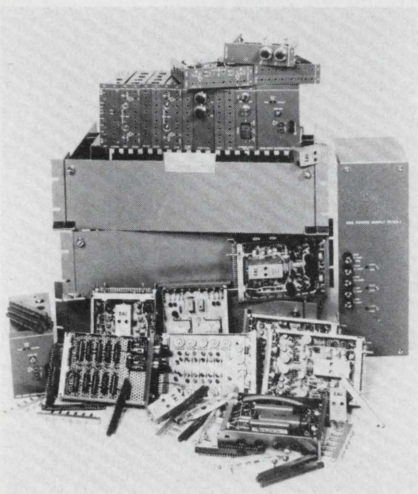

Electronic Associates, Inc. has introduced a low cost **industrial analog data processing package**—the PC-12 Experimenter's Kit. The kit is designed to provide engineers in diverse fields with a means of developing control systems for processes and machinery.

This configuration of PC-12 Analog Computer subsystems has been specially developed for use by industrial, process, production and equipment engineers in all types of manufacturing disciplines. Experience with the PC-12 has shown that it will find applications in on-line data reduction, on-line implicit calculation, on-line process optimization and on-line proces scontrol.

The kit's equipment complement consists of 28 PC-12 subassemblies providing up to 34 functions. Included in the kit are 18 operational amplifiers (including eight integrators), three diode function generators, a quarter-square multiplier and three mounting racks as well as necessary power supplies and reference supplies. The all solid-state system features component accuracies from .01 per cent to 1.0 per cent.

For more information, circle No. 67 on the Reader Service Card

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A new **electronic keyboard,** developed to provide error-free code generation for computer and other information handling and display systems, provides a significantly simplified design which eliminates specific problems associated with electro-mechanical and photo-optical keyboards.

The IKOR Keyboard patent pending contains all solid-state circuits. There are no mechanical links to fall and no lights to burn out or become masked by dirt thus contributing to coding errors. The coding for each key is completely self-contained within the key module, and the code generation utilizes universal Transmit and Receive Bars which serve the same function for all keys. Therefore, the IKOR keyboard permits an exceptionally wide variety of keyboard configurations as well as the addition of other keys at any time.

As supplied, the standard IKOR Model 6000 keyboard has 44 keys and spacebar with provision for use of up to 73 keys. Changing or adding keys involves merely snapping the desired keys into and out of their positions without any modification of basic circuitry or need to "wire in" the new keys.

The IKOR Model 6000 keyboard provides either serial or parallel inputs to any information system, using standard 7-bit ASCII code format. It provides clocked output and may be directly interfaced with digital printers, computers, CRT's, alphanumeric display systems, etc. The keyboards are supplied for mounting in customer console or as self-contained units.

For more information, circle No. 66 on the Reader Service Card

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Information Science Incorporated has reached an agreement with Software Resourced Corporation to market 151's new **General Retrieval System (GRS),** it was announced by Dale H. Learn, President, Information Science Incorporated.

GRS is designed to allow non-programmers to interrogate a master data base of computer files and records by means of simple English statements. It is said that the structuring of a report request for GRS can be performed in minutes.

The System, which is written in COBOL for the IBM 360 and other COBOL machines, is "fully operational and can be installed within 30 days of the contract date."

For more information, circle No. 65 on the Reader Service Card

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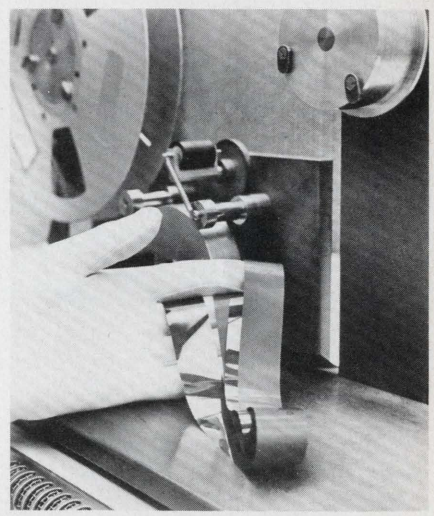

The first **digital magnetic computer tape** which can be used in extremes of hot or cold temperatures has been developed by a subsidiary of Wabash Magnetics, Inc.

The new tape will permit extended use of computers in aviation, aerospace, and other applications where it is not feasible to control environmental conditions.

According to the manufacturer, extreme environment tape performs at temperatures ranging from —55° F. to +180° F. Rapid fluctuations between these temperature extremes have no adverse effects on X-N tape performance. It is also not affected by humidity extremes.

X-N tape uses a polyimide substrate. Polyimide is stable at temperatures ranging from —100° F. to +400° F.

The new X-N tape has the performance capability of 1600 BPI, a measure of data storage capacity required in the computer industry today.

U. S. Magnetic Tape Company is now offering X-N tape in widths of ¼ through one inch and in lengths of 200 feet through 1,000 feet.

For more information, circle No. 64 on the Reader Service Card

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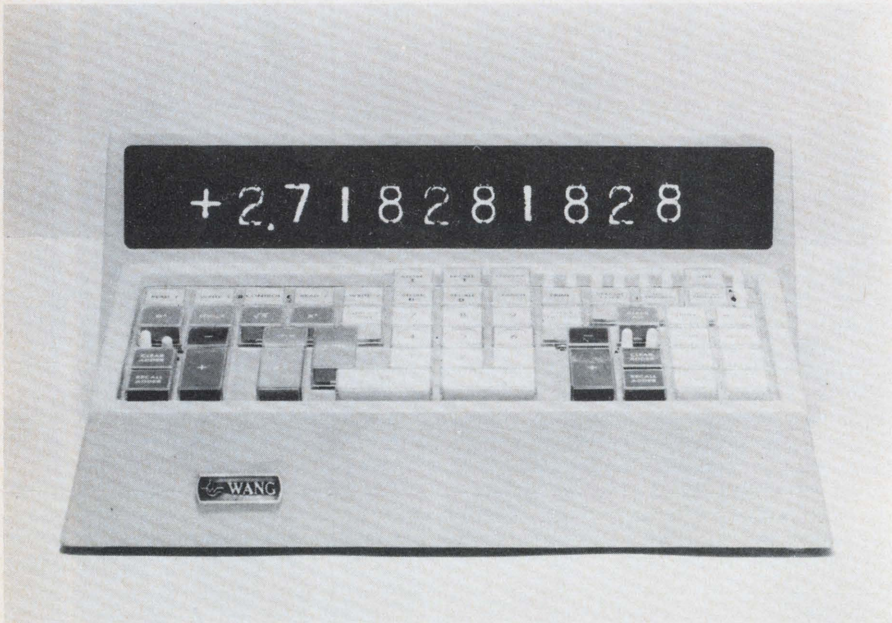
A new option has been added to the Wang Laboratories 370 calculating system. This new item is the **373 data storage unit.** The Wang 373 is a 64 register core storage device. Each register consists of a 10 digit decimal number with algebraic sign and decimal point. A total of 64 registers is available.



The 373 is provided with a row counter and a column counter to facilitate operation with systems of linear equations or matrices. The unique operation of the 373 allows a 370 calculating system to solve simultaneous equations with only two card readers (160 program steps). This feature will make it a useful tool for general statistical calculations as well as other engineering and physical computations.

For more information, circle No. 63 on the Reader Service Card

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A series of **printed circuit card files**—with dimensions that can be varied to fit any required storage capacity or type of construction—is available from Scanbe Manufacturing Corp., Monterey Park, Calif.

Designated as the Scanbe Series-T, the printed circuit card files can be obtained in single and multiple configurations. Design of the T-series card files incorporates side mounting bars, which are available in different lengths.

Any desired number of card guides and spacers can be mounted on the side mounting bars. In multiple configurations —available for holding any desired number of adjacent card rows—the double file, for example, has six mounting bars, the triple file has eight, and so on.

For more information, circle No. 62 on the Reader Service Card

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Auerbach Info., Inc., of Philadelphia has available a **two-volume,** detailed, analytical **evaluation of scientific, systems/ and control computers.** It is being published as Volumes "A" and "B" of Auerbach Standard EDP Reports. Hardware covered in the new volumes—Control Data 1700; Honeywell DDP124, 224, 416, 516; Digital Equipment Corp. PDP 8, 8/X, 9, 10; Scientific Data Systems Sigma 2, 5, 930, 9300; IBM 1130, 1800; General Electric GE/PAX 4020, 4040, 4050, 4060; Data Machines 620, 620-I; Raytheon 703; EMR Advance 6000 Series; Westinghouse Prodac 50, 250, 500; System Engineering Laboratories SEL 810A, 840A; and Electronic Associates Inc., EAI 640, 8400.

For more information, circle No. 61 on the Reader Service Card

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Potentiometric recorders are converted into universal temperature systems by adding Atkins **"T into V" Probes and Modules.** In use the operator sets temperature start point digitally at any temperature between —100° C and +200° C (or —150° F and +400° F), then sets the desired span to be covered above the start point. Spans can be 100, 50, 20, 10, or 5 C degrees (or 200, 100, 50, 20, or 10 F degrees). When the probe temperature rises through "start point" temperature a linear mv output is generated over the span which has been set. Output to the recorder is 0-1, 10, 50, or 100 mv, rear-panel settable, to match user's recorder capability.

A second output is provided by the Atkins module for connection to any digital voltmeter for direct display of the temperature digitally. This output is a linear signal of 10 mv/C° between —100° and +200° C, zeroed at 0° C. Digital volt-meters with 0.1 mv resolution can therefore read temperature changes to 0.01° using the Atkins #5H55 "T into V" Module equipment. Equivalent °F models with 1 mv/F° output are also available.

For more information, circle No. 60 on the Reader Service Card

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AMP introduces low-capacitance **shielded programming system.** Featuring conductor-to-shield capacitance of only 0.001 pf, this completely shielded patch-cord programming system offers better **than 106 db crosstalk isolation at 100** kHz. At 10 MHz crosstalk isolation exceeds 74 db. Unique back panel terminations permit plugging printed circuit boards **directly into the rear bay, thereby eliminating** extensive wiring. Other back panel terminations compatible with existing automatic machine or hand wiring techniques are also available. A short-lift camming action, in conjunction with a "chevron-shaped" contact area, produces a double-wiping action at the contacting surfaces. Average contact resistance is only 1.93 milliohms and insulation resistance is greater than 1 x 10^{13} ohms. Currently available sizes have 960, 1680, 1920, and 3840 contacts on 0.375" square grid pattern.

For more information, circle No. 59 on the Readers Service Card

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Five **digital-to-analog (D/A) logic modules** for systems and subsystems builders have been announced by Honeywell's computer control division.

The line is designed to provide standard components for users' building systems that must control analog outputs. The D/A modules may be used for driving and positioning a variety of equipment including plotters, machine tools, valves, meters and scopes.

The new line, made up of four-bit and six-bit D/A converter modules, operational amplifier modules, power converter modules and reference modules, is the most recent addition to the division's line of more than 50 modules.

For more information, circle No. 58 on the Readers Service Card

software age

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THIS INQUIRY IS IN DIRECT RESPONSE TO YOUR ADVERTISEMENT IN SOFTWARE AGE MAGAZINE

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JOB DESIRED: ____________________

List computer hardware knowledge (names of systems, tape, disk, terminals, etc.): ____________________

Programming specialties and years of experience (commercial, scientific, theoretical, experimental, analog, etc.): ____________________

Systems programming on which you have had development experience (compilers, assemblers, executives, monitors, O.S., etc. Indicate for what computer): ____________________

Programming languages used and extent of experience (COBOL, FORTRAN, etc.): ____________________

Applications programmed (aerospace, banking, insurance, math subroutines, compilers, etc.): ____________________

Systems analysis experience (card design, flow charting, operation analysis, etc.): ____________________

EDP management experience (include years and number of people reporting to you): ____________________

SALARY: ________ (current) ________ (desired) **DATE OF AVAILABILITY:** ________

EDUCATION: Indicate major as well as degree unless self-explanatory.

Degrees ________ | ________ | ________

Years ________ | ________ | ________

Schools ________ | ________ | ________

EMPLOYMENT: Indicate present employment and previous jobs below.

Employer ________ | ________ | ________

City ________ | ________ | ________

Years ________ to ________ | ________ to ________ | ________ to ________

Title or Function ________ | ________ | ________

Name ____________________ Age ________

Home Address ____________________ Home Phone ________

________ (city) ________ (state) ________ (ZIP code) U.S. Citizen? ________

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Marital Status ________

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