DECsystem-10 in the Sciences

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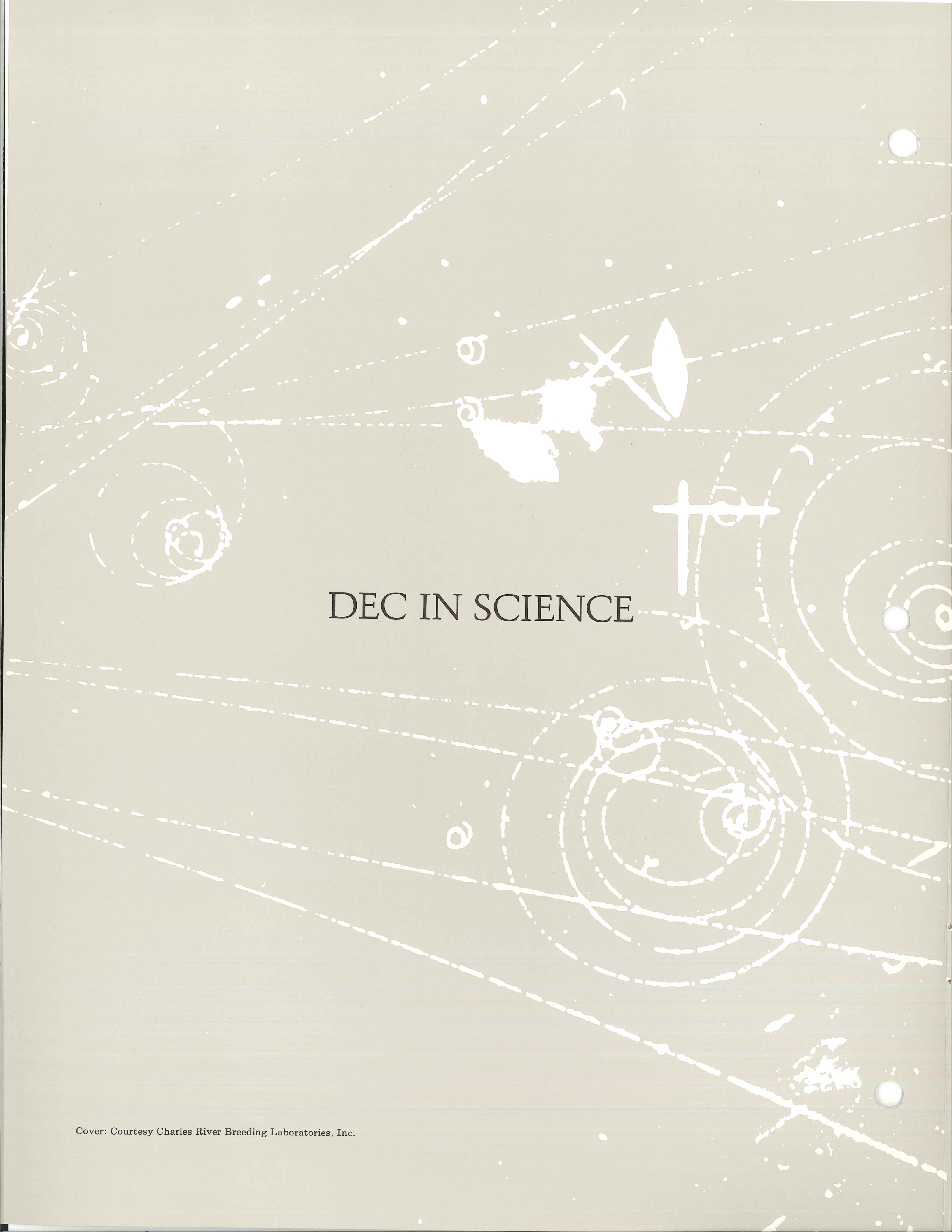

DEC IN SCIENCE

Cover: Courtesy Charles River Breeding Laboratories, Inc.

Digital Equipment Corporation is a leading supplier of general-purpose computers for the sciences. Our commitment began about a decade ago with PDP-1, the first high-performance "scientific" computer to sell for less than a million dollars. Over the next few years, PDP-1 was followed by PDP-5, the very first really small computer. Then by PDP-6, the first time-sharing system. And by PDP-8, the first computer to sell for under $10,000.

Today, we offer the world's broadest line of general-purpose computers, from 12- and 16-bit minis to 36-bit large-scale systems.

In the pages that follow, we'd like to tell you about the real-time capabilities of DECsystem-10, a new family of large-scale computers based on our PDP-10 processors. The family includes both single- and dual-processor systems and offers combinations of computing power and capability unobtainable anywhere else.

But first, here are some of the tasks PDP-10 based systems are performing for researchers here and abroad: monitoring particle accelerators and nuclear reactors, controlling mass spectrometers, x-ray diffractometers and other instrumentation in large laboratories, analyzing bubble and spark chamber data, simulating complex chemical and physical systems, testing experimental aircraft engines, interpreting chromosome patterns, investigating moon rocks, cataloging environmental pollution data, supervising networks of computers . . .

And here's where some of those PDP-10s are working: MIT, Caltech, Carnegie Mellon, Michigan, Harvard, Oxford, Bonn, Max Planck Institute, Faculte de Medicine, Queensland, NASA, Brookings Institution, ARPA, Brookhaven, Argonne, Oak Ridge, NIH, SRL, Bolt Beranek & Newman, Sanders, Eastman Kodak, Royal Aircraft Establishment, Rolls Royce . . .


SENSE SWITCHES
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MULTIFUNCTION OPERATION

TOPS-10

DEC's 36-bit multiprogramming computer offers true multifunction capabilities: it serves interactive timesharing users, it operates local and remote batch stations, and it performs data acquisition and control functions for on-line laboratory projects.

Through the unique TOPS-10 (Total OPerating System) monitor and advanced processing hardware, the PDP-10 can simultaneously service a wide range of job types and response requirements. The monitor allocates memory, storage, peripherals, and processing time among system users, employing an adaptive scheduling algorithm to dynamically adjust system operation.

The PDP-10 provides many features for each class of user. The timesharing user has a powerful command language and a choice of language processors including FORTRAN, ALGOL, COBOL, and MACRO. Utility programs include on-line editing, debugging, and file copying programs. Files can be shared and/or protected against unauthorized access. Also, software is reentrant to save user core space.

The multiprogramming batch user has the same services available to interactive users and can operate his programs from local stations, remote stations, or interactive terminals. In addition, the user can specify many processing parameters, including start and complete dates, order of program execution, and recovery action in case of errors. Through an operator's console, jobs can be started, stopped, deleted or restarted. Throughput of batch jobs is also optimized by a large number of PDP-10 features.

CHOICE OF RESPONSE MODES

The real-time PDP-10 user has a choice of response modes. One provides microsecond response to interrupts while another provides millisecond scheduling of jobs in high priority run queues. On-line data acquisition, for example, might be performed in the first, while reduction of the data — a less critical task — could be handled by the second. Multiple real-time users can be accorded other privileges by the system manager — such as the ability to lock a job in core for fast response. By granting privileges, the manager preallocates system resources to assure required response for each user. Real-time programs may be written in either FORTRAN or assembly language.

For remote users, the PDP-10 introduces the concept of remote stations. In this concept, peripherals normally located at the main site can communicate with the PDP-10 from remote locations. These peripherals, which operate through a PDP-8/I or similar computer, appear to the user to be directly connected to the PDP-10. Under this scheme, the remote processor in a batch processing station not only services a line printer and card reader, but it can also serve as a terminal concentrator for up to 16 devices. In another station arrangement, the remote processor can perform data acquisition through an A/D converter.

All PDP-10 users benefit from TOPS-10 file handling features. With the PDP-10, file organization is completely independent of both the device and the access method. In fact, different users can access a shared file by different methods. Allocation is also flexible. File space can be allocated upon user demand or preallocated and a file can extend over more than one like device. TOPS-10 also provides many features to optimize file access and allows the user to specify file protection codes.

SYSTEM SOFTWARE

ONE OPERATING SYSTEM

With TOPS-10, the PDP-10 interactive user can perform a wide variety of tasks from solving a simple mathematical formula to implementing a complete information gathering and processing network.

Depending on the system configuration and total computing load, the system can handle up to 127 active terminals simultaneously. These terminals can include CRT's and other terminals which operate at speeds from 110 to 2400 baud.

TOPS-10 timesharing is general-purpose; i.e., the system is designed so that the command language, file structure, I/O processing, and job scheduling are independent of the programming language being used. In addition, standard software interfaces make it easy for a user to develop his own special languages or systems. The large number of languages implemented by DEC and PDP-10 customers witness the value of this general-purpose approach.

Through an easy-to-use command language, the user can control the running of his job to any desired extent. Specifically, he can:

- Compile, execute, and debug programs.
- Create and edit files; list and delete files.
- Communicate with the system operator and request such services as the mounting and dismounting of disk packs, mounting of tapes, and copying of tapes on disk.
- Assign himself specific resources such as magtapes, private disk packs, etc.
- Start, suspend, or terminate the job.
- Spool program output to line printer, card punch, etc.
- Determine status of system and resources available.
- Request a time and resource accounting of his own use of the system.
- Send a message to any terminal in the system.

In addition, since TOPS-10 multiprogramming batch uses the same command language as timesharing, any user may enter his program into the multiprogrammed batch run queue. Thus any timesharing terminal can act as a remote job entry terminal.

HIGH OPERATING EFFICIENCY

To keep multiple user programs running concurrently, TOPS-10 uses multiprogramming and swapping. The monitor maintains as many jobs as possible in core memory. However, if memory demand exceeds the supply, TOPS-10 can bring higher priority programs from disk or drum into memory, swapping them with lower priority jobs.

Because each memory block operates independently, the processor can be executing a program in one memory block while programs are being swapped in another. In addition, a program that has been swapped out does not have to be swapped into the same location to continue execution. Thus operation is much simpler than with systems that employ fixed or other cumbersome partitioning schemes.

TOPS-10 saves core through reentrant software. Only one copy of a language processor (or any systems program larger than 1K) need be core-resident to serve multiple users simultaneously.

ADAPTIVE SCHEDULING

TOPS-10 maximizes throughput by using an adaptive scheduling algorithm to schedule system resources. By assigning resources based on the recent history of each program, response time is kept to a minimum for highly interactive jobs, and jobs which require heavy processor use are operated efficiently without excessive swapping.

TOPS-10 performs all I/O for the timesharing user: buffering data, queueing I/O requests, and performing throughput optimization. In addition, all data seeks are overlapped, that is requests for data transfer that are received simultaneously are queued in least-time-to-go order, taking into account the head's current track position and the rotational position of the disk or drum.

Although the monitor supplies the user with a broad range of services, it accomplishes its tasks with exceptionally low overhead. Studies indicate that, under TOPS-10, a single compute-bound program experiences only five per cent more overhead than it would if operated singly, without the monitor. If swapping occurs, this overhead increases by only seven per cent.

TOPS-10 never requires the user to preallocate file storage but dynamically provides storage space on demand. This feature is not only convenient for the user, but it also prevents large blocks of storage from being tied up unnecessarily.

REAL-TIME OPERATIONS

To meet the response requirements of real-time tasks, TOPS-10 provides a complete range of services. These services are gained through monitor calls or by console command. The calls, which are part of the user's program, request the monitor to perform real-time functions. These include starting the execution of FORTRAN or machine language code upon receipt of an interrupt, starting a real-time device, testing device status, disconnecting a real-time device from its interrupt channel, and reading or writing data in blocks or in single words.

A monitor call allows a user to lock his job in core so that it will not be swapped during program execution. When a program issues the LOCK call, the monitor first checks to see that the lock privilege has been granted. If not, the monitor issues an error indication. If the program has the privilege, the monitor optimizes job placement and locks the job in core so that it can respond quickly to a subsequent real-time event.

Through monitor calls a user may acquire as much of the system as is needed to meet his response requirements.

To obtain fastest response, a job may be driven directly in response to the priority interrupt system and be run in monitor mode. In this mode, response times are typically under 10 microseconds and are limited only by the ability of the hardware to respond to interrupts.

User mode operation, by means of the real-time trap monitor call, provides response times of 100 microseconds and, at the same time, provides I/O privileges and protects the real-time programs from access by other users through dual memory protection and relocation hardware. This hardware also protects the system against errors in the real-time job itself.

Response times of a few milliseconds or less may be achieved by placing the program in any one of 15 high priority queues maintained by a software scheduler. Through scheduling, system response may be biased to favor real-time, batch or other programs — a very useful tool for optimizing throughput and response time.

Through a series of monitor calls, jobs may run on a periodic basis under control of the system clock. Also, one job may request that another be run. For example, when a block of data has been collected, the associated data analysis job on disk or drum could be quickly brought into core and executed.

The TOPS-10 monitor does not limit real-time users to operation within fixed partitions. It also allows a program to use the system or real-time clock so that it can operate at predetermined intervals.

REMOTE STATIONS

In the TOPS-10 remote station concept, the PDP-10 uses a small computer, such as a PDP-8/I, as a device controller for a variety of peripherals that are normally directly connected to the central processor. Through a communications link to the small computer, peripherals such as card readers, line printers, terminals, and A/D converters can be operated almost anywhere within phone communication distances of the central processor. To the users at these locations, the remote peripherals appear like peripherals at the main site.

This concept not only brings the processing power of the PDP-10 to remote locations, but it also makes possible a variety of remote station configurations. For example, a batch processing station is no longer restricted to a card reader, line printer, and console Teletype. In addition to inputting batch programs, the station can serve as a terminal concentrator for up to 16 timesharing users.

A remote station can also serve real-time functions, using the small computer to collect data from an A/D converter. This data, recorded on magtape, can later be read by the PDP-10.

The remote station concept can also be applied to real-time applications, combining the advantages of a dedicated control computer with the power and flexibility of a large general purpose computer. Real-time functions of the remote station can be as simple or as complex as the user desires. In the simplest case, the small computer can be used to acquire data on PDP-10 compatible magnetic tape. A PDP-10 program can later access the tape. through the station, and reduce the data.

In more complex operations, the PDP-10 can request samples of process variables, make needed calculations and, with the results, adjust the parameters being maintained by the remote station control system.

To perform these more comprehensive control operations, the remote station software requires some modifications by the user. Such custom software is also available from the Digital Systems Group on a negotiated fee basis.

MULTIPROGRAMMING BATCH OPERATION

The multiprogramming batch system of the TOPS-10 monitor provides many new and unique features which make the system easy to use, yet provide wide flexibility for both the user and the computer system operator. Users can enter programs through equipment at the central computer site, remote batch stations, or by using interactive terminals. The system also provides increased throughput by employing various input/output features and by dynamically scheduling system resources among user programs.

USING MULTIPROGRAMMING BATCH

The multiprogramming batch command language is easy to learn and compatible with the commands for interactive timesharing. Programs often require only a few control cards to operate. For example, to run a simple FORTRAN program, the user only requires the following control cards.

$ JOB
$ FORTRAN
Program
$ DATA
Program Data
END OF FILE
(This card may be supplied by the installation operator.)

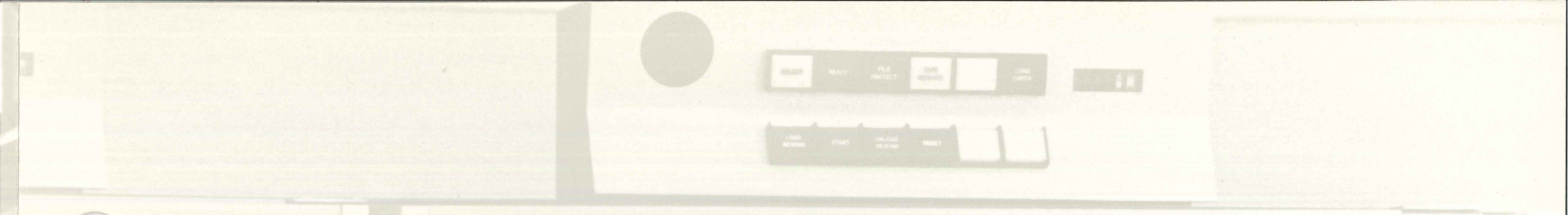
The batch command language also provides wide flexibility for the experienced user. For example, the user has a choice of submitting his job via card reader, magnetic tape, DECtape, or disk packs, in a variety of input modes: ASCII, binary, image, or 026 or 029 keypunch codes. He can also set "start" and/or "complete" time limits for program execution, giving a DO NOT START BEFORE date and time, or the date and time that a program must be completed. If execution order is important, the user can state, for example, that programs A and B cannot be started until program C has been executed. He can also request that a particular program be executed at specified intervals.

The user can control system response to error conditions. He can specify the emergency action to be taken if his program should contain a fatal error — such as, skip to the next program or transfer to a special error handling routine. To stop looping, he may set an execution time limit. He can also set limits on program output, such as the number of pages printed, number of cards punched, etc.

A user can also delete any of his jobs or change their parameters through his remote batch station or interactive terminal.

Although the system allows a large number of batch operating parameters to be specified, it will operate with very few user-specified values. If a particular parameter is missing, the monitor supplies a reasonable default parameter. These parameters can be adjusted by the installation.

To optimize batch throughput, the TOPS-10 monitor dynamically schedules system resources among user programs. The system can be entirely dedicated to batch operations or the computer system manager can dynamically specify the percentage of processing time and core memory that can be dedicated to batch processing. Jobs are scheduled on the basis of core requirements, the ratio of processing to input/output, processing time limit, and any specified user deadlines or priorities.



TIMESHARING

A timesharing system isn't just any computer with some additional hardware and software. It's a system designed specifically for timesharing. Otherwise, facilities are limited, fewer users can be handled efficiently, and economics are unattractive.

The TOPS-10 system performs multiprogramming; that is, it allows several programs to reside in core simultaneously and to operate sequentially. The switching between programs, called context switching, is initiated by a clock which interrupts the central processor to signal that a certain time period has elapsed. The interrupt function is provided by the priority interrupt system.

The monitor is also involved in keeping the actions of a user within his assigned memory space. A memory protection register, which is set by the monitor, limits the core area that a particular user can access. Any attempt by the program to read or change information outside that limit will automatically stop the program and notify the monitor.

To increase the number of users serviced, a secondary memory is employed. This memory — usually magnetic disk or drum — is slower than core or main memory but provides greatly increased capacity at reasonable cost. User programs can be located in secondary memory and moved into main memory for execution. Programs entering main memory exchange places with a program (or programs) that has just been serviced by the central processor.

In operation, main memory is divided into separate memory blocks. Secondary memory is connected to these blocks through a high speed data channel — a hardware device that allows the disk or drum to swap a program into any one of the main memory blocks without any aid from the central processor. This structure allows the central processor to be operating a user program in one block of memory while programs are being swapped to and from another block. This independent overlapped operation, which greatly improves efficiency and processing power, is characteristic of the asynchronous system design philosophy used in the PDP-10.

Round robin scheduling, in which each program operates in sequence and receives a fixed amount of time, is effective only if all programs have similar requirements. Such is not the case, however. At any particular time, a timesharing system will be handling some programs which require extensive amounts of computing time (and are said to be compute bound) and other programs that must stop frequently for input or output (I/O bound).

To serve programs at and between these two extremes, the scheduling algorithm must provide frequent service to I/O bound programs and must give compute bound jobs longer time quantums to prevent wasteful swapping. A simple dynamic scheme could provide two queues — one for each type of job. When a user first logs on to the system, he is placed in an I/O bound queue (waiting line) where he receives frequent service and small time quantums. If the program isn't completed or does not request input or output during the time allotted to him, the job needs more computing time and is placed in the compute bound queue. Thus the scheduling algorithm optimizes system efficiency by automatically adjusting to program requirements.

In the present state of scheduling art, algorithms are constantly being changed and improved. Current TOPS-10 algorithms are extremely sophisticated, providing excellent service for most timesharing job mixes. They also allow fine tuning, if such modifications are necessary. The ability of the algorithm to match processing to program requirements insures the best service possible for all user programs.

LANGUAGES

Standard PDP-10 (DEC-supported programming languages include:

COBOL — ANSI standard data processing and business application compiler.
FORTRAN, ALGOL* — Scientific compilers.
AID, BASIC — Interpretive compilers designed specifically for interactive use.
MACRO — Assembly language compiler.

User-developed languages include:

FAIL — PDP-10 assembler.
SNOBOL 10 — Symbol manipulation language.
GIST — TRAC® with JOSS® arithmetic primitive.
PAL-10 — Assembler that produces PDP-8 object code.
PAL-11 — Assembler that produces PDP-11 object code.
PAL-12 — An assembler that produces object code for the PDP-12.
LISP 1.6 — List processing language.
SAIL — ALGOL-like language.
*JOVIAL '70 — ALGOL-like language.
*BLISS — High-level system software implementation language.
*APL — Interactive language based on Iverson notation, requiring a special character set.
REDUCE — Algebraic symbol manipulation language.
MATHLAB — Solves differential equations symbolically.

*Under development.

PERMANENT FILE STRUCTURE

TOPS-10 file service for disk packs, drums, and disks, is designed for maximum convenience and system efficiency. Each user may have as many files as he desires on any of the file storage devices in the system. The only limit on file size is a quota, which the installation can set for each user, or the physical capacity of the installation-defined file structure, which can include storage on several like devices. Each file is referred to by name so that the user is not required to know where his file is physically located.

For user convenience, file organization is independent of access method. Therefore it is not necessary to reorganize a file completely to change from sequential-access to random-access methods. The user may even change his access methods during file processing. For example, he could use random-access methods to find a pointer block, and then use more efficient sequential access for the remainder of his processing.

DYNAMIC ALLOCATION

File storage is dynamically allocated by TOPS-10 during program operations, so there is no need to preallocate a certain number of blocks before a file is established. This feature is especially useful during program development and debugging, when the final size of the file is still unknown. However, a user is not limited to automatic allocation. If he wants to, he can reserve a contiguous area on a drum or disk pack to make sequential processing even more efficient. When processing is completed, he can keep his preallocated file space for future use . . . or return some or all of it to the public pool.

For convenience and flexibility in system design, files can be shared concurrently (even with different access methods) among specified users through the use of protection codes. These codes, which are assigned when the file is created, describe the access privileges of the person who created the file, members of the same project, and all other systems users. These persons or groups may be assigned any number of privileges such as EXECUTE ONLY; READ AND EXECUTE; READ, EXECUTE, AND MODIFY; or any of the groups may be completely excluded from file access.

INSTANT UPDATING

Updating a file is performed by either superseding or updating in place. When a person makes a change by superseding a shared file, concurrent users are not affected until they finish using the file and later reaccess it. In situations where users need immediate access to the most current data, such as in management information systems, data bases are updated in place. In this method, concurrent users receive changes as soon as they are made.

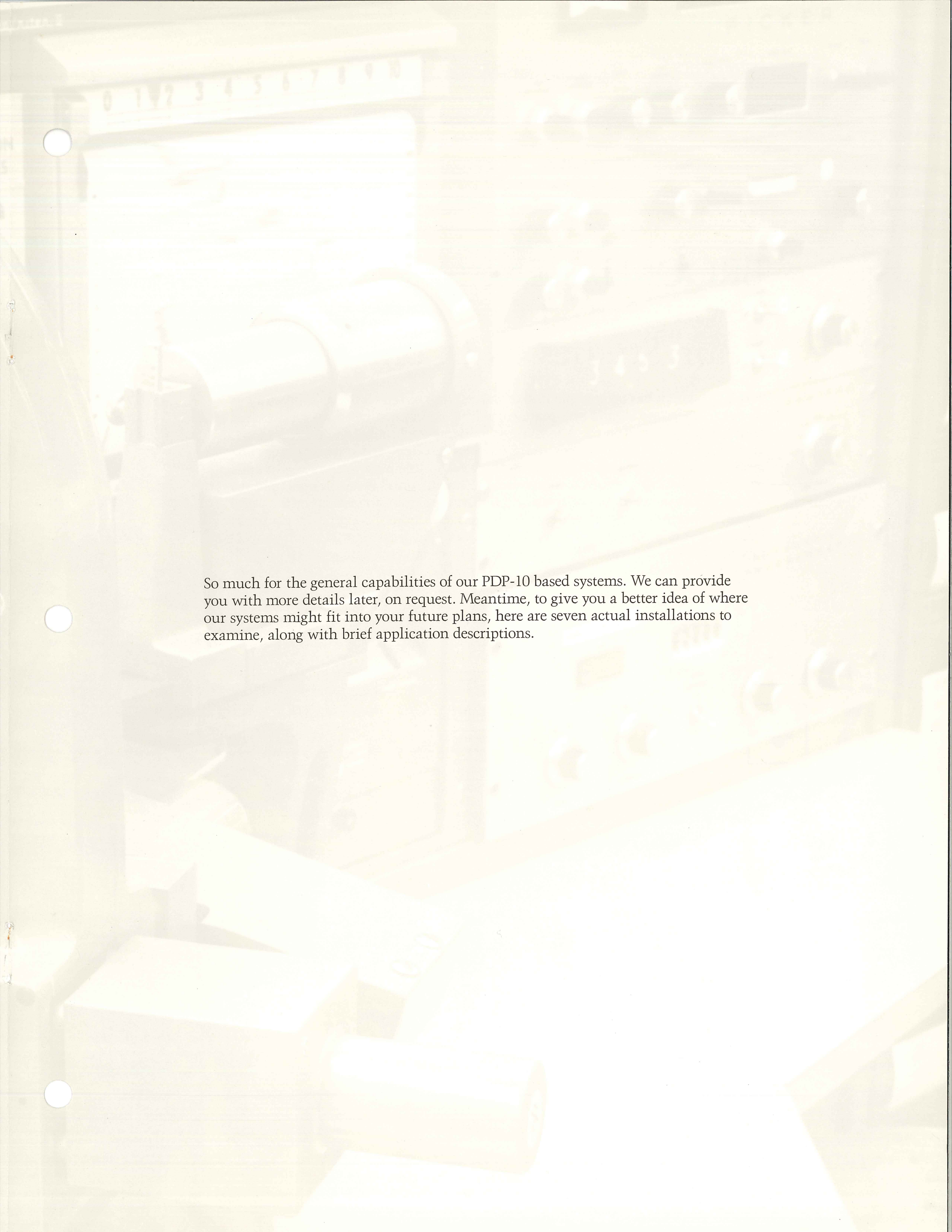
In some applications it is necessary for a person or group of users to have complete control of a file structure, such as when file processing depends on the mounting or dismounting of disk packs. With TOPS-10, a disk pack can be designated as private and assigned to one user, so that packs can be mounted or dismounted without disturbing other users.

EFFICIENT PROCESSING

In addition to providing user convenience, TOPS-10 makes file processing highly efficient. In sequential processing, the monitor checks to see if the next block of data requested by the user physically follows the current block; if it does, the monitor uses command chaining, a hardware feature of the data channel, and loads additional buffers scattered throughout the user's core area. The system optimizes accesses. I/O requests are queued and processed on the basis of minimum access time. To assure retrieval of data positioned farthest from the moving head, both seek and latency algorithms employ a fairness clause, which means that after a given number of retrievals, the data that has waited the longest is accessed next. The number of retrievals is an installation parameter and can be adjusted to meet specific operating conditions. When multiple moving-head disks are employed, the monitor also overlaps seeks on all devices and allows simultaneous transfers to and from core memory via separate data channels.

TOPS-10 avoids unnecessary file accesses by maintaining retrieval information for recently active files in an in-core data base. For reliability, the retrieval information is recorded in two separate locations on the file device, reducing the probability of destroying both directory locations simultaneously.

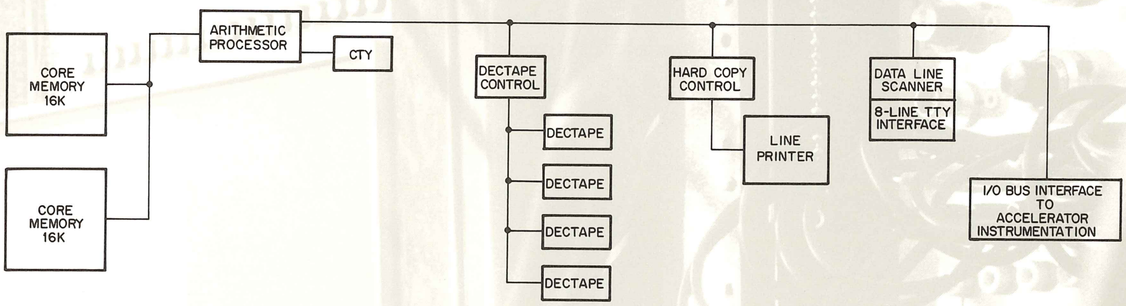
Swapping space (random access storage which receives core memory overflow) may be allocated on any file storage device. The monitor employs the fastest device first. When its allocated space is full, the next-fastest device is employed for swapping. With TOPS-10, no special device is required for operation; the system can use disk packs as the sole storage media just as easily as it can employ a full complement of disks, drums, and disk packs.



So much for the general capabilities of our PDP-10 based systems. We can provide you with more details later, on request. Meantime, to give you a better idea of where our systems might fit into your future plans, here are seven actual installations to examine, along with brief application descriptions.

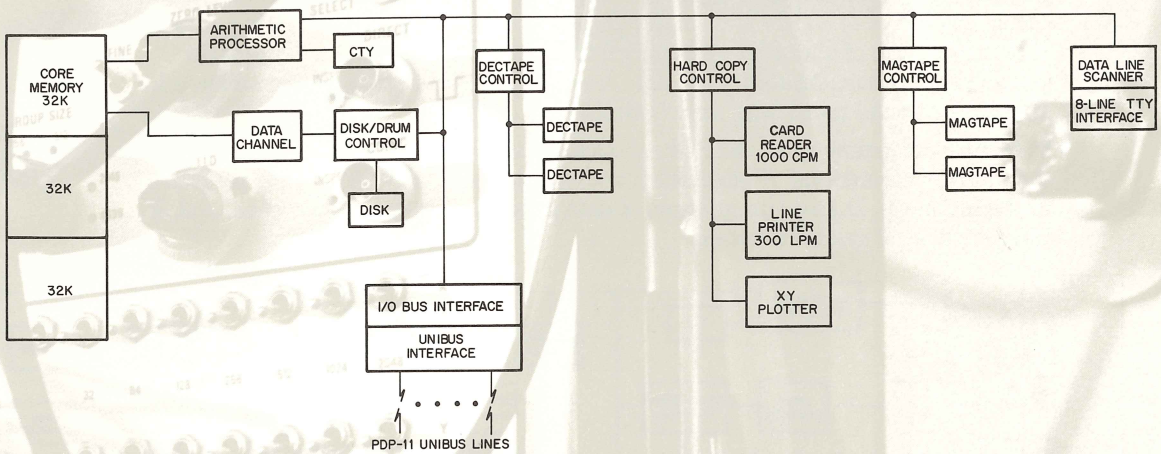
BROOKHAVEN NATIONAL LABORATORY
Beam Studies and Control Group

A PDP-10 system has been implemented at the Brookhaven National Laboratory to assist in accelerator control and beam studies. The computer performs monitoring and control functions on the Alternating Gradient Synchrotron and provides for analysis of data for beam studies and accelerator research. The system samples and reacts to a wide spectrum of parameters obtained on-line from the accelerator and beam control stations, target stations, and the experimental areas. Results from the analyzed data are used to stabilize and trim the accelerator to meet specific requirements of the experimenters, to maintain operations during minor equipment failures, and to provide operational data for beam and accelerator research. A special monitor handles the real-time functions and any concurrent data analysis and program development. The system library, language processors, and user files are stored on DECtape.



CORNELL UNIVERSITY
Laboratory of Nuclear Science

A network of PDP-11 computers tied to a PDP-10 based system performs control, data acquisition, and data analysis tasks for the electron synchrotron at the Cornell Laboratory of Nuclear Science. The PDP-11 computers log the data either directly onto magnetic tape or buffer it into the PDP-10 for on-line analysis in real-time. Operating in a multiprogramming mode, the PDP-10 handles program development for the PDP-11s as well as concurrent data logging and analysis.

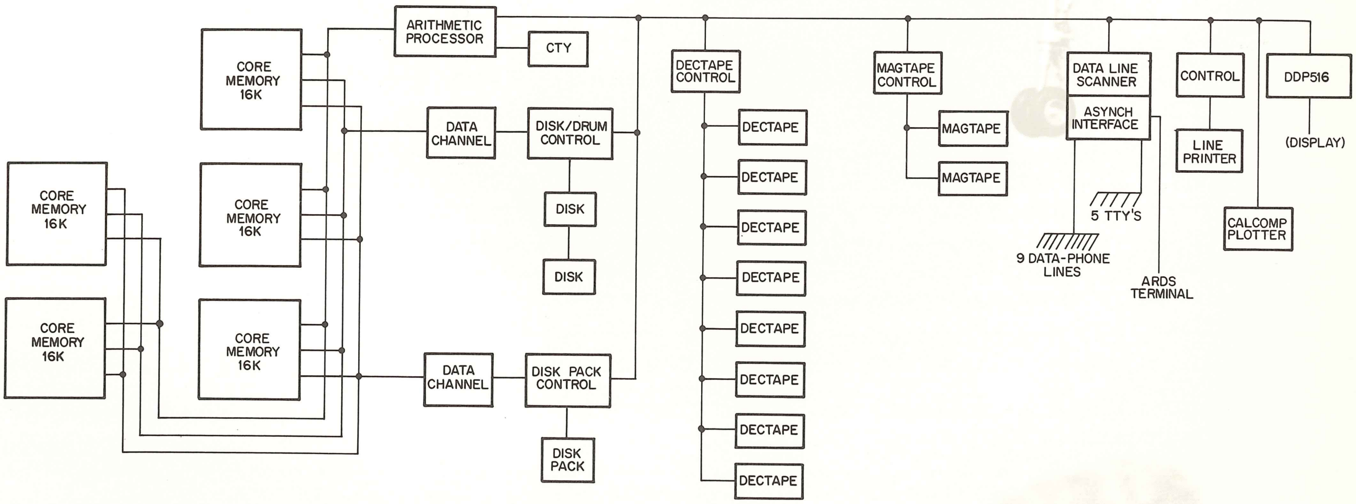


U.S. DEPARTMENT OF TRANSPORTATION Transportation Systems Center

A laboratory with real-time simulation capability is being developed at the Transportation Systems Center to simulate command and control functions in transportation systems. An initial effort is defining and evaluating the most effective role of air controllers in future ATC systems.

The functions performed by the PDP-10 based system are: 1) simulation of aircraft traffic, 2) control of traffic with modular automation and decision making algorithms, 3) manipulation of data files and control to update the display list, 4) scenario generation for each simulation, 5) data recording and reduction, 6) controller/pilot aircraft command processing, and 7) flight strip printing.

In between real-time runs, the PDP-10 operates as a timeshared computer performing the following functions: 1) generation and debugging of all PDP-10 user programs for experiments, 2) post-run analysis of data generated by simulation runs, and 3) improvement of system software.



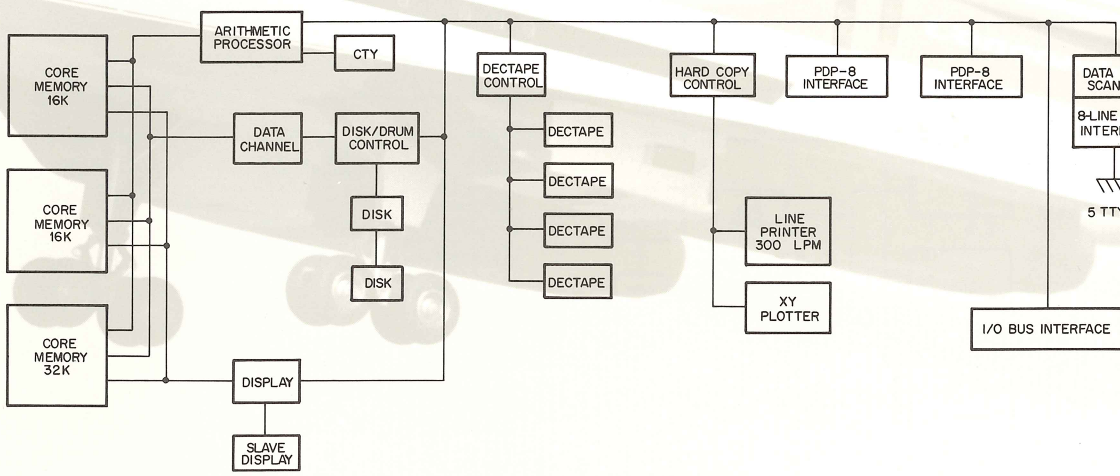
ROYAL AIRCRAFT ESTABLISHMENT

A test program which includes the simulation of flight conditions such as slowly varying and gust loads, aerodynamic heating cycles and pressurization effects is being carried out by the Royal Aircraft Establishment for the Concorde Project.

Approximately 30,000 flying hours will be simulated over a period of ten years, giving the test aircraft considerably more flying hours than any of the Concordes in service.

During a flight simulation test, 150 channels are used to apply loads to different parts of the aircraft. Other channels govern additional variables such as temperature and pressure. The entire operation must be concurrently monitored by a set program which supervises the tests and keeps the loads and other variables within tolerable limits.

Since the computer complex for this task consists of a PDP-10 and two PDP-8s, control programs are designed to keep the machines in step throughout the test and allow one computer to control the others when necessary.

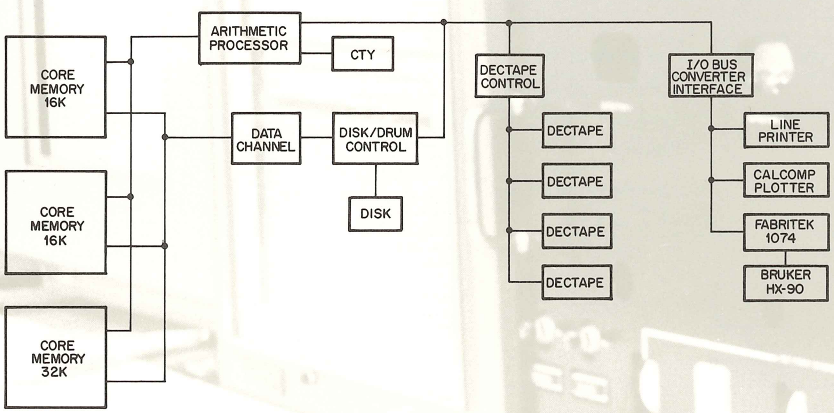


EMORY UNIVERSITY
Chemistry Department

A PDP-10 based computer in the Chemistry Department at Emory supports a dual program of scientific research and computer development. An example of the developmental work is a bus converter which permits the attachment of positive logic devices to the standard PDP-10 bus. With this modification, peripheral interfacing can be carried out economically. Some of the devices which have been interfaced in this manner include a Mohawk 4330 printer, Calcomp 565 plotter, and a Fabritek 1074 time-averaging instrument computer.

Because of the characteristics of the PDP-10 system, the installation operates on an open-shop basis. This mode of operation and the ease with which system development can be pursued locally, have led to a reduction in overall operating costs.

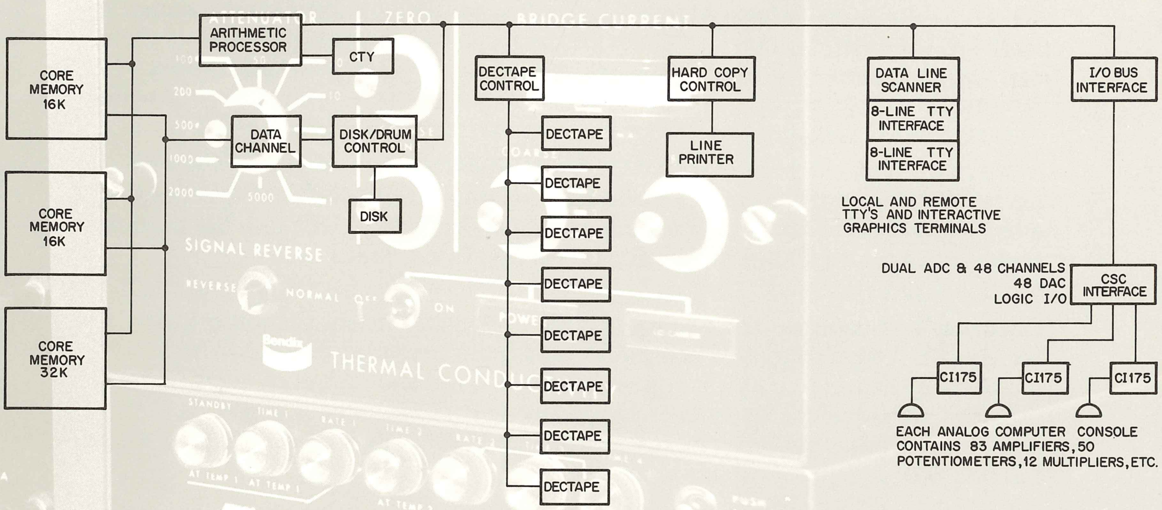
Real-time as well as standard jobs are performed on a timeshared basis. The PDP-10 is linked via the Fabritek 1074 to a sophisticated nuclear magnetic resonance spectrometer (the Bruker HX-90) for efficient data transmission, NMR spectral analysis, resolution and signal enhancement. Other computations include fast Fourier transforms, molecular orbital and normal coordinate analyses, non-linear regressions, and graphic display of molecular structures.



UNIVERSITY OF MANCHESTER
Control Systems Centre

The Control Systems Centre of the University of Manchester Institute of Science and Technology specializes in control system research and runs a large postgraduate course in the theory and practice of automatic control. The research is primarily concerned with the design of multivariable control systems and the simulation of industrial processes and their control systems. The Centre's computational work includes computer graphics for computer-aided design, and analog and hybrid computation for process simulation.

The system itself was designed 1) to enable the simulation of a plant or process on the analog computer and the control of such a plant or process on the digital computer, 2) to provide interactive display facilities for the CAD of control systems, 3) to allow on-line program preparation and debugging of scientific programs for control studies, and 4) to process a batch stream of other scientific programs in the background.



SALES, SERVICE AND SUPPORT

DEC's worldwide sales network includes over 60 offices in 11 countries. The Company's field force, which includes sales, service, and software support personnel totals 1,400.

The account representative — the leader of the account team — is the customer's primary contact with DEC and has ultimate responsibility for the success of the system. He is backed by software support specialists who serve as customer consultants. They instruct customer programmers in the special uses of the computer, and provide assistance as customers design and implement special programs.

The field service representatives supervise the acceptance test and provide maintenance service. One of DEC's 700 field service engineers, who are located at approximately 100 service points, can generally be at any location within a few hours if a problem develops. In some cases, resident engineers are located at customer sites on a full-time basis. To speed customer service, DEC has established a network of depot repair stations. Located strategically, each station is a complete service center staffed by full-time engineers. DEC service specialists spend up to 75 per cent of their first year in training and return to the main plant each year for refresher courses. Senior field service engineers — about half the total force — have an average of more than six years of computer experience and nine years in the electronics field.

In Maynard, a training center with 42 full-time instructors provides software and hardware familiarization courses for customers. During 1970, over 2,600 customers attended courses in Maynard for a total of 3,550 student weeks. DEC also has training centers in Palo Alto, California; Reading, England; Paris, France; and Munich, Germany.

Particularly valuable to DEC customers is the Digital Equipment Computer Users Society (DECUS), a voluntary, non-profit users group supported by DEC. With a membership of over 10,000, a European branch and numerous local chapters in the U.S., DECUS provides a lively interchange among customers through meetings, seminars, technical publications and program exchange. The DECUS Program Library has over 500 programs available to members.

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