Honeywell DPS 8/Multics
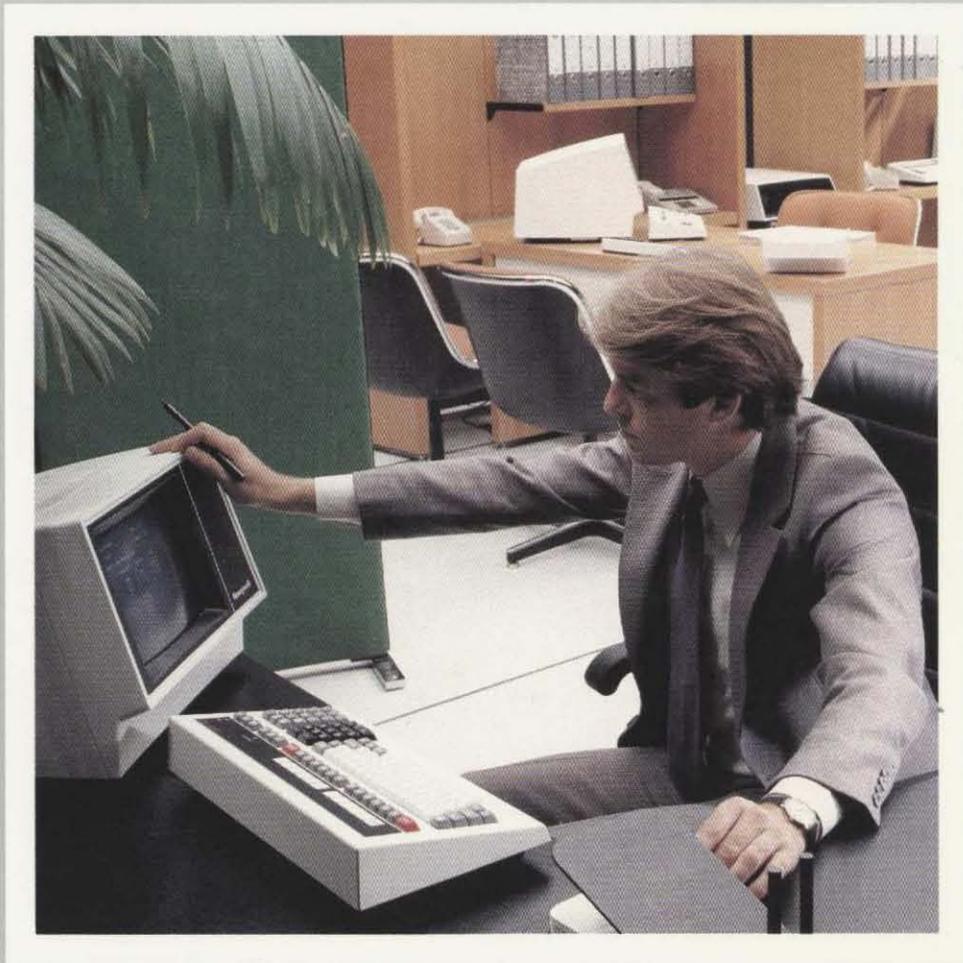
**Honeywell Multics
Distributed Processing System**
Summary Description

Contents

1. Overview

In the past, many computer system designs required users to bring their jobs to the central computer facility, leave them for processing, and then later return for the results. This mode of computer operation has been termed "batch processing."

Over the last few years, however, a dramatic evolution has been taking place in the way computing power is made available to the end user. The most significant factor in this evolution is the change from batch processing to "online processing," within which users can access the computer via remote terminals.

Because productivity can be greatly improved with online, terminal-driven systems, application designers began to adapt batch-oriented computer architectures to terminal-oriented applications. However, such adaptations are not always effective or economical. In many cases, entire large-scale systems must be dedicated to processing a single online application.

The operational implications of online processing on a batch architecture raises questions of resource allocation, workload control, data security and integrity, and access control. These were not major concerns in a batch environment, but become important requirements in online processing.

To directly address such concerns, Honeywell offers Multics — an operating system whose entire architecture is oriented toward online processing and whose administrative tools are designed for control of such terminal-driven environments.
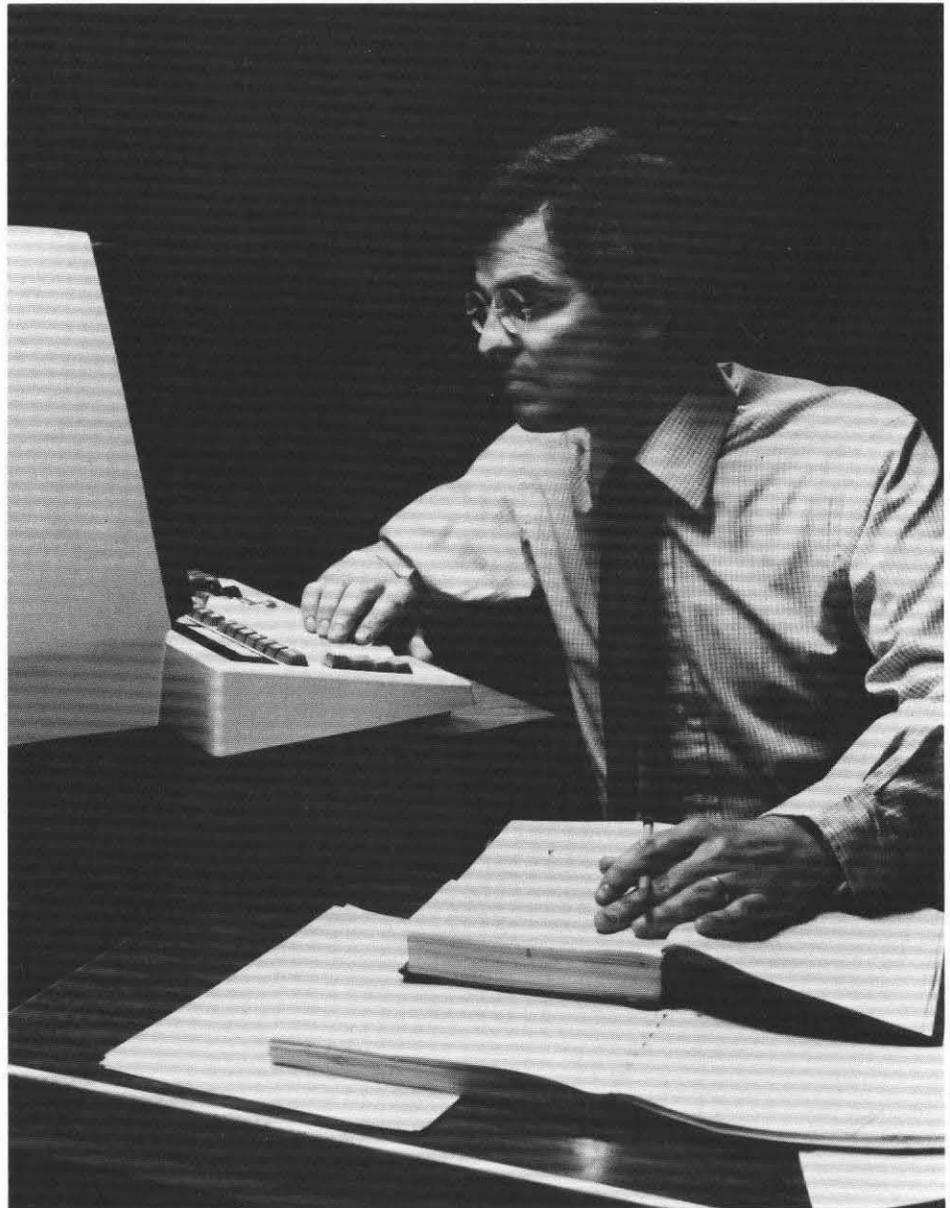
Multics is the communications-oriented operating system for Honeywell's Distributed Processing System 8/Multics (DPS 8/M), designed to provide an easily accessible utility-grade computer service. Largely because of the capabilities of the Multics operating software, DPS 8/M is a highly interactive and adaptive information management system that is well-suited to today's environment of on-demand processing.

Unlike many computer systems designed for the structured environment of scheduled production processing, a DPS 8/M system excels where the workload is primarily unstructured and unpredictable. Its large-scale power is combined with flexibility and ease of use, making it particularly efficient at serving many users doing different kinds of activities throughout an organization.

Multics Definition and Potential Advantages

The Multics operating system is the controlling software for the Distributed Processing System 8/Multics (DPS 8/M) systems. The functional capabilities of these Multics systems span the total spectrum of processing modes from batch to transaction processing, and each system is able to service workloads that consist of a cross-section of processing modes simultaneously. For example, a Multics system can provide transaction processing for manufacturing and finance people, and concurrently provide time sharing for engineers, word processing for office staff, and online inquiry and batch report generation for management personnel. Multics can provide significant potential advantages over many other computer systems in the following areas.

Productivity

The computer can aid the productivity of an operation only if its processing power is accessible to people. Many other data processing systems are difficult to use and require users to become familiar with very complex and esoteric interfaces and jargon. For example, financial people might understand all the financial aspects of a situation, but would also have to be familiar enough with the programming language (e.g., COBOL) and with the system's user interface (e.g., Job Control Language) to be able to specify in computational terms what processing is to be done and then to cause the machine to execute the program.

Multics provides end users with a simplified interface and a number of tools which can help shorten the problem-solving cycle. As a result, the people who use Multics can become more productive because they can apply the system to their own work situations without becoming computer experts.

Management and Control of Computer Resources

The computer system, as an integral part of a business or institution, is an important resource which requires proper management and control. When several groups use online capabilities, one group of users may monopolize processing time, downgrading system response and performance for others. Many systems provide very few administrative tools to allow the operational control needed to avoid such problems.

The basic administrative orientation of Multics is designed to permit a degree of control sufficient to simultaneously and satisfactorily serve many user groups. When properly administered, the process of any one group is not allowed to interfere with the work of any other group. For example, adding terminal users to a system's workload will not impair the response time of terminal users in another group. This approach allows the separation of user groups and the isolation of workloads, providing a stable operational environment for users.

Data Integrity and Security

Privacy legislation and the increasing incidence of computer fraud make adequate security a growing concern in today's data processing environment. While the basic requirements for security are straightforward, the implementation of adequate safeguards is a difficult proposition.

The data stored in a business or institutional computer system must be properly protected from inadvertent or malicious destruction. Furthermore, sensitive information (personnel and salary records, for example) must be properly secured from unauthorized access.

Computer security does not happen by accident. If the basic architecture of an operating system is not secure, no amount of security programming within an application will provide real data integrity and security. Computer experts are in general agreement that such controls should be designed into the system's basic structure. Multics is designed to meet this criterion.

Growth Capabilities

Unlike many other systems, Multics is designed to permit step-by-step growth. A Multics operation can grow by adding only the modules it needs at the time. Thus, Multics allows the user to buy today for today's data processing needs and avoid the unnecessary expense of an under-utilized system.

Furthermore, Multics provides excellent growth capabilities. It is possible to expand a DPS 8/M system to approximately five times the processing power of the system's entry level configuration — all without ever changing either the operating system, the system libraries, applications, or user programs.

Processing Modes and Capabilities

DPS 8/M systems are designed for both experts and novices. The totally online, interactive orientation is well suited to a variety of processing activities.

Time Sharing

Time sharing is especially useful to organizations that have many users working simultaneously with the system on diverse, individual projects. Multics time sharing can handle hundreds of users as it helps distribute the workload. In addition, the FAST subsystem provides the user with controllable levels of time sharing power and processing performance.

Transaction Processing

Multics transaction processing is designed to offer flexibility and scope. The terminal-oriented system does not require special executive programs to monitor terminal input and then to process user requests in batch. Applications can be written in any language and directly accessed from any number of terminals or batch jobs simultaneously in a completely shared environment. System facilities allow the interfaces to specialized data bases as well as concurrent access control.

Word Processing

Word processing capabilities are achieved through use of:

- Powerful text editors
- Document formatting capabilities
- Error detection tools
- SPEEDTYPE (shorthand for typists)
- Artwork facilities
- List processing
- Photo composition

- Online dictionaries
- Electronic mail

Together, these features can help the user create and maintain error-free documents and produce formatted output.

Graphic Processing

A general-purpose interface helps user and application programs create, edit, display, and animate graphic material. The graphic features include:

- Terminal independence
- Powerful editing capabilities
- Permanent storage capabilities
- Sharing sub-objects and structures
- Dynamic animation
- Local editing
- Incremental picture updating

Real Time Processing

Multics can provide real-time response to specified users or jobs (e.g., real-time job scheduling). Thus, the system is useful in operations control functions, such as process control monitoring.

Batch

The Multics operating system supports both local and remote batch processing. Interactive users can submit batch jobs for execution and can also run them interactively without change. Batch jobs can also initiate other batch jobs. The free-format command language is simple enough for the novice, yet powerful enough to handle elaborate applications.

Remote Job Entry

Remote users can submit batch jobs from a variety of Honeywell DPS 6 systems. Job output can be returned to the originating station, printed at the central-site printer, or stored for online perusal. Extensive administrative features control the authorizaton of users and stations.

Numerous devices support remote job entry. These include most devices that emulate IBM 2780 and 3780 protocols.

User Orientation

DPS 8/M systems offer users many potential advantages. End users access all processing functions in the same way each time, providing a consistent user interface. Ease-of-use features include: interactive orientation, sharing, no job control language, flexible environment shaping, the EXEC-COM and help facilities, and the abbreviation processor.

Uniform User Interface

A single user interface to processing functions — from batch to time sharing — is a key accessibility feature. There are no format or execution differences between usage types. A program written in an interactive environment will run in batch without conversion or modification, and vice versa. In addition, there are no restrictions on languages used to access data bases or files. For example, programmers may develop COBOL applications to use with modules written in other languages. Moreover, data and programs associated with one processing dimension (e.g., transaction processing) are accessible from any other dimension.

Total Online Orientation

While many other systems provide online capabilities only through executive packages, Multics architecture is designed to be interactive. All aspects of Multics are online-oriented, including the language processors, applications, data base management facilities, utilities, administrative tools, and metering and tuning capabilities. An interactive Multics system is potentially advantageous in high-volume, transaction-oriented environments with significant terminal activity.

Sharing

Multics permits the controlled sharing of operating system software and libraries, language processors, data bases, and user code and data. For example, even if multiple users are simultaneously compiling COBOL jobs, only one copy of the COBOL compiler is used. Since all supported language processors generate reentrant code, user programs can be shared without special programming. Multics features also enable multiple-user jobs to simultaneously access a single copy of a file or data base.

No Job Control Language

Many other systems require that the user learn a job control language (JCL) prior to running a job. In contrast, the Multics operating system provides control functions via a standard command processor approach. System commands and routines supply the logical branching, conditional execution, file system, and I/O control required to direct a job through simple and complex execution paths. The Multics user need not learn a new batch interface or become a JCL expert to use the system for problem solving.

Flexible Environment Shaping

Multics is designed to match the computer's processing environment with the user's particular needs. Its flexible interface can help users to use the computer in their customary way even though they are changing to a new system. The concept of shaping environments can be particularly beneficial to data processing organizations that simultaneously service many diverse user groups. Each group can develop — using standard administrative tools — specialized interfaces to satisfy unique operating requirements. For example, the abbreviation processor tool allows users to define their own abbreviations for frequently used command lines or sequences of commands.

Help Facility

Printed text in the help facility provides immediate, online assistance to users requesting data on various system topics, including the use of Multics operating system commands and subroutines. Users can document their own programs and routines, and avoid continual referral to cumbersome hardcopy documentation.

Abbreviation Processor

Multics incorporates a powerful abbreviation processor which enables the user to define short abbreviations for frequently used or hard-to-type input commands. When used with the EXEC-COM facility, the abbreviation processor also allows the user to create powerful meta-commands without writing a single program.

EXEC-COM Facility

With the EXEC-COM facility feature, users can write programs to execute sequences of pre-defined command and input lines which typically require programming effort in higher level languages on many other systems. A variety of additional control capabilities are provided.

Interactive Software Development

To assist in software development, Multics has powerful source code manipulation techniques for entering, editing, and archiving code, and for automatically structuring programs for easy reading and use. Online debugging tools help check out new code and fine-tune programs and standard calling sequences for system libraries and user programs.

Program Development

Compatible language processors contribute to the system's excellent program development capability. These processors — including PL/I, COBOL-74, FORTRAN, APL, ALM (assembler), and BASIC — can be fully shared. Because of their compatibility, programs written in APL, for example, can call those written in PL/I or FORTRAN. Compatibility is restricted only by the data types supported by each language. Since all compilers generate reentrant code by default, the system shares user programs. No special coding procedures are required.

Applications Development

The Multics operating system provides a standard applications environment that can be shaped to individual needs. In many systems the programmer developing applications must be concerned with terminal control, data base management, interfaces to system functions, data security and integrity, and I/O interfaces. With Multics, programmers can concentrate on programming and shorten the development cycle.

Data Base Management

The data base management capabilities available with DPS 8/M systems are provided by three primary software tools: Multics Relational Data Store (MRDS), Logical Inquiry and Update System (LINUS), and Multics Report Program Generator (MRPG).

Multics Relational Data Store

Honeywell Multics systems offer one of the few relational data base systems available — the Multics Relational Data Store (MRDS). MRDS provides data and program independence via model/submodel data base definitions and non-procedural user retrieval and update mechanisms. It allows interactive or batch usage, sharing, concurrent access, and access via programs written in any language supporting a "call" statement available on the system.

MRDS operates as a subsystem, making full use of the Multics virtual memory storage system and the file management system.

In MRDS, there are two levels of data base definition: the data model and the data submodel. The data model is the actual physical definition of the data base and is created and maintained by the Data Base Administrator. The submodel, a proper subset of the data model, provides the user or application program with its view of the data base. It contains information necessary to map data between the user and data model definition. The user program may access more than one submodel.

MRDS relies primarily on access control lists rather than on security locks (passwords) to provide security at the relation level.
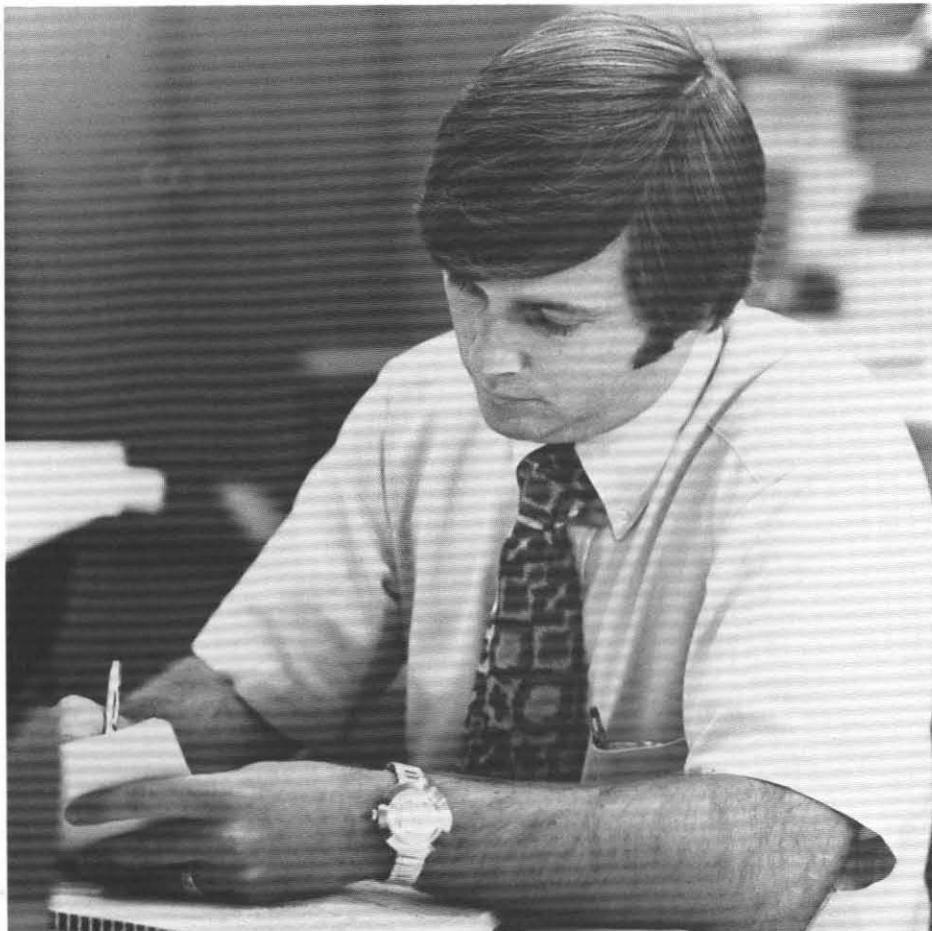
MRDS is designed to create data bases that have a minimum of internal structure in order to facilitate data base reorganization when the need arises.

Logical Inquiry and Update System

The Logical Inquiry and Update System (LINUS) provides a data base query and update capability for users who may not be computer specialists, but who are willing to learn to converse with a computer in a fairly structured manner via a high-level, nonprocedural language. This facility is designed primarily for interactive use, but an extensive macro capability is provided to allow a "canned" series of operations to be performed as required.

LINUS operates as a subsystem and provides the capability to retrieve and update data in an MRDS data base. Data to be selected is specified via expressions in the LINUS language (LILA), which is designed for individuals who might not be computer programmers. The user views the data base as a set of tables containing rows and columns of data. LILA allows the selection algorithm to be specified as a series of table look-up operations, similar to the way an individual would manually scan a set of tables for information.

Report Generator Language

The Multics Report Program Generator (MRPG) is designed to assist a user in describing formatted reports. The result of compiling a program written in MRPG is a report command; the results of executing a report command are the production and distribution of reports.

The user describes a desired report by answering three questions: What is the input like? What is the output like? What phases of processing are necessary? The input may have fixed or variable fields, and each input record may produce one or more lines of data in one or more reports. The user may define the length for each page of output and the data which appears before and/or after the pages of formatted data. Processing is described in one or more phases where each phase represents one pass through the data. The final phase description ends with a PRINT request; all other phase descriptions end with a HOLD or HOLD/SORT request. All phase descriptions may contain one or more PRINT requests.

Report commands need not be compiled each time they are used. The user may invoke an already compiled report command from the command level, or from within a program, in the same manner in which commands and programs are normally used in the Multics system.

2. The Distributed Systems Environment (DSE)

With Honeywell's Distributed Systems Environment (DSE), users can distribute or centralize the power of their Multics system to the degree that best suits the needs of the individual organization. Computer resources can be placed at locations nearest the work — or at several functional areas in the same physical location. These resources can then be interconnected to reflect the structure and objectives of the organization.

Each field location, for example, might collect and process data locally for its own requirements while reporting all pertinent information to a central site.

DSE is a concept, not a rigid framework around which information processing systems *must* be built. Users can arrange the separable functions of a system (information processing, data base management, and network processing) to meet current needs, yet still have the flexibility to adjust their Multics system as organizational needs change.

Today's distributed processing offers these potential advantages to users:

- Increased end-user productivity — by shortening (or reducing the number of) communications links and improving data accessibility

- Increased flexibility — by making components and functions modular, autonomous, independent
- Increased availability — by localizing the effect of component failures and making backup systems practical
- Improved equipment utilization — by matching hardware and software to tasks
- Improved decision-making effectiveness — by giving decision makers almost immediate access to current data, either locally or remotely
- Reduced communications costs — by decreasing data communications frequency and volume

Elements of the Distributed Systems Environment

Three elements constitute the most basic capabilities of a Honeywell Distributed Systems Environment: distributed processing power, data base management capabilities, and network communications capabilities.

Distributed Processing Power

Three system building blocks let users configure the correct level of computing power where it is needed.

The host processor functions in a supervisory capacity at a central site. Satellite processors can be placed at strategic locations in the organization where business operations occur. Terminals allow personnel to enter transactions, update data, and extract needed information from the system.

Host Processor

The host processor provides supporting services to users and controls satellite processors and terminals. It requires no supervision from other processors and contrary to expectation, may be as small as a minicomputer or as large as the Multics system. Honeywell's systems offer a broad range of choices — from the small DPS 6 to the large-scale DPS 8 systems.

Satellite Processor

Linked to the host by communications facilities, the satellite processor controls concurrent operation of batch-oriented devices, such as unit record equipment and line printers. It also allows a user to move files between the host and the satellite processors.

As satellite processors, Honeywell's DPS 6 family features concurrent connection to multiple hosts, local application execution, subsets of the host language, and file management functions.

Terminals

A system's terminals put the power of the computer more directly in the hands of the end user — on the factory floor, at the bank or office branch.

In addition to a DPS 6 used as an intelligent terminal, Honeywell has a complete line of Visual Information Projection (VIP) terminals.

Data Base and Data Management Software

The Distributed Systems Environment requires highly capable data base and data management software to handle data input, storage, and retrieval with considerable flexibility. It needs software that supports concurrent access to common data bases.

Multics Relational Data Store (MRDS) is such a software system. With MRDS, the user has no need to know how data is managed.

Network Communications Capabilities

Network communications consist of communications hardware and software that provide for the movement of data from one location to another, while allowing all the components in the system to work together effectively.

Front-End Network Processor

The front-end network processor (FNP) controls the system's data communication facilities and performs such functions as routing,

concentration, and link terminal control. Basically, it serves as the link between each host processor and the network, so it frees the host from routine communications burdens.

For FNP software, the Multics Communications System is one of the more comprehensive communications control programs available today. It supports remote job entry, transaction processing, time sharing, and comprehensive data collection and distribution. It also supports interactive graphic and word processing functions.

DPS 6
Satellite Processing

DPS 8/M distributed processing is accomplished primarily in conjunction with Honeywell's powerful multi-functional computer system, the DPS 6.

DPS 6 is a full data processing system. Its GCOS operating system provides multiprogramming facilities for concurrently performing batch, remote batch, data

entry, program development in COBOL and FORTRAN, and transaction processing. When operating on a distributed processing system with DPS 8/M, interface is via the G115/RCI protocol.

File transmission between the DPS 6 and Multics system is via high-level commands. Files may be in either ASCII or binary format.
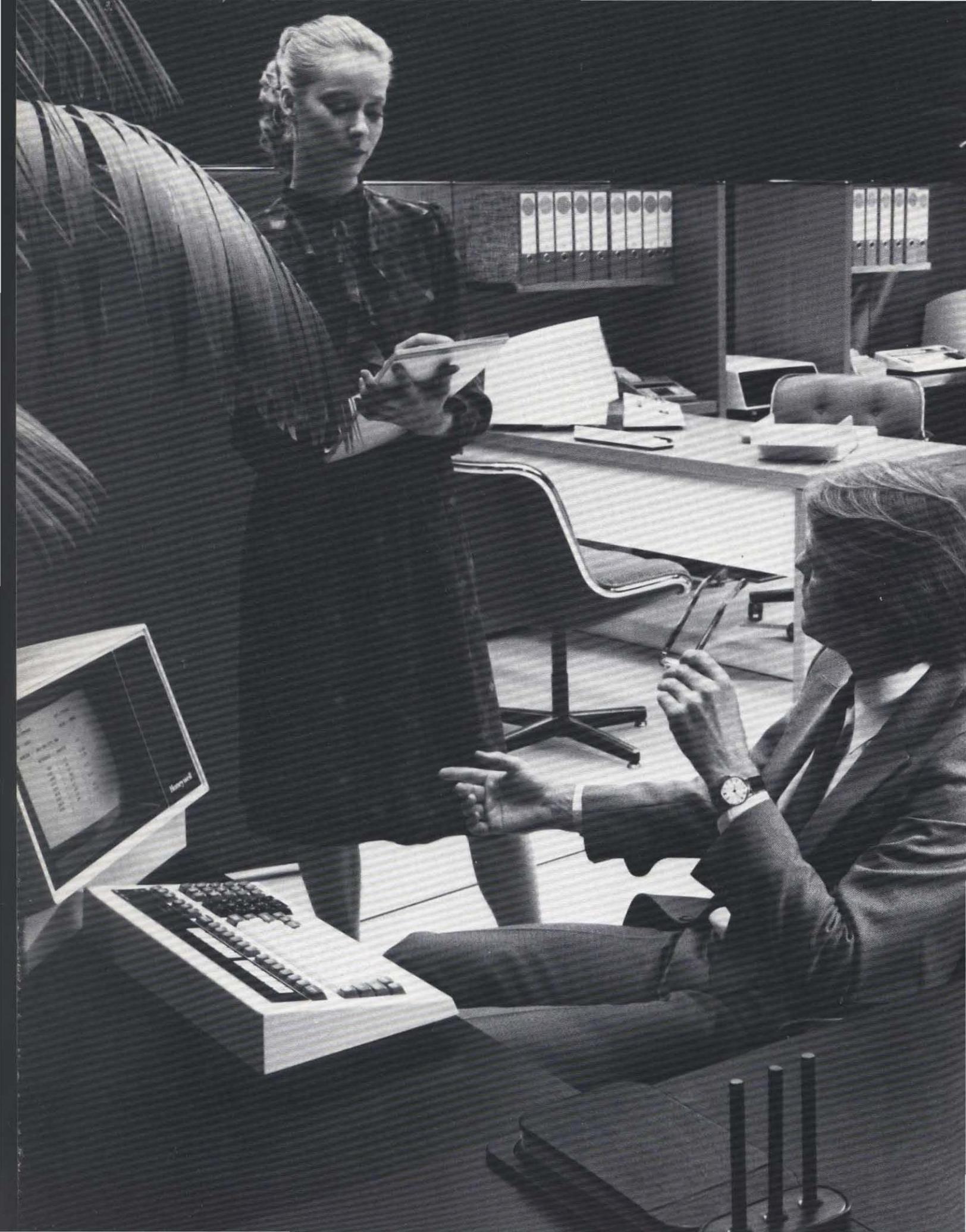
3. System Software

Some of the major characteristics of the Multics system include:

- Virtual memory organization, including system and user information
- Selective sharing of information through controlled access
- Hardware-enforced security mechanisms, including the ring structure that allows programmable access control
- Open-ended, modular system design to facilitate technological improvements and expanding user requirements
- Structural administration, allowing decentralized control and management of system resources
- Flexible user interfaces, allowing a wide variety of programming environments
- Minimal service disruption through dynamic hardware reconfiguration and online software maintenance and system administration
- Reliable internal file system
- Convenient remote terminals as the normal mode of system access
- Efficient service for users of both large and small Multics systems
- Powerful, versatile, efficient, and easy-to-use data base management capability
- Integrated word processing system for developing a wide range of documents online
- A graphics system that can create, edit, store, display, and animate graphic material

Interactive Programming Environment

The Multics interactive programming environment is designed to provide a complete range of facilities that satisfy both the novice and the professional programmer. Both use appropriate software tools to work on the same system, protected by hardware/software security features.

The user interface provides an environment for a wide scope of applications. The multiprocessing and multiprogramming capabilities of the Multics systems and their diversity of languages and utility routines provide the user with a wide range of support.

The Process

A user who accesses (logs into) a Multics system is allocated system resources in an environment termed a "process." Specifically, the process is dynamically assigned space within the virtual memory (address space) and other system resources as required. In this environment, the user's address space dynamically grows and shrinks as program requirements expand and contract — and the activity is totally transparent to the user and under control of the shared operating system. The system creates a process at login time and destroys it at logout time on behalf of each user. Users execute their programs and system commands in co-existence with the processes of all other logged-in users under the multiprogramming control of the Multics operating system.

Environment Shaping

The administration of a typical Multics system includes one system administrator and multiple project administrators. Each project administrator defines the working environment of users in that project. The project administrator may give users maximum flexibiity by allowing them complete control in creating their own initial processes, or may limit the users' capabilities by restricting access to various software functions.

The project administrator then defines the range of access each user has to system software functions. If the user has complete control of his own process environment, he may change parts of that environment and still be within the normal operating conventions of the system.

Language Processors

Multics supports several fully compatible language processors. Foremost is a functional and trend-setting PL/ compiler that is used for both system programmers and applications programmers. The present compiler has undergone several major design iterations to become perhaps one of the more stable and reliable PL/ compilers in the industry. This is the same PL/I compiler that is used to produce the Multics operating system software itself, most of which is written in the PL/I language.

Multics supports COBOL-74. COBOL programs can call programs written in any other language, thereby offering developers added flexibility.

A Multics FORTRAN-77 compiler is available to satisfy any FORTRAN requirement as well as to facilitate the transfer of software from other computer systems. The FORTRAN language processor conforms to the FORTRAN-77 standard.

A BASIC compiler offers quick compilation and execution. It can be used as an independent language processor or in the simple time sharing subsystem called FAST.

An APL language processor is also available. This is an interactive interpreter with extensive functionality.

For those users who find it necessary to write portions of their software in the language of the host computer, the ALM (Assembly Language for Multics) assembler is available, supporting all system requirements for interprogram communication.

A program written in any language available on Multics can also call programs written in another language by merely following that language's calling conventions. For example, APL functions can call PL/I procedures.

All Multics compilers will automatically generate pure, reentrant code for users, making all programs immediately shareable.

This can lead to more efficient use of main memory and storage, because multiple users can concurrently execute and/or share the same copy of a compiler or a user program.

Support Facilities and Tools

Stable and reliable software components within the Multics operating system provide numerous utility and support functions. Prominent among these are the editors, which range from a simple editor supporting line-numbered files to an advanced video editor and screen management system.

Several interactive debugging packages help a user to analyze and correct a compiled program to both the original source level and the more specific machine-register level.

Tools to measure performance help the user to analyze a program's behavior and facilitate the improvement of applications software.

Interuser communication facilities, both immediate and deferred, permit online messages to be transmitted among users. In addition, online documentation facilities provide the user with useful word processing and document preparation tools.

The Command Processor

The command processor (the means by which requirements are communicated to the system) accepts input from a terminal, interprets the user's request, and invokes the software component to perform the desired function. The software component can be either system- or user-supplied; there is no distinction at the command level. The command processor allows recursive, iterative commands and the embedding of function calls in the command line.

The command processor is a shared, replaceable module, written in PL/I. Therefore, if the project administrator desires, a user can be required to interface with a special version of the command processor (possibly user-created), thereby limiting the software requests or commands available to that user. The command processor thus permits a wide range of interfaces to all system facilities either on a controlled or open-ended basis.

Tools are available to the user that allow the abbreviation of commands or character strings for the development of personalized shorthand methods for directing program execution or accessing files.

Also, users can program in commands with logical branching, file management, I/O control, nested if-then-else statements, setting and testing of variables, statement execution tracing control, and comment lines, all of which means that complex applications can be developed without involving the language processors.

The command syntax has been designed to provide a sophisticated and flexible user interface for both a commutative and associative syntax form. However, simple requests have a simple form.

Virtual Memory and Storage System

The storage system for Multics systems is a modular, hierarchical file system augmented by a comprehensive virtual memory.

Storage Hierarchy Concept

All information in the virtual memory is organized into segments. The segments and their directories are organized into a *single* tree-structured hierarchy. This hierarchy defines the storage system for users, administrative and accounting information, and the system software itself. This directly contrasts with conventional systems, which provide one class of data storage for users and reserve another for the system.

Directory Concept

The sole function of a directory segment is to catalog the segments residing below it in the tree. Each directory names the subordinate segments; lists the attributes of each (e.g., length, virtual memory address, and date and time the segment was modified); and lists the users allowed to access the segment and with what access mode (read, write, execute, or null).

The directory concept is the key to several Multics features including storage structure, administrative control, access control, search rules, and naming conventions. For example, all users registered on the system are grouped into projects. Each project has a directory. End users in that project have their own directories, subordinate to the project directory. Users can create additional subordinate directories under their own directories or under directories to which they have been granted specific access. Users can also create "links" to segments if they have the proper access, a capability often used to share data and/or programs.

Segmentation Concept

A segment is a collection of instructions and/or data associated with a particular segment name. A subroutine, such as a square root subroutine, is a segment. Subroutines are dynamically located and linked when first referenced; explicit action by the user is not required. Data and/or programs can be shared among many users; each user program merely references the segment by name. Segmentation permits information sharing in a more automatic and general manner than found in nonsegmented systems. Sharing is accomplished without duplication of information, and access to the shared information is controlled in both main memory and secondary storage.

On the DPS 8/M, each segment is accessed by the hardware through a segment descriptor containing the segment's attributes. Among the attributes are access rights that the hardware validates on each reference to a segment. The segment can be relocated anywhere in memory and can grow or shrink independently of other segments. For example, a compiler can reside in a segment where writing is not permitted, but execution is allowed. Thus, users can execute the compiler but not change it.

Each segment appears to users as an independent memory, associated with a descriptor. Communication between segments is done via symbolic names. Therefore, a segment does not have to be in a specific storage location. There is no requirement that all the segments that belong to a process be in main storage at the same time.

DIRECTORY SEGMENT

NONDIRECTORY SEGMENT

⟶ DIRECT CONNECTION

---→ LINKED CONNECTION
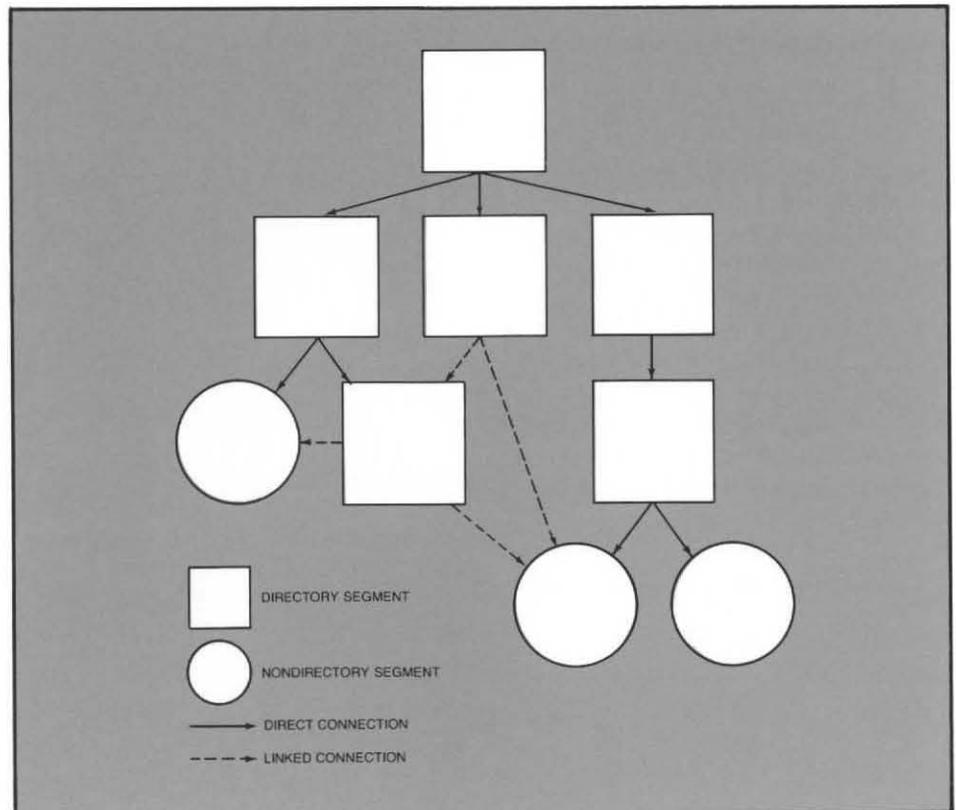
Segments not being used do not occupy valuable main storage space but reside on secondary storage.

Referencing a Segment

Provided a user has the proper access rights, all information is directly addressable. In addition, all of the information within the storage system is placed within the Multics ring structure — a hardware-software feature that provides security for the information being shared.

The physical movement of information between main memory and secondary storage is wholly automatic and of no concern to programmers when establishing the structure of applications. The usual complex combination of file access methods and job control language are replaced in Multics systems by a simple two-dimensional addressing scheme involving the symbolic name of a segment and the address of the desired item within the segment. Even the relative address is usually given in symbolic terms through the data description facilities of the language used.

Each segment is identified by a user-assigned symbolic name as well as by a unique, system-assigned identification. The system identification, unknown to the user, can help to greatly simplify functions within the storage system itself and help eliminate ambiguity and overhead in sharing data.

The fully specified name of any one segment is the list of the subnames that reflect that segment's position in the directory hierarchy with respect to the root directory. This name, called a pathname, shows the "path" from the root directory to the specific segment and is the symbolic name by which users must reference the segment.

Users have control over every segment in their own directories, and can grant or restrict access to these segments in any way. In fact, a user can grant different access privileges (read, write, execute, or null) to different users of the *same* segment. The system constructs a descriptor according to the access information given by the creator of the segment.

Once the segment is created, the user program can address any item within the segment. The maximum segment size is over one million bytes. Logical files may span multiple segments and contain more than a quarter of a billion bytes.

The Paging Concept

With most computer systems, the limiting physical resource is main memory. The amount of main memory online is a major factor in determining the performance of a system. The problems associated with "swapping" large files in and out of main memory severely limit system performance. Even if files were not all large, the difficult problem of core management would remain. Since Multics allows users to create and/or manipulate large segments, it is neither feasible nor desirable to have an entire segment in main memory when the segment is in use.

Therefore, in DPS 8/M systems, segments are automatically subdivided by hardware into "pages" with a fixed size of 4096 bytes. This feature is transparent to the user. Additional address mapping at the hardware level allows the system to determine whether or not a page of a referenced segment is in physical memory.

If the page is not in memory, a missing page exception occurs (called a "page fault"). The software system intervenes at this point and processes the page fault by locating the desired page in the storage system and transporting it into main memory. Once the page arrives in main memory, the system notifies the "waiting" process and schedules it for continued execution.

This "demand paging" technique with its fixed page size helps simplify space allocation problems and improves the system's cost/performance factor. Only those segment pages currently needed are in memory at any one time.

File Handling

Application programs can optionally manipulate large files directly within the virtual memory's constructs or through a standard system file manager called "vfile." This file manager allows keyed sequential and other commercially oriented data storage to take place on a fully logical basis, with no direct reference to the segments used to store the data within the virtual memory.

Controlled Sharing and Security

DPS 8/M systems provide capabilities for the controlled sharing of information which are universally applied to all system and user functions. In fact, without these security mechanisms it would not be possible to provide many of the end-user facilities available with Multics. Through a simple command interface, programmers can apply the same security mechanisms to their own programs and data without programming for that function. The major characteristics of controlled sharing and security within Multics systems are as follows.

- All information (both system and user) is under storage system control and is therefore protected.
- Access control is initialized by software and enforced by hardware on each reference to the information.
- Access control lists for each file specify users who may or may not access the file.
- Access modes are separately specified for each user on an access control list.
- Access control for each file consists of access control lists, an access isolation mechanism, and ring protection.
- Ring protection levels are established for controlled access to sensitive data bases within a user's process.
- Access isolation mechanism provides for non-discretionary access control of data and interprocess communication.

Passwords

At the time of registration, each user is assigned a password of up to eight characters in length. This password can be changed any time the user logs into the system, or the system administrator can request that the password be changed at the next log-in. In addition, a system-supplied random password generator will deliver a new pronounceable password, if needed, to the user. All passwords are stored online in an irreversibly encrypted file for additional security.

Information Sharing Controls

Beyond the password control (which screens every person attempting to use the system) three additional controls regulate access rights to all data and programs in terms of individual users and processes. These information controls are access control lists, the access isolation mechanism, and the ring protection mechanism.

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Access Control List

The Access Control List (ACL) defines the access rights for each segment and directory. Through the ACL, users can, at their own discretion, grant or deny access to their segments and directories. The ACL specifies the users who have been granted access to the segment or directory and the mode of access allowed them. Users who do not appear on the ACL have no access to the segment or directory. Read, write, execute, and null permissions may be specified for segments (both data and program). Status, modify, and append accesses may be specified for file system directories. These permissions may be specified by user name, by project, or "instance" (whether a process is absentee or interactive), or by any combination of these. Classes of users can also be specified (e.g., all the users in a project, a specific user in a project, or even all users in all projects). Access is initially verified by Multics software and then continues to be enforced by hardware every time the segment is referenced.

Access Isolation Mechanism

The Access Isolation Mechanism (AIM) allows system administrators to define several levels of privilege, which the system itself enforces. Enforcing the separation of these levels is totally independent of other access control or user action. This administrative mechanism overrides user discretion in granting access and helps ensure privacy by preventing inadvertent or malicious disclosure of information between these privilege levels, even by those who own the information.
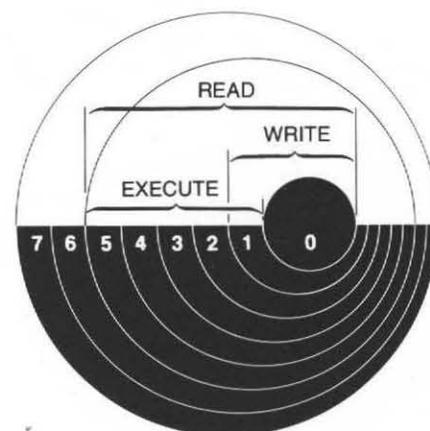
AIM supports eight clearance levels and 18 need-to-know categories within each level. Access is granted or denied explicitly on the basis of the security classification of a file or program and the security clearance of the user. This mechanism supplements the access control lists. Like the ACL mechanism, it verifies access initially by Multics software and thereafter enforces it by hardware at every reference. AIM can be invoked or disabled at the discretion of each DPS 8/M site. AIM also provides security auditing controls to monitor user activity.
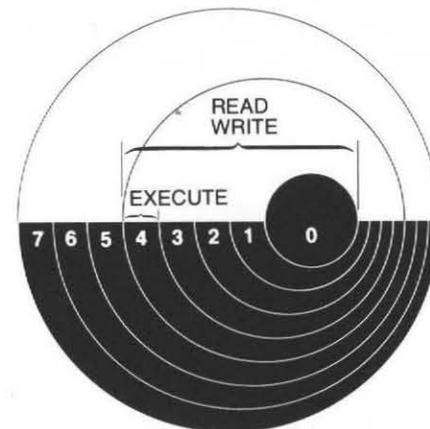
Ring Protection

The DPS 8/M security system uses a hardware-implemented, multi-level, ring structure to control its users and to protect itself. The structure consists of eight rings of protection numbered 0 through 7; ring 0 is the most privileged and ring 7 the least. The operating system resides in the most privileged rings, 0 and 1, while users generally operate in the less privileged rings, 4 and 5. The segments of the operating system are in the most privileged rings to help prevent uncontrolled access or modification by the users of essential system information.

The basic rule of the mechanism is that users can only reference those segments in the same level or higher (less privileged) than the ring in which they are currently executing. Access to lower-numbered (higher privileged) rings is only possible by a software gate.

In its use of the ring protection mechanism, the Multics security system is similar to conventional systems that employ some form of master/slave mode to control their users. However, the DPS 8/M systems surpass these systems in having eight levels of protection rather than two. This extended protection allows applications programmers to have the same type of control over their users as the operating system has — all without extensive security programming within the application.

TYPICAL LIBRARY SEGMENT

TYPICAL USER SEGMENT

Resource Utilization Control

Resource control in Multics systems involves three primary areas: on-line storage utilization, physical access to system communication lines, and user/job prioritization. Standard, built-in tools are used in each area.

Multics enables an administrator to control the use of online storage on a "per project" basis. To maximize the use of storage resources, the administrator can allocate this storage to individual users within a project. For example, a storage quota can prohibit the allocation of storage space when a specified workload limit is reached.

Load Unit Weighting

An administrator can establish the maximum work units that the system will adequately support for the particular site. Issuing load unit weighting factors for each user helps ensure that the system's capacity cannot be exceeded. Different users can be issued different weighting factors to reflect different processing requirements. To help guarantee that specified privileged or high priority jobs will always be executed regardless of the total workload on the system, certain users can be given guaranteed access status.

Dynamic Scheduling

Dynamic control of the priority scheduler establishes user and job priorities. This capability makes it possible, for example, to add either more batch jobs or more interactive users to a system without impacting the productivity of time sharing programmers or transaction processing activities already in execution.

Administration and Operating Features

Multics provides general purpose data processing service for users dealing with various challenging business and scientific problems. Its administration and operating features can help make processing capabilities simpler and easier. These features can help give the user more efficient control over on-line applications, improved response to individual user and group needs, and optimal utilization of all processing-related resources.

Decentralized Administration

A fundamental design concept in Multics holds that productivity is tied directly to accessibility. The system's approach to administration is consistent with that concept. Administration is decentralized. Thus, specific resources can be allocated to specific projects and accounted for accordingly. The project administrator can in turn allocate these resources to individual users within the project as necessary.

Allowing remote users and user groups autonomy in their use of the system and enabling them to control their own resources, gives them the opportunity to more effectively deal with their day-to-day problems and varying processing requirements.

Resource billing flexibility illustrates the potential advantage of decentralized administration with Multics systems. This billing can be done automatically or on demand. Individual project administrators can even do their own sub-billing. Sites can substitute their own billing algorithms, use different algorithms for different users, or install new algorithms dynamically. The administrator can establish up to eight separate work shifts, with different rates applied to each, encouraging use during slack periods. Users can also be restricted to working on specified shifts, and these restrictions can be changed dynamically. This can result in more efficent load leveling and more effective use of resources.

Workload Balancing

Multics systems incorporate a workclass concept which facilitates workload isolation. That is, the workload of one group of users will not affect other users. Workload isolation is implemented by grouping users into classes (workclasses) and allocating each class a guaranteed percentage of processing capability. Regardless of the total system workload, each group of users will receive the predetermined minimum percentage of available processor time. "Free time," any time not utilized by a given workclass, can be made available to other work classes requiring more than their allocated time, thux maximizing central processor use.

Real-time Scheduling

Another facet of the Multics system's online processing administration is real-time scheduling. This feature can be used for a limited number of users or applications to help guarantee that a predefined amount of processing time is available to these users within a predefined time after an interaction or job submission. The number of users or applications that can utilize real-time scheduling is a function of available hardware resources and their processing requirements. Real-time scheduling helps ensure that batch jobs will finish within a specified time period, and interactive users will receive a response within a predefined time span after a transaction.

Changes to allocated resources, response characteristics, and batch job scheduling, can be accomplished dynamically or scheduled to happen automatically at a predetermined time. For example, a key application can be real-time scheduled for no more than a four-second response time during prime shift, but only a maximum eight-second response time on second shift.

Environment Shaping

Multics environment shaping tools let you define system interfaces to match users' application processing needs. These tools not only make it possible for nonexperts to use the Multics system for problem solving but also enable system administrators to define and limit what users can do with the system and what they must know to process their applications.

Environment shaping tools allow the creation of a limited service subsystem or a closed subsystem.

- A limited service subsystem enables the project administrator to define exactly those functions which the user cannot perform; all other functions of the Multics system are available to that user by default.

- A closed subsystem lets the administrator define all the functions that the user can perform; all other functions are unavailable by default.

A limited service and closed subsystem can also be used for defining new command languages and interfaces that convert "foreign" system commands into Multics system commands. This can be useful to first-time users. In addition, these subsystems can help nontechnical users to access the system via a highly simplified command interface (e.g., the word processing operator could call a series of complex text processing routines with only a simple set of commands). The capabilities afforded by these structured interfaces do not have to be programmed; they can be established via simple commands. The administrator need only create a new file with the new restrictions or guidelines in it, and it is immediately available to all authorized users.

Simplified System Operation

A Multics system is comparatively easy to operate. This is due largely to comprehensive operator controls, simplified system maintenance, and responsive online metering and tuning capabilities.

Operator Controls

The dynamic reconfiguration capability of the DPS 8/M is used to maintain continuity of processing service in the event of a malfunction in a system component. When a failure occurs in a processor, for example, a single operator command automatically moves jobs and data to another unit, notifies the other system components of the processor's absence and removes the processor from service. Processors, memory, and peripheral devices can be dynamically added to or deleted from a configuration via operator command.

This reconfiguration process can also assist in the testing of certain components. The operator or field engineer can dynamically remove certain devices from service, submit them to test and diagnostic routines and reconfigure them automatically, without interrupting processing service. Alternatively, devices can be removed from service on one system, configured as a separate system, used for testing of new software, and then reconfigured in the original subsystem without shutting down service.

A Multics system can run unattended, providing processing service on holidays and weekends, without the need for operators. During unattended operation, the system can be run in the automatic reboot mode, and, in the event of a system failure, Multics will automatically reinitialize itself so service can continue.

A Multics system can be operated from any terminal inside or outside the computer room. Due largely to the system's security features, an administrator with the proper authority can log into the system and issue most commands that could be issued from the main operator's console. This gives the system greater operational flexibility.

Multics systems provide traditional batch job status and control capabilities as well as communication between system users. Operations messages can be sent to individual users: messages can be broadcast to the entire user community or to those on a particular project.

System Maintenance Features

For simplified maintenance, the DPS 8/M does not require system or library generation or edit. Multics software releases are also delivered patch free.

With the exception of the hardcore supervisor, new software can be installed without a system shutdown. New compilers, applications, and procedures can be installed without interrupting processing service, even while users are using old versions.

Metering and Tuning System Performance

Standard Multics metering and tuning tools allow an administrator to monitor and adjust system performance according to specific needs and changing workloads. The system constantly gathers data that can help administrators to retune the system, move users from one processing class to another, or even change the percentage of processing power allocated to a user, depending on any number of variables and requirements.

This control is possible because the administrator can analyze all facets of system performance from this constant flow of metering data. Some of the information supplied includes:

- I/O and device activity data
- Processor utilization, communications, and I/O queuing
- Average CPU time spent on certain functions, or used by certain applications
- State and characteristics of the communications lines attached to the system
- EDAC (Error Detection and Correction) data associated with main memory hardware errors and peripheral controller errors

Integrity Mechanisms

To maintain file integrity in the event of a malfunction, DPS 8/M systems have file back-up mechanisms:

- An automatic back-up mechanism journalizes all changes to the file system and makes it possible to "roll back" following a failure.
- Online file system integrity checks help ensure a consistent reliable file system.
- Main memory flush-to-disk is a data protection mechanism invoked after a system service interruption. All data in main memory that has been modified is written out to secondary storage to reflect all changes prior to the failure.

Data Base Management

Honeywell's Multics Relational Data Store (MRDS) is designed to provide Multics users with a powerful, versatile, efficient, and easy-to-use data base management capability. MRDS functions as a subsystem of the Multics operating software, and makes use of Multics virtual memory and file management subsystems. It is designed to support concurrent access to up to 64 data bases of up to 180 billion characters each.

MRDS can simplify the job of programmers and end users, as a detailed knowledge of the logical structure of the data base is not required to use it. For example, a person seeking data writes a statement that defines the nature of the data required, rather than providing specific instructions as to where and how the data is to be retrieved.

Potential MRDS Advantages

- *Improved programmer productivity* — MRDS's relational capabilities can help programmers accomplish data base tasks with less effort.
- *End-user flexibility* — The simplicity of the relational technique permits end users to independently retrieve data base information without support from the programming staff.
- *Ease of maintenance* — The tasks of entering and changing data can be simplified.
- *Data storage efficiency* — One data base system can potentially meet the needs of an entire organization and thus reduce the need for redundant files.
- *Improved data accuracy* — The elimination of redundancy can mean consistent information with fewer chances of error.
- *Data integrity and security* — Inherent DPS 8/M integrity and security features are available to the MRDS user.
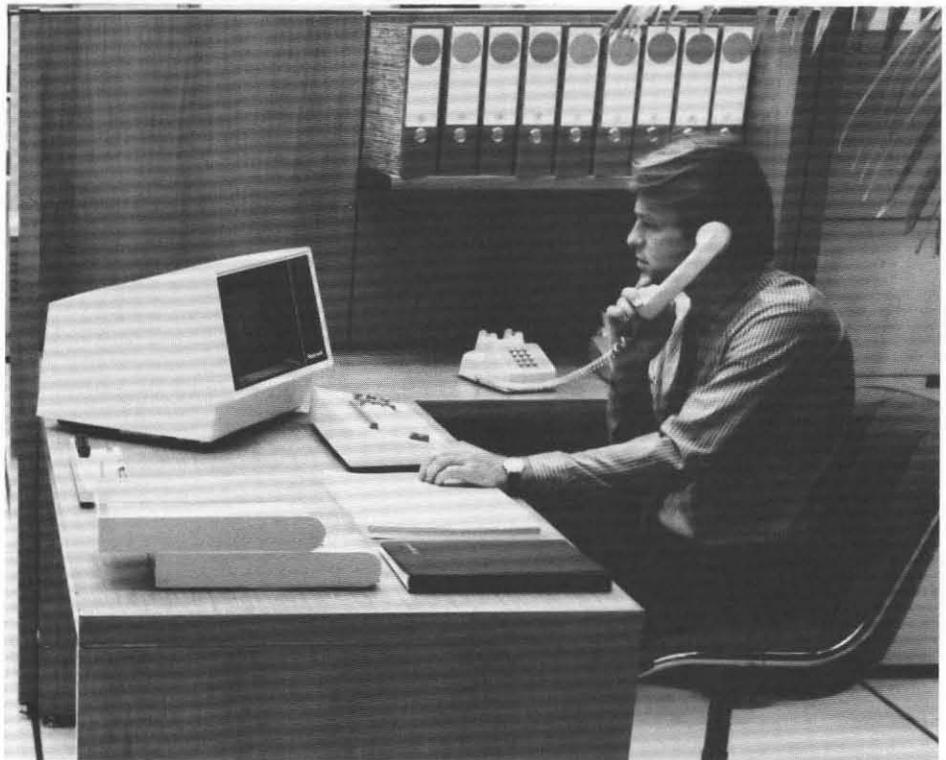
MRDS Features

The Multics Relational Data Store includes several significant system design features.

Relational interface — MRDS represents data relationships by means of formal algebraic entities. A user structures and accesses data files without concern for how or where the data is actually stored, which can help simplify the user's task.

Language independence — Any system-supported language may be used to access MRDS facilities, including COBOL-74, PL/I, FORTRAN, and Assembler. Well-defined CALL statements are employed.

Independence of processing modes — MRDS supports all processing modes, such as transaction processing, batch, and remote job entry. All of these modes can be supported simultaneously.

Controlled sharing — All user data (as well as operating system software, libraries, and user code) may be shared at the discretion of its owner. Since all Multics-supported language processors generate only pure reentrant code, no copies or reloads are required.

Data definition and program independence — Data definition is an independent function. In most cases, changes to the data base will not require reprogramming of user applications.

Query capability — LINUS (Logical Inquiry and Update System) allows users to access an MRDS data base from a terminal. access an MRDS data base from a terminal.

Online access and update — Data may be easily added, modified, or deleted online. Multiple users may access the same data base concurrently. MRDS can be invoked by as many users as are allowed on the system.

Concurrent access and update controls — Through Multics Access Control Lists, update privileges can be restricted. To help ensure integrity, users may specify exclusive use of the data base when it is opened. If sharing a data base, users may temporarily reserve a relation during critical update operations.

Report generation — The Report Program Generator facilitates the production of reports, in conjunction with either the LINUS query language or ASCII files.

Automatic data recovery and restart — MRDS provides a mechanism to help ensure that a consistent version of a data base can be backed up to tape or disk. This feature provides recovery of a data base after system failure or when a disk has been damaged.

Dynamic tuning — A system administrator can view current monitoring data from a terminal and dynamically alter parameters to affect performance.

Data integrity and security — MRDS derives its integrity and security characteristics not from provisions within the data base manager, but rather from design features of the Multics operating system and system hardware.

Traditional Data Processing Terminology	Honeywell MRDS Approach	CODASYL[a] Approach
Record type, class or format (physical)	physical record	physical record
Record type, class or format (logical)	relation	record type
Record occurrence	tuple	record occurrence
Field/element	attribute	data element field
Range of values (the set of all values associated with a field type)	domain	largely ignored
Total data base definition	data model	schema
Program view of data base	data submodel	subschema

[a]Conference on Data Systems Languages

Data Base Definition Process

To define a MRDS data base, the user or data base administrator defines a *data model*.

The data model definition file contains the complete description of the different data elements in the data base.

The data descriptions are not directly referenced by user application programs, and each application program may have a different view of the data base. The definition of that portion of the total data base affecting a particular program is accomplished by defining a data submodel.
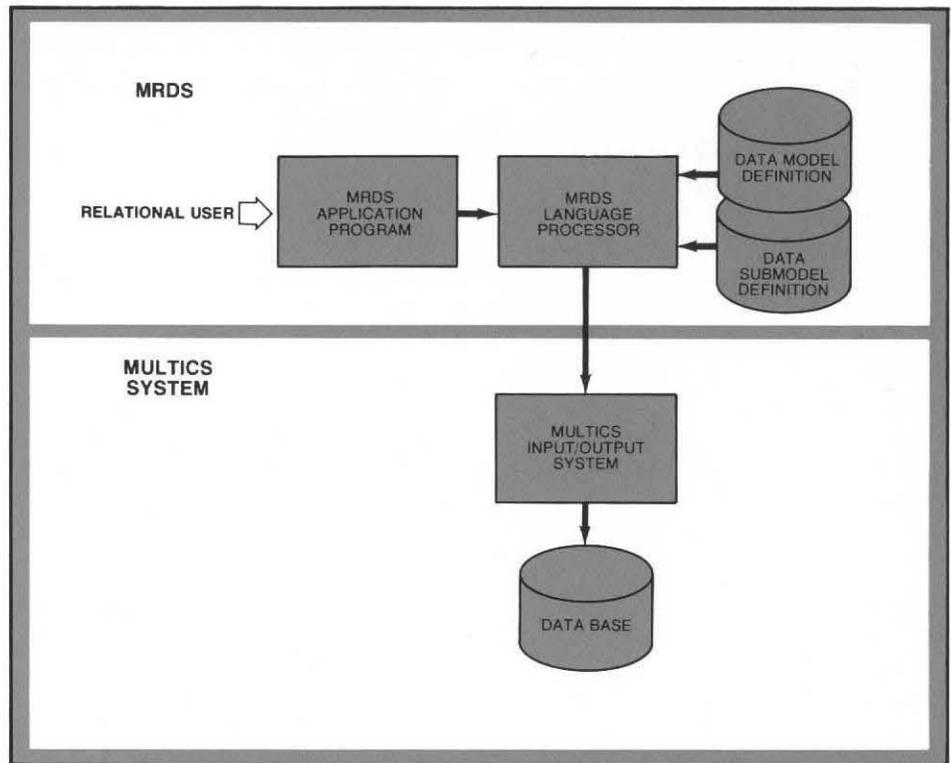
Partial views (data submodels) must be proper subsets of the total data base definition.

The data model or data base definition is defined, accessed, and maintained by the data base administrator. The administrator, in conjunction with application users, defines a valid data submodel to be referenced by each application program. Under certain user-controlled circumstances, a user may act as the administrator and deal directly with the data model.

The definition of a data submodel may differ from that of the data model in several ways:

- Attribute names may differ
- Attributes may be omitted
- Attributes may be ordered differently within a relation
- Relations may be omitted
- Relation names may differ

A data submodel definition may be created separately or in conjunction with an application program. Several data submodels may be associated with the same data model or may be referenced by the same application program. Data submodel definitions may intersect.

MRDS

RELATIONAL USER

MRDS APPLICATION PROGRAM

MRDS LANGUAGE PROCESSOR

DATA MODEL DEFINITION

DATA SUBMODEL DEFINITION

MULTICS SYSTEM

MULTICS INPUT/OUTPUT SYSTEM

DATA BASE

Data types for data submodel attributes are defined within the application program, not within the data submodel. They may differ from the data types defined in the data model for the corresponding attribute name. Allowable data types (in PL/I terms) are real and complex fixed binary, real and complex floating binary, real and complex decimal, varying and nonvarying bit string, and varying and nonvarying character strings. Binary data types may be single or double precision.

When defining a relation in a data model or submodel, the creator must specify which attributes or fields are to be used as components of the primary key (i.e., key attributes). Each tuple or record occurrence must be identifiable by some non-null primary key value which must be unique. The expression for defining a relation and its attributes resembles the format used in most relational literature.

MRDS Language Processor

The MRDS Language Processor allows the user to:

- Open and close a data base defined by a specified data model or submodel
- Retrieve data based on a flexible selection capability
- Modify and delete items within a data base
- Enter new information into the data base
- Allow for concurrent access by other users

The data manipulation capability is relationally complete — it possesses the full power of relational calculus. Any query expressible in first-order predicate calculus is expressible in an MRDS selection mechanism.

LINUS

LINUS (Logical Inquiry and Update System) is a powerful and easy-to-use facility for accessing data bases from a remote terminal. It is designed to provide complete data base management capabilities, including both retrieval and update operations. LINUS functions as a subsystem of the Multics operating software and uses Multics Relational Data Store (MRDS) for data base access. LINUS is used by a variety of business professionals, including inventory control personnel, budget planners, geologists, and school administrators.

LINUS uses a high-level, non-procedural data selection language called LILA (LINUS Language). LILA can help people who are not trained programmers to solve problems by working with data bases. The user views the data base as a simple set of tables, consisting of rows and columns; LILA provides an easy way to "look up" information contained in those tables.
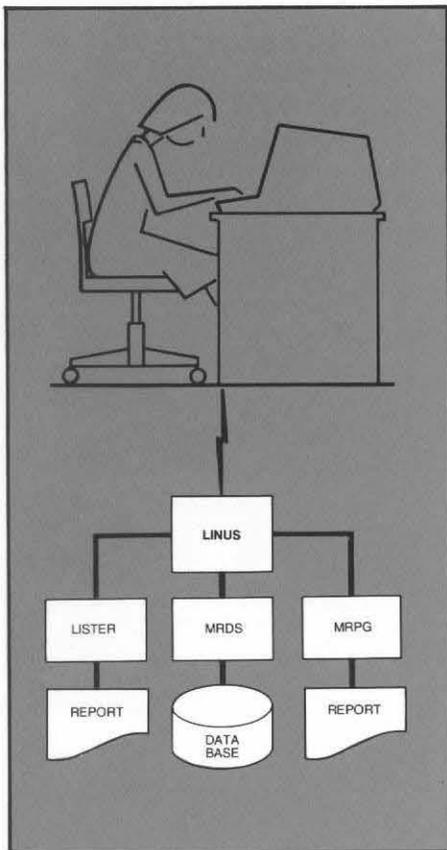
Features

LINUS is designed for ease of use. With as few as three key words, even an inexperienced computer user can get information from a data base using LINUS. In addition, LINUS offers:

- *Direct End User Access* — Using LINUS, the user can independently retrieve and update data base information without support from the programming staff.
- *Support of Unforeseen Requirements* — The LINUS user can immediately respond to unexpected information requirements by interactively selecting the desired data via a terminal, without writing a program.
- *Complete Selection Capability* — LINUS allows the user to select any information contained within the data base using LILA, subject to security constraints.

Capabilities

- *Complete Data Base Functionality* — LINUS allows users to add and delete rows from a data base table, to modify column values in a table, to define temporary tables for personal use, and to retrieve information from one or more specified tables.
- *Macro Facility* — A parameterized macro facility allows the user to invoke previously saved sequences of LINUS requests. This allows the tailoring of an environment to an individual user.
- *LILA Line Editor* — A BASIC-like line editor built into LILA simplifies construction of data selection expressions.
- *Built-in and User-defined Functions* — Built-in functions allow the user to determine sums, averages, and counts of data as well as to search such items as partial character string values and rounded or truncated numeric values. In addition, there is a well-defined method for dynamically adding functions required by users.
- *Internal Variables* — The LINUS user can assign retrieved data values to internal variables, allowing subsequent data selections to be dependent upon previously retrieved data.
- *Help Facility* — A help request available within LINUS provides information on how to use its many facilities. The user need only type "linus" to invoke the subsystem, and "help" in order to begin using LINUS.
- *Table of Contents* — The user may display information about the contents (tables and columns) of the data base. Thus, LINUS can be used even by those who are unfamiliar with the structure and content of the data base.
- *Report Writing Capability* — Reports from retrieved data can be created using either the Multics Report Program Generator (MRPG) or the WORDPRO facility, List Processing. Either facility can be invoked with a simple LINUS request.
- *Multics* — Any Multics command can be invoked from within the LINUS subsystem. Some possible uses of this feature are: sorting retrieved data via the Multics sort facility or editing retrieved data with one of the Multics text editors.
- *Data Base Creation* — The user can create a private data base via easy-to-use MRDS commands. Special documentation oriented to the LINUS user makes this process comparatively simple. The data base can then be maintained and accessed using LINUS.
- *Data Sharing, Integrity, and Security* — LINUS fully utilizes MRDS and Multics facilities for concurrent usage control, data base security, and data base back-up and recovery.

Communications System

The Multics Communications System manages the transfer of data between the Multics virtual memory and remote-user equipment (particularly terminals) over communications channels. Thus, the host system is freed from communications control and can concentrate on data processing.

With its high performance and flexibility, the Multics Communications System offers a number of potential operational advantages:

- Supports terminals and hardware of many manufacturers
- Can be interfaced to Honeywell's DPS 6 computer for satellite applications
- Permits customizaton of software for specialized user applications
- Permits administrators to easily monitor and tune system performance
- Supports a wide variety of communications protocols
- Has extensive built-in diagnostic and debugging capabilities for increased system availability
- Provides security on a per-channel basis through Access Control Segments

The Multics Communications System resides in both the central system and in the Front-End Network Processor (FNP). The central system software has user process and supervisor portions that manage the terminals and high-level protocols (e.g., 3270, 2780), and the FNP manages the physical channels and low-level protocols (e.g., bisync, HDLC).

Both asynchronous and synchronous protocols are supported. Synchronous examples include DPS 6 Remote Computer Interface (RCI), binary synchronous, HASP, IBM 3270, IBM 2780, IBM 3780, and Honeywell-polled VIP (synchronous). As a special option, X.25 support is available. The Multics HASP facility provides support for communications with foreign remote-job-entry workstations and computer systems utilizing the HASP protocol.

FNP Software

The various protocols supported by the FNP are implemented by software modules known as control tables. These tables consist of data assembled by means of macro instructions and interpreted by the FNP operating system. A site may implement its own protocols by supplying modified versions of these tables and/or additional control table modules of its own.

Multiplexed Channels

A multiplexer is a software program that controls multiple devices or terminals associated with a physical FNP channel. The Multics Communications System treats each such device as a separate logical channel; these logical channels are called subchannels of the multiplexer. The physical channel used/controlled by the multiplexer is called a multiplexer channel. Since an FNP controls many channels, but communicates with the central Multics system over a single channel (the Direct Interface Adapter), the FNP is regarded as a multiplexer itself. All multiplexed channels and their subchannels (which can be mutiplexed, too) must be defined in the Channel Definition Table (CDT). Thus, each FNP must be defined in an entry in the CDT; the FNP core image specified in this entry must exist, and must support at least as many line adapters as specified.

Central System Software

The central system communications software is responsible for:
- Association of communications channels with Multics processes
- Dispatching input from communications channels to the appropriate Multics processes
- Converting output supplied by Multics processes to a form suitable for sending to its destination (e.g., terminals)
- Input and output conversion (processing of escape sequences, character erase, line kill, etc.)
- Canonicalization (placing input characters in a standard order)
- Managing terminal I/O buffer space
- Multiplexing and demultiplexing the subchannels of a multiplexer
- Managing the FNP, i.e., loading it at system initialization, dumping it and recovering when it fails, etc.

User Interface

Most user and system programs interface to the Multics Communications System through the general subroutine interface. This interface allows most programs to perform I/O in a standard way, whether the I/O is to tape, remote terminals, or files in the virtual memory. An interactive terminal is normally attached through the tty_ I/O module. For the user's log-in terminal, this attachment occurs automatically during process creation. Additional terminals connected to the user's process can be attached explicitly. Other types of devices that use special communications protocols may be attached through special-purpose I/O modules, several of which are supplied with the system. For even greater flexibility, users and sites can also write their own I/O modules.

Word Processing System (WORDPRO)

WORDPRO provides a comprehensive set of software tools for developing a wide range of documents online. The spectrum of applications suitable for WORDPRO ranges from simple form letters to complex technical documents. Because WORDPRO is integrated within the Multics operating software, its users can develop and maintain these types of documents simultaneously with other data processing activities. The result can be rapid turnaround time, as well as improved productivity and document quality.

Features

Since WORDPRO is part of the Multics system, it offers the user potential advantages over other less comrehensive word processing systems:

- Ease of Use – People with little knowledge of computer systems or word processing can use WORDPRO for numerous text processing tasks.
- Security – The security provided by WORDPRO is the same security provided for all information stored in the Multics virtual memory. Because WORDPRO-prepared documents reside in virtual memory, they receive the same degree of security afforded any other job, file, or program.
- Document Management Tools – WORDPRO document management tools make it easy to maintain documents online or offline in a standard format. For example, these tools can be used for document file manipulation, and archiving. The same tools which control system storage also control WORDPRO documentation.
- Maximum Equipment Utilization – WORDPRO can help users make maximum use of slack computer time. Rather than have the system sit idle when not processing data, WORDPRO can use this extra time efficiently for text processing – thus helping to increase equipment use.
- Total Integration with Data Processing – Within DPS 8/M systems, word processing and data processing are fully integrated. Data and text files created and maintained by WORDPRO can be accessed and used by data processing applications. Conversely, files created and maintained by data processing applications are available to WORDPRO users, all without special programming or conversions.

Input Devices

Any terminal accepted by Multics systems can be used for word processing, increasing use of terminal equipment.

Users need not purchase special equipment nor dedicate terminals for WORDPRO applications. If one set of terminals is used for input and update, other devices can be used for output. Text entered from one terminal can be modified by another without regard to terminal characteristics.

Text Entry Tools

Tools are provided with WORDPRO for the entry of new text. With these tools, an individual with little or no prior word processing experience can easily power type raw text into the system for later update or incorporation into a document.

SPEEDTYPE – Similar to typing shorthand, it allows users to specify abbreviations for input of character sequences. These abbreviations are easily expanded to their predefined strings. SPEEDTYPE can result in fewer key strokes typed and higher document quality.

Document Formatting and Hyphenation

The WORDPRO text formatter (COMPOSE) provides document format control. In addition to margin and page length control, the formatter handles automatic page and paragraph numbering, widow processing, table of contents and index generation, font and forms control, artwork placements, and automatic hyphenation. Further, the formatter can control:

- Headers/Footers – Up to 20 running headers and footers can be specified. These can be page numbers, copyrights, logos, or

the current date. These need only be specified once; they will be inserted automatically thereafter.
- Footnotes — WORDPRO automatically generates numbers and inserts footnotes. If footnotes are added or deleted, the remaining ones are automatically renumbered.
- Hyphenation – An online dictionary (optional) can automatically hyphenate documents.
- Multi-column – WORDPRO can format and automatically balance up to 10 columns.
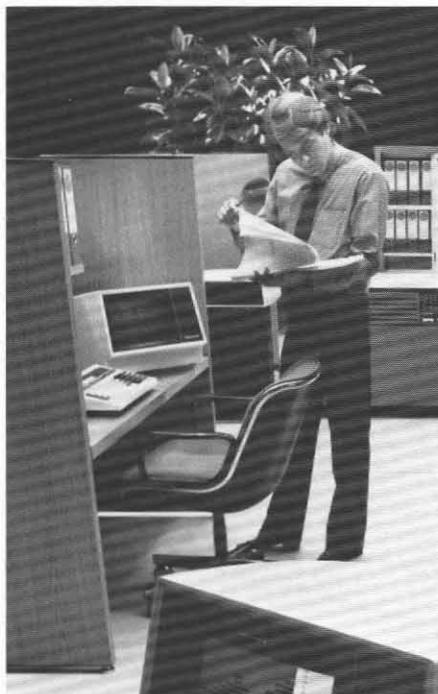
Quality Control

WORDPRO contains a set of quality control tools for detecting and removing typographical errors from documents. First, SPEEDTYPE can be used to correct typing errors at entry time. For example, common typing errors such as "hte" instead of "the" can be automatically corrected by predefining the former string as an abbreviation to be expanded to the latter. Or long, difficult-to-spell words can be abbreviated, thus eliminating frequent misspellings.

Online dictionaries can also be used to detect misspelled words within a document. WORDPRO offers a dictionary containing over 25,000 English words. The content of a document is compared with the dictionary's entries, and any words not found are entered in an error file or printed at the user's terminal. Multiple dictionaries can also be developed. For example, a dictionary of technical jargon could be established so that frequently used non-English words will not be considered misspelled. Dictionaries can be shared, if desired, or used as private versions. Dictionaries can also be added to or deleted from as desired.

Change bars can be generated on documents undergoing review. A complete list of changes (line-by-line) can also be generated in a separate file of notes. Additionally, text comparison programs allow review of new documents against older versions.

List Processing

WORDPRO's list processing facility can generate personalized form letters and billing statements. Lists of mailing addresses can be used concurrently by many terminal operators to create these types of documents with key pieces of information inserted at various points. These list processing tools can also be used in conjunction with other Multics facilities (such as the data base manager) to supply current up-to-date account information for monthly statements, billings, etc. Mailing labels or pre-addressed envelopes can also be generated.

Artwork

WORDPRO can be used to generate diagrams, organization charts, flowcharts, and logos. These figures can be included as part of the final, printed copy of a document.

Output Control

Many devices can be used to print review copies of final documents. A terminal operator may request that a segment of text be output on a local or remote printer, thereby freeing the input terminal for other work. Line printers, plotting terminals, and CRT devices can all be used for output.

High-speed offline printers, such as the Honeywell Page Printing System, can be used in conjunction with WORDPRO to generate multiple copies in multiple colors with-preprinted forms. Special forms control capabilities for line printers and plotting terminals permit documents to be printed on multipart, tear-away, or peel-off forms.

Computer output microfiche interfaces are available for generating, distributing, or archiving documents on micro media. Documents can also be stored in files online, or maintained offline on tape or cards.

Photocomposition

The WORDPRO design incorporates a photocomposition interface to allow the generation of control infomation for automatic typesetting devices. This photocomposition facility is table-driven so that a variety of devices can be supported by simply modifying control tables.

Accessibility of Other Facilities

Because WORDPRO is an integrated part of the Multics system, its users can access other system facilities. For example, financial data stored in a Multics data base can be selectively inserted into a WORDPRO-generated document to produce an up-to-date monthly or quarterly statement. The Multics file management and manipulation tools can be used with online WORDPRO files.

Administrative Tools

Implemented on a project-oriented basis, WORDPRO can control the use of processing resources, access to documents and tools, billing for usage, etc. Users can be restricted to certain functions, or allowed access to full capabilities of WORDPRO. All the administrative controls provided by the Multics systems are applicable to WORDPRO administration.

Graphics System

The Multics Graphics System provides a general-purpose interface through which user or application programs can create, edit, store, display, and animate graphic material.

Features

- High degree of terminal independence
- Ability to define graphic objects that may be used repeatedly in higher level objects
- Powerful editing facilties for graphic objects
- Ability to store graphic objects permanently

Terminal Independence

The Multics Graphics System is organized into two distinct parts: the terminal-independent portion and the terminal interfaces.

User and applications programs communicate exclusively with the terminal-independent portion of the system. This helps ensure that:

- User programs and applications routines are not restricted to one particular terminal type, but can use whatever graphic terminal is available.
- Users are not isolated from each other because of the types of terminals they use, but may freely use each other's programs on their own terminals.
- Graphic applications may easily be transferred as new and improved terminals become available.

The Graphics System can accept new types of graphic terminals with a minimum of coding. In most cases, the user need only specify a terminal's special characteristics in a table and construct a program to perform any code conversion necessary. No special I/O programming is required. Any existing program or graphic file may then be used on the terminal to obtain comparable results.

Structured Graphic Objects

Rather than treat graphic data as an unstructured collection of graphic elements (much as a sketch could be considered an unstructured collection of lines and points), the Graphics System deals with structured descriptions of objects.

This organization has three potential advantages for the user:

- Natural representation of most objects can be made in terms of their own inherent organization. For example, a piston, a complex object in its own right, may be treated as an elemental object within a graphic description of an engine.
- Subpictures can be shared, thereby eliminating redundancy.
- Powerful global picture editing capabilities are possible.

Permanent Graphic Storage

Facilities provided allow the user to attach a name to any graphic object and store it in a Multics segment. Such objects may be used at any time by any user authorized to access the segment.

Terminal-Independent Graphic Transmission

Graphic information is transmitted in a well-defined, terminal-independent code. This code may be interpreted by a Multics program and converted
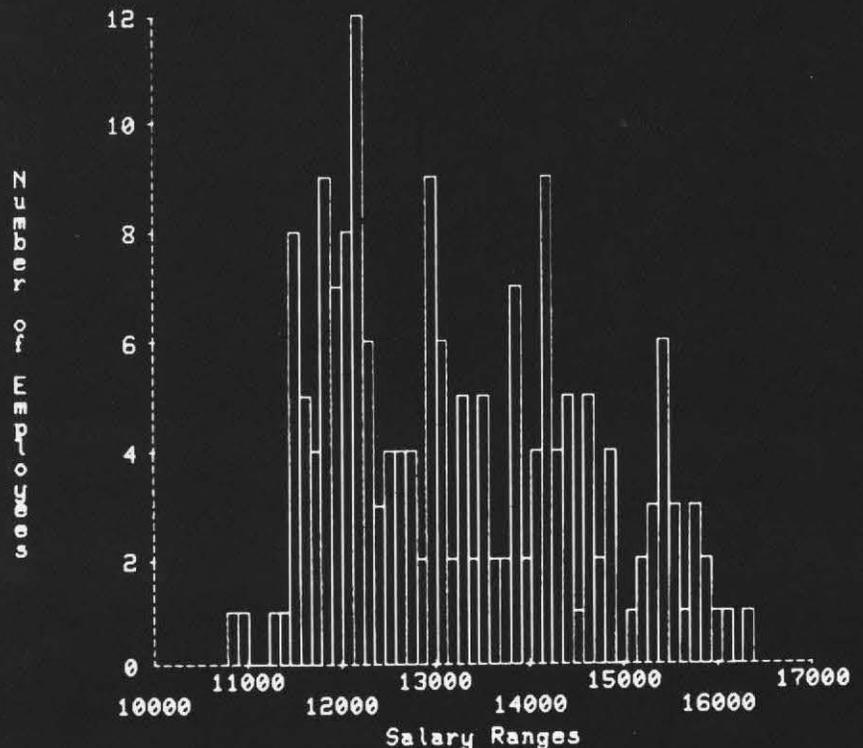
to the appropriate codes to drive a graphic terminal; or it may be transmitted directly to an intelligent graphic device that performs its own interpretation with a corresponding increase in efficiency. It may also be directed to a system file and "played back" on any graphic device to form background scenes or standard "canned" pictures.

System Compatibility

Unlike many graphics systems, Multics implementation is fully compatible with the general data processing environment. Thus, data base and word processing applications can utilize these unique graphics tools.

Programs originally written on other computers that make use of the most widely used set of graphic subroutines may, with minimal conversion, interface in the same way with the Multics Graphics System. Interfaces to mimic other popular graphics systems are easily constructed.

Dynamic and Interactive Graphics

When used with a terminal of sufficient intelligence, the Multics Graphics System can perform real-time graphic operations, such as dynamic animation, incremental picture update, local picture editing under control of the terminal, and sophisticated graphic input.

End User Tool

The Multics Graphics System can be used to generate graphic displays of data pulled from Multics data bases. This provides a powerful tool for developing end-user oriented applications.

Additional Features

Text Editing

The Multics system provides several simple to advanced text editing tools for the online development, modification, and formatting of source programs, memos, documents, etc. These tools provide a wide array of editing functions, ranging from simple line-oriented editing to powerful global editing operations and context-oriented searching and replacement.

The broad categories of editing are line and string editing and video screen editing. Both the line and string editing features are incorporated in the video screen editor that provides additional capabilties. The screen editor can locate, move, or delete any predetermined portion of text from words to document sections. Abbreviations for commonly used words may be expanded the instant they are typed, leaving only the final text in the buffer, on the screen, and ultimately in the user's file.

Electronic Mail

Multics Electronic Mail allows message-switching networks to be established through simple commands. Users can send and receive mail over these networks, ranging from short teleconferencing messages to lengthy memos or documents. Security is provided via a personal or shared mailbox area which is subject to access control checking. Electronic mail can be the basis for the automation of a business's entire in-house mail operation, helping to eliminate the need for couriers. The electronic mail facility can offer the following potential advantages to the user:

- Each user can create a private "mailbox" – a special storage segment for mail delivery – or mailboxes may be shared for group use.
- Any terminal recognized by the Multics system can send or receive electronic mail – no special devices are required.
- A user can access his mailbox from any terminal recognized by a DPS 8/M system.

Electronic mail provides such distinctive functions as:

- Teleconferencing via terminals
- Immediate or deferred delivery of messages, text, and other mail
- Broadcast delivery to groups of users
- Selective delivery only to persons with a "need to know"

- A secure mailbox facility, protected by the full range of stringent security controls in Multics system software and hardware, to guard mail from unauthorized access
- Simple commands to prescribe the mailbox access and mail functions allowed for specified users
- Many document management tools for text manipulation and storage
- Header information in memo format, allowing the system to request information such as the date, subject, sender, receiver, and all recipients of mail copies; more extensive headers include information concerning replies and the forwarding of mail
- Mail copies, forwarded automatically to those persons specified
- Mailbox summaries, including the sender, date and time the mail was sent, and subject of the mail

GCOS Simulation

Special Multics subsystems called the GCOS Batch Environment and GCOS Time Sharing Environment allow GCOS job decks or Input Media Conversion tapes (IMCVs) to be run without change. GCOS files can also be transferred between GCOS systems and Multics systems using standard GCOS tapes. The GCOS Environment also supports several languages that run under GCOS, including JOVIAL, ALGOL, COBOL-68, GMAP, and FORTRAN.

Diagnostic and System Protection Features

Honeywell's Error Logging and Analysis System (ELAN), the Total Online Test System (TOLTS), and the Offline Test and Diagnostic

System are a comprehensive set of system maintenance packages that identify potential processing problems allowing steps to be taken to help prevent system downtime.

ELAN

The Error Logging and Analysis System (ELAN) can detect marginally malfunctioning central or peripheral processors and memory modules — usually before service is interrupted. The error analysis and logging modules, and error reporting programs attempt recovery from transient errors, log detected errors in an error colection file, and print a summary of these errors from that file. ELAN runs concurrently with normal system operation and is invisible to the user.

The appropriate ELAN module is initiated when a processor or memory module error is detected. After analysis and logging, normal Multics fault processing continues. If a nonrecoverable error occurs, the space occupied by the program involved is removed from the available memory table.

The Error Reporting Program is initiated daily, when the error log becomes half full, or on operator request. The program prints, analyzes, and summarizes each record in the error log and retains summary data in an error summary file.

TOLTS

TOLTS strikes a balance between two aspects of large-system integrity assurance: the need to ensure that all system components are functioning correctly and the need to minimize interference with the processing of user applications. TOLTS runs in the multiprogramming environment, concurrently with other system and user programs on an optional basis. It performs periodic tests on system components and, if it finds indications of

errors, calls in specific diagnostic tests and online troubleshooting programs to determine their nature.

TOLTS directs diagnostic and maintenance tests using three subexecutives:

- The Peripheral Online Test System (POLTS) tests peripheral subsystems, both device processor and attached devices, under operational conditions
- The Isolated System Online Test System (ISOLTS) provides a means of testing Multics processors online after they have been removed from system use
- The Mainframe Online Test Systems (MOLTS) checks the central system modules (system controllers and memory)

TOLTS also incorporates a remote testing facility that allows maintenance engineers to call up the system from a remote terminal and run test and diagnostic programs (both standard TOLTS programs and specific tests that they devise themselves using a conversational test language).

The overall effect of TOLTS is to diagnose incipient errors before they impact system operation and to do so with minimum effect on the processing of user applications.

Offline Test and Diagnostic System

The Offline Test and Diagnostic System allows Customer Services personnel to test all central system hardware subsystems. Offline testing for the processors, system controllers, and memory units detects and isolates problems more easily. Peripherals can be tested individually or in conjunction with system operations driving other peripherals. To simulate the normal software environment, mainframe test programs can be executed simultaneously with peripheral programs, in any combination.
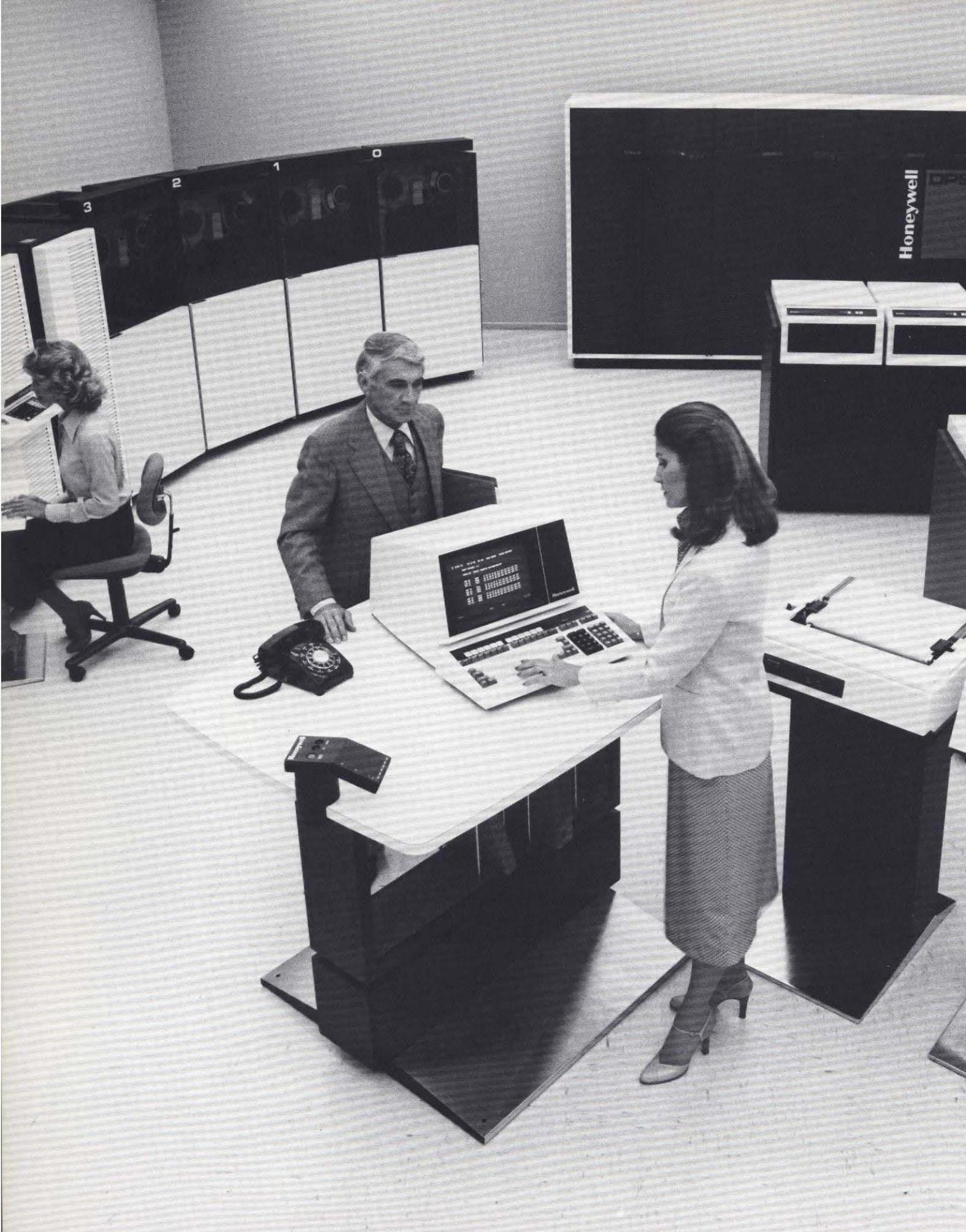
4. System Hardware

The DPS 8/M systems offer many powerful features that can help simplify processing procedures and provide capabilities that can help large-scale computer users to solve complex processing problems quickly and easily.

The DPS 8/M consists of a base system to which performance modules can be added in incremental steps, thus offering various levels of performance. This easy expansion allows users to configure the size of the system needed, and protects equipment investment.

System Configurations

An example of an entry level configuration would be:

- One central processor with cache memory
- One system control unit with four megabytes of memory
- An input/output multiplexer (IOM) with 36 channel function slots
- One DCU6661 front-end network processor
- One MTP0610 magnetic tape processor with a minimum of two MTU0410 tape units
- One MSP0607 mass storage processor with four MSU0451 mass storage units
- One system console
- One printer
- A full selection of terminals

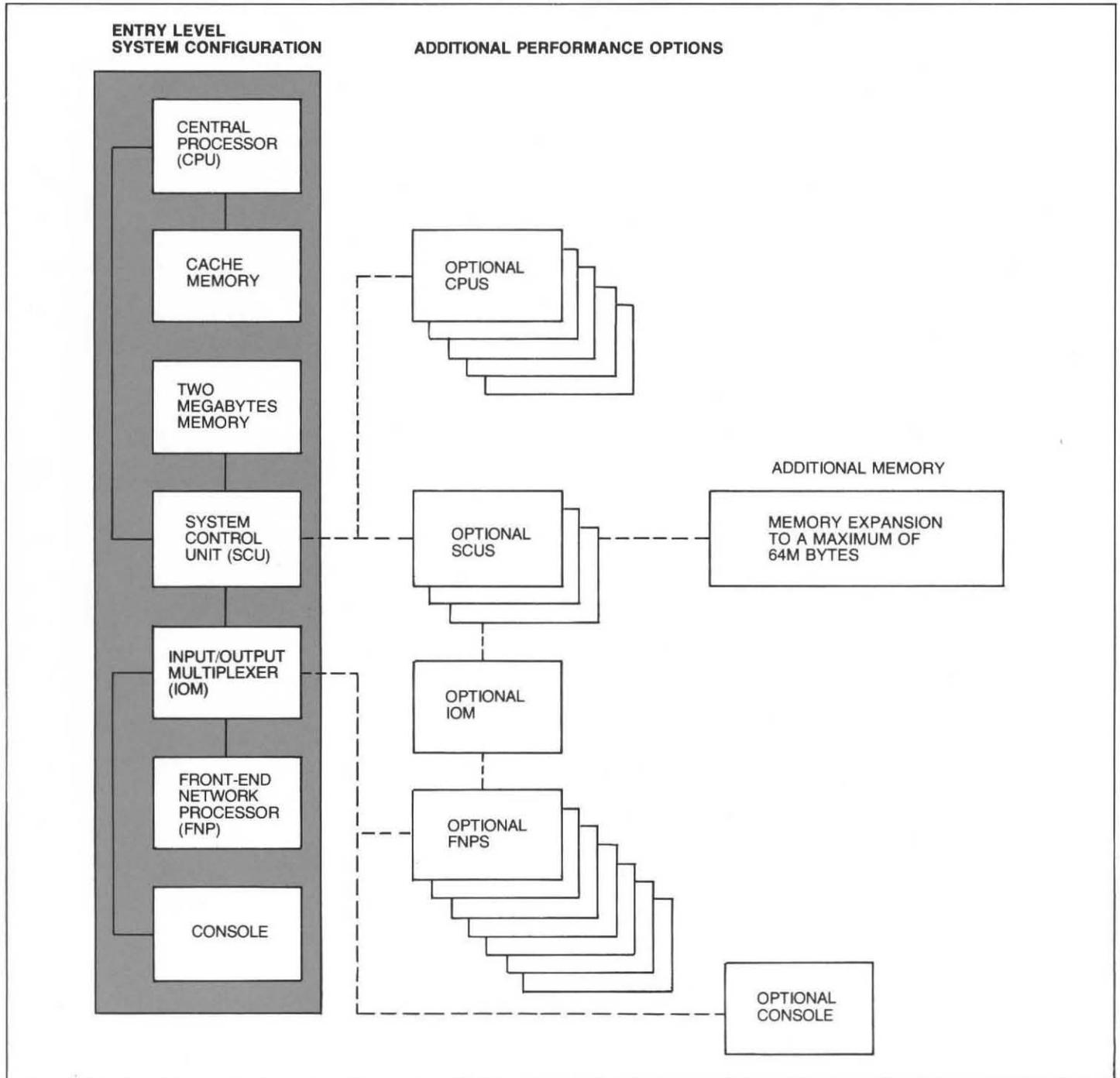A basic system configuration could be expanded to the following maximum configuration:

- Six central processors with cache memory
- Four system control units with up to 64 M bytes of memory
- Two IOMs, each of which can be expanded from 36 to 54 channel slots

- Eight DCU6661 front-end network processors
- Mass storage processors and MSU0500/0501 mass storage units providing up to 150 billion bytes of storage

- Sixteen MTU0610/0630 magnetic tape units per subsystem
- Eight unit record devices per subsystem; this could include multiple printers, punches, etc.
- A full selection of terminals

The following diagram illustrates an entry-level central system configuration, and displays the maximum DPS 8/M central system configuration.

ENTRY LEVEL SYSTEM CONFIGURATION

ADDITIONAL PERFORMANCE OPTIONS

CENTRAL PROCESSOR (CPU)

CACHE MEMORY

TWO MEGABYTES MEMORY

SYSTEM CONTROL UNIT (SCU)

INPUT/OUTPUT MULTIPLEXER (IOM)

FRONT-END NETWORK PROCESSOR (FNP)

CONSOLE

OPTIONAL CPUS

OPTIONAL SCUS

OPTIONAL IOM

OPTIONAL FNPS

OPTIONAL CONSOLE

ADDITIONAL MEMORY

MEMORY EXPANSION TO A MAXIMUM OF 64M BYTES

Central Processor

The processor for each DPS 8/M system is the primary unit to execute all information processing instructions. It performs many system control functions independently, overlapping most operations for highly efficient instruction execution. Byte-oriented ASCII (American Standard Code for Information Interchange) is the native mode for the Multics system.

Other features of the processor include:

- Hardware for handling segmentation and paging in virtual memory
- Hardware for interrupting a process in execution at any point (including in mid-execution of an instruction), saving processor status, and restoring the process later without loss of continuity
- High-speed cache memory for improved performance
- Hardware for enforcing several modes of memory access
- Hardware for implementing data integrity and security mechanisms
- Associative memory for fast hardware access to virtual memory
- Program-addressable registers for preparing virtual memory addresses

DPS 8/M systems employ Large-Scale Integration (LSI) circuit elements, which involve more densely packed logic. With LSI circuitry, less power and overall space are required. The DPS 8/M processor also incorporates microprocessors for less expensive, faster processing.

Processor Organization

The processor module for each DPS 8/M system is organized around functional units:

- Control Unit — Provides the interface between the operations unit and the system controllers.
- Operations Unit — Contains the logic to execute binary arithmetic and logical functions.
- Decimal Unit — Includes an Extended Instruction Set (EIS) within the processor's basic repertoire of instructions, including instructions for processing character string, decimal data, and bit string.
- Appending Unit — Implements segmentation and paging of the virtual memory; provides 24-bit addressing; contains 64 segment descriptor words and 64 page table words on a most recently used basis; and provides a descriptor segment base register, eight segment pointer registers, and ring protection hardware.
- Cache Memory Unit — Holds the most recently used information from main memory and improves system performance by reducing instruction and data fetch time.

Processor Modes of Operation

The processor operates in three modes: absolute, privileged, and nonprivileged. All instructions are available in the absolute mode. Privileged instructions, such as those that operate on the descriptor base register and input/output devices, are available only in absolute and privileged modes. Most, but not all, of the instructions are available in nonprivileged mode. General users are restricted to the nonprivileged mode and thus are prevented from executing any instructions that could interfere with other programs or with the Multics operating system software.

The full segmentation and paging capability of the processor is used in the privileged and nonprivileged modes for fetching instructions and operands. Addressing in the absolute mode does not use the segmentation and paging capability, and is not available to user programs.

Segmentation

Segmentation divides the user's address space into many parts and assigns attributes (access control and length, for example) to these parts based on their logical use.

Like a conventional file, a segment is a collection of instructions or data specified by the user. It has a symbolic name and access control list, and can vary in length.

The segment is the basic unit of information sharing. Different users can incorporate a single segment into their programs merely by specifying the segment name. A program need not copy a segment to use it, saving time and eliminating duplication in main memory. To control this sharing, each segment has an access control list containing the name and access privileges of each person who can use the segment. The hardware checks these access privileges on each reference to a segment by any user.

The potential advantages for the user of segmentation are:

- Stored data and procedures can be referenced easily and directly
- Logical units such as programs and data are protected by hardware
- Users can directly share procedures and data bases

Paging

Segments can be of different sizes, and a segment's size can change during the operation of a program. In order to simplify allocation of main memory, each segment is divided automatically into fixed-size storage units called pages. This division — and the subsequent manipulation of the pages — is totally transparent to the user and requires no action on the user's part. In addition, any access controls established for a segment apply to the pages that make up that segment.

The pages of a given segment need not be located in contiguous storage blocks. They need not even be in main memory at one time. As a page is needed in main memory, it is retrieved automatically from secondary storage and placed in any available block in main memory. When main memory is filled and more pages are needed, some pages have to be displaced. Pages not used recently will be migrate (swapped) to secondary storage.

Paging can be advantageous for the user in the following ways:

- A user can write and operate a program without planning for its storage allocation needs or for the management of the segments.
- It provides a simplified technique for dynamic storage management and can help reduce operating system overhead by allowing maximum loading of main memory and avoiding compaction problems.
- It uses the system's high speed storage effectively by fetching only pages that are actually referenced, rather than an entire program or file.

Ring Structure

The DPS 8/M system provides eight states of execution with adequate tools to allow proper administration of access privileges to the system users within them. This implementation allows segments to be grouped into rings. The number of each ring (0-7) designates the level of privilege assigned to procedure segments executed in that ring. Ring 0 has the highest level of privilege. Privileged ring segments, such as the supervisor and special user subsystems, are protected from uncontrolled use by less privileged rings. These segments can only be used by procedures in less privileged rings if called via a special "gate" mechanism. The access permission checking is enforced as well.

The information protection features inherent in the ring structure allow the following procedures:

- Users can create protected programs and data bases for controlled use by others.
- A supervisor program can be implemented in layers with differing degrees of privilege.
- A programmer can debug a program in an unprivileged environment and then move it to a privileged environment with no recompilation or modification.

System Control Unit

The system control unit (SCU) is the principal interface between all central system components. It provides complete system interrupt control which regulates communication between components and services all demands on memory. The SCU handles the switching of all control signals, addresses, and data into and out of the memory units. Memory units are modular and each connects directly to a system control unit.

Up to four SCUs may be configured in a DPS 8/M system, with each SCU capable of controlling 16M bytes of memory. The maximum total memory size currently available is 64M bytes. Multiple SCUs are recommended for optimal system performance.

Memory

The Metal-Oxide Semiconductor (MOS) memory of the DPS 8/M systems can range from 4M bytes to 64M bytes, with increments of varying sizes. Eight bytes, plus Error Detection and Correction (EDAC) bits, are accessed in each memory cycle.

Input/Output Multiplexer

All transfers of data between memory and peripheral devices or communication lines pass through the input/output multiplexer (IOM), which is responsible for coordinating the input/output operations of system controllers, peripheral processors and network processors.

I/O transactions are controlled by lists of control words prepared by Multics and stored in memory. When an I/O transaction is complete, or when special conditions are detected, the IOM causes a program interrupt.

The IOM has attractive performance characteristics:

- Peak IOM transfer rate of more than 4M bytes per second
- Either 36 or 54 simultaneously active data channels per IOM
- Peak channel transfer rates of more than 1M byte per second
- Scratchpad storage for control words
- Eight special channels for specific system functions

The IOM offers memory protection for all I/O data transfers. Each data channel functions independently with its own memory assignment. Parity is generated and checked on all information sent to and from the system controllers and the peripheral subsystems.

The Multics systems permit up to two IOMs to be configured on each system.

Front-End Network Processor

The Front-End Network Processor (FNP) provides large-volume, network communications power for Multics systems. Because the FNP controls message management and message handling in a DPS 8/M system, the resources of the central processor are required only when a message is submitted for information processing.

The DATANET 6661 serves as FNP for DPS 8/M systems. A system can accommodate up to eight FNPs. The primary components of the DATANET 6661 are the processor, input/output multiplexer, and memory.

FNP Processor

The central FNP processor operates asynchronously under firmware control. Its instruction repertoire is fully compatible with the instruction sets of the DATANET 6641, 6651, and 6678, as well as DATANET 66 and 355.

FNP Input/Output Multiplexer

The DATANET 6661 FNP input/output multiplexer (IOM) performs all operations required for the transfer of data between input/output devices and the FNP memory. Internally, the IOM operates asynchronously in an interrupt-driven fashion.

FNP Memory

The high-speed, random-access, semiconductor memory subsystem of the DATANET 6661 performs all storage functions without restrictions on address sequences, data patterns, or repetition rates.

Memory features include single- and double-word fetch, self-contained initialize and refresh logic, and standard EDAC (Error Detection and Correction) functionality.

A basic DATANET 6661 FNP includes 64K bytes of memory and can be expanded to 128K bytes. Two processor performance enhancements are available. The first increases processor performance up to 47 percent and the next provides up to an additional 82 percent.

Data Communications Functions

Hardware and software of the DATANET 6661 FNP are designed to optimize the management of communications traffic entering or leaving the system through specific hardware adapters.

The Channel Interface Base provides the line interfacing arrangements necessary to accommodate terminals with various data transfer rates, bit orders, bits per character, information codes, character sets, message formats, and communications control procedures.

Low-, medium-, and high-speed data communications terminals and subsystems, capable of operation at up to 9.6K bits per second, can be connected to the system. In addition, synchronous and asynchronous transmissions and any combination of half-duplex and full-duplex transmission modes are supported. To meet various functional requirements, the FNP can accommodate 4, 8, or 12 Channel Interface Bases, depending on available configurability options ordered. Each Channel Interface Base supports up to eight communication lines.

Reconfiguration

Memory modules, central processors, network processors, peripherals, mass storage devices, and terminals in a Multics system can be reconfigured dynamically, without interrupting user service. This allows devices to be removed from processing for maintenance and configured automatically following repair.

In addition, failing memory pages are automatically deallocated whenever a double-bit (uncorrectable) error is discovered. Large configurations can also be split into smaller separate systems for block time processing or testing.
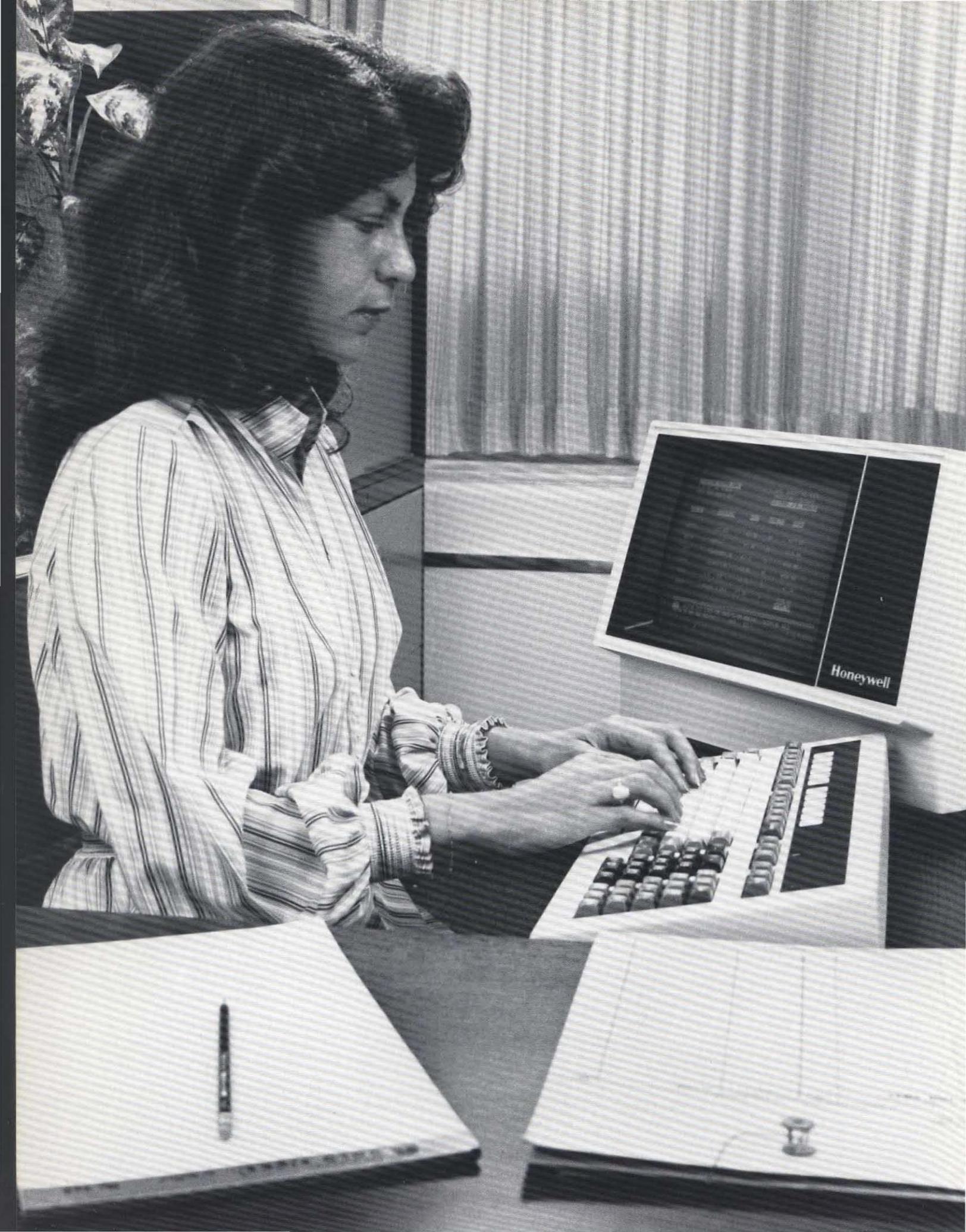
5. Peripheral Subsystems

All DPS 8/M peripheral sub-systems communicate with the central processor through the Input/Output Multiplexer. Multics issues peripheral commands through the IOM and each device requests action through it with special interrupts. Mass storage, tape, and unit record subsystems connect to the IOM through high-speed interfaces that transfer up to 1.25M bytes per second. Network processors and consoles connect to the IOM through their individual channels.

Consoles

The DPS 8/M console is free-standing and has components for interactive message transfer and communication with the operating system. Console keyboards permit operators to enter messages to the system and respond to inquiries and requests. Quiet printers permit the use of forms with as many as three carbons. One CSU6601 console is required with each system.

Optionally, additional control terminals can be attached to the network processor to allow multiple devices for input or output of operator functions. After the initial bootload sequence, these devices can be utilized for all control functions normally performed via the console. The additional terminals can be any terminal supported by Multics.

Console Characteristics	CSU6601[a]
Controls	Emergency Power Off Initialize Bootload
Indicators	Processor Activity DIS
Printer Speed Option Format Forms (max)	120 cps — 80 characters/line 3 carbons
Console Keyboard Typing Rate Supported Character Types	20 cps 26 alphabetic 10 numeric 28 special
Displays Capacity Type/Size	1920 characters (twenty-four 80-character lines) 1 built-in/12-in. (31 cm)

[a]Controls and Indicators for CSU6601 are located in a pod included in an optional console table.

Mass Storage Subsystems

A DPS/8M mass storage subsystem includes a mass storage processor and up to 32 disk units. Multiple subsystems can be configured.

Mass Storage Processors

Mass storage processors are microprogrammed devices that control the transfer of information between a mass storage unit and an input/output multiplexer. The connection between these devices is a channel, of which there are three types:

- Primary channel — included within the processor for connection to the IOM
- Optional nonsimultaneous switched channel — connects the mass storage processor to the network processor in support of the Network Processing Supervisor software
- Dual simultaneous channel — a secondary channel to the IOM, and simultaneous access to any two disk units in the system (This channel is available only with subsystems using the MSU0400/0402/0451 mass storage units.)

Mass storage processors can support up to 16 MSU0400/0402/0451 or eight MSU0500/0501 or combinations on the single channel model, and up to 32 MSU0400/0402/0451 or 15 MSU0500/0501 or combinations on the dual model.[1]

Mass Storage Units

The mass storage units MSU0400, MSU0402, MSU0451, MSU0500, and MSU0501 incorporate advanced design technology and offer excellent capacity and performance features.

Check characters inserted into data records or sectors help to ensure the validity of that data. Additionally, a write-protect capability, standard with each unit, helps protect individual disks against inadvertent writing. Online error status reporting and offline diagnosis and testing can help to reduce overall repair time.

Rotational position sensing helps reduce effective device latency time, thereby increasing I/O channel efficiency. System-controlled offset track spacing in MSU0400/0402/0451 permits the recovery of data lost due to disk head misalignment. The MSU0400/0402/0451/0500/0501 have a dual access, radial configuration.

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[1] MSU0500 or MSU0501 include two disk spindles; MSU0400/0402/0451 include one spindle. Each spindle must have a dual access feature for crossbarring between the two channels.

Mass Storage Unit Characteristics	MSU0400	MSU0402	MSU0451	MSU0500	MSU0501
Data Capacity (millions)					
Formatted characters	117	117	235	940	1651
Formatted 9-bit bytes	78	78	156	626	1101
Peak/Effective Transfer rate (thousands)					
Characters per second	1074/922	1074/922	1074/922	1597/922	1597/1474
9-bit bytes per second	716/614	716/614	716/614	1065/614	1065/983
Access time (ms)					
Minimum seek	5	8	8	10	10
Average seek	25	25	30	25	25
Maximum seek	45	45	55	50	50
Average latency	8.3	8.3	8.3	8.3	8.3
Media					
Type	Removable M4050A	Removable M4451	Removable M4451	Fixed Included	Fixed Included
Spindles per physical unit	1	1	1	2	2
Logical units per spindle	1	1	1	2	2
Recording surfaces per logical unit	19	19	19	19	20
Number of tracks per recording surface including T&D/Alt. tracks	411	411	815	1630	1686
Spindle speed (RPM)	3600	3600	3600	3600	3600
Options					
Rotational position sense	MSF0004	MSF0007	MSF0007	Included	Included
Dual Access	MSF0002	MSF0006	MSF0006	MSF0011	MSF0011

Magnetic Tape Subsystems

A DPS 8/M magnetic tape subsystem consists of a magnetic tape processor and one or more magnetic tape units. Multiple subsystems can be configured on the Multics system.

Magnetic Tape Processor

The magnetic tape processor is the microprogrammed unit that transfers control information between the IOM and the magnetic tape units. It is designed to support a wide range of magnetic tape unit performance and processing capabilities. A single magnetic tape processor can support eight tape units with a single channel to the IOM. With a dual simultaneous channel configuration, a processor can control 16 units.

The magnetic tape processor functions efficiently in several different tape processing environments and can operate in NRZI (non-return-to zero-inverted), PE (phase-encoded), and GCR (Group Coding Recording) modes. All written information is immediately read and checked. An extensive checking scheme is used throughout the tape processor subsystem. In seven-/nine-track NRZI mode, the processor detects errors using both vertical and horizontal redundancy checks to detect data bit errors. Nine-track NRZI tapes recorded at 800 bits per inch (bpi) also have cyclic redundancy check characters that are generated when writing and then checked during reading to detect dropped-bit errors. When reading at 1600 bpi in PE mode, the processor dynamically corrects single-track and skewing errors.

When reading at 6250 bpi, GCR techniques are used to provide automatic error detection and correction for both single- and doubletrack errors.

Magnetic Tape Units

Honeywell offers a wide performance range of magnetic tape units with speeds of 75, 125, and 200 inches per second (ips). Seven-track units are available at densities of 200, 556, and 800 bits per inch (bpi). Nine-track units support densities of 800, 1600, and 6250 bpi.

Consistent with their high operating standards, DPS 8/M tape units are also convenient to operate. Advanced hub designs and automatic or semiautomatic threading features lock and position tape reels securely, and help eliminate unnecessary tape handling. All units feature automatically controlled power windows that protect tapes from contamination.

A DPS 8/M configuration can include multiple tape subsystems.
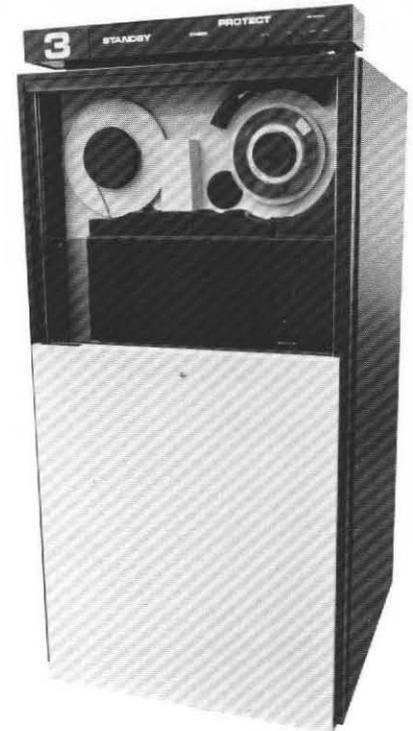
| Characteristic	MTU0500	MTU0610	MTU0630
Tape density (bpi)			
7-track	200/556/800	—	
9-track	200/556/800/1600	800/1600/6250	800/1600/6250
Transfer rate[a]			
200 bpi, 7-track	19	—	—
Bytes per second			
200 bpi, 9-track	25	—	—
Bytes per second			
556 bpi, 7-track	52	—	—
Bytes per second			
556 bpi, 9-track	70	—	—
Bytes per second			
800 bpi, 7-track	75	—	—
Bytes per second			
800 bpi, 9-track	100	160	60 @ 75 ips
Bytes per second			100 @ 125 ips
1600 bpi, 9-track	200	320	120 @ 75 ips
Bytes per second			200 @ 125 ips
6250 bpi, 9-track		1250	468 @ 75 ips
Bytes per second			781 @ 125 ips
Operating speed (Ips)			
Read/write	125	200	75/125
Rewind	500	800	500

[a] In thousands.

Unit Record Subsystems

A DPS 8/M unit record subsystem consists of a unit record processor and a selection of card readers, card punches, and printers. Multiple unit record subsystems can be configured on each Multics system.

Unit Record Processor

The unit record processor connects the IOM to the unit record devices in a system. With just one system channel, the processor can simultaneously control up to seven devices.
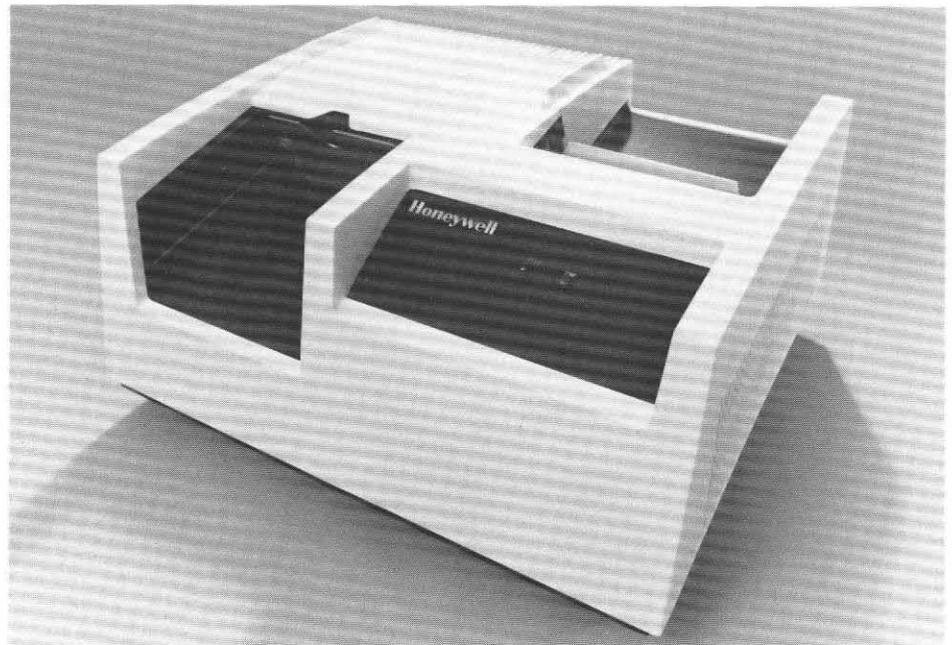
Card Equipment

The CRU0501 and CRU1050 Readers, CCU0401 Reader/Punch, and PCU0121 Punch share several operating features and data integrity functions. On each unit, optical synchronization procedures check the trailing edge of each incoming card for data accuracy. Read comparison, parity, and validity tests check for input errors. For the CCU0401 and PCU0121, any cards in error are offset from the rest of the deck and error status reporting is under software control.

Operation of all these units is simple and convenient. The hoppers are large and designed for smooth card handling. Color-coded displays can be easily understood. And any alert conditions that arise — such as full output stacker, feed error, or card jam — are clearly identified so operators can respond quickly.

Card Reader and Card Punch Characteristics	CRU0501 Card Reader	CRU1050 Card Reader	CCU0401 Reader/Punch	PCU0121 Card Punch
Speed (cpm)	500	1050	400 (read) 100 to 400 (punch)	100 to 400[a]
Card type	80-column	80-column[b]	80-column	80-column
Input hopper capacity	1000	3000	1200	1200
Output hopper capacity	1000	2500	1300	1300
Reading technique	Photoelectric/column by column/serial	Photoelectric/column by column/serial	Photoelectric/column by column/serial	

[a]Depending on the number and position of card columns punched.
[b]Optional 51-column reading is available (CRF0003).

Online Printer Characteristic	PRU1200	PRU1600	PRU0901	PRU1201
Type	belt	belt	belt	belt
Maximum speed (lpm)	1200[a]	1600[b]	900[d]	1200[d]
Characters	63 or 94	63 or 94	64-96	64-96
Print positions	136 or 160	136 or 160	136	136
Characters per inch	10	10	10	10
Lines per inch	6 or 8	6 or 8	6 or 8	6 or 8
Line skip (ips)	90	90	25/44	25/44
Vertical format control	programmable	programmable	programmable	programmable
Paper width	4 in. to 22 in. (10 cm to 56 cm)	4 in. to 22 in. (10 cm to 56 cm)	4 in. to 19 in. (10.2 cm to 48.3 cm)	4 in. to 19 in. (10.2 cm to 48.3 cm)
Length (fanfold forms)	3 in. to 22 in. (8 cm to 56 cm)	3 in. to 22 in. (8 cm to 56 cm)	3 in. to 11 in. (8 cm to 28 cm)	3 in. to 11 in. (8 cm to 28 cm)
Carbons (maximum)	5	5	5	5

[a]Based on a 48-character set (Maximum speed using 63-character set is 975 lpm; 700 lpm for 94-character set)
[b]Based on a 48-character set (Maximum speed using 63-character set is 1325 lpm; 985 lpm for 94-character set)
[c]In multiples of 8
[d]Based on a 64-character set

Online Printers

The PRU0901, PRU1200, PRU1201 and PRU1600 printers are 136-column, removable belt devices. Although they may have different operating characteristics, they incorporate features for fast, continuous operation and operator convenience. These features include:

- Special editing capabilities to speed the preparation of data for printing
- Programmable vertical format control
- Rapid paper skipping
- Clearly visible indicators of low paper, paper out of stock, and feeding error
- Several character sets
- Ability to handle single-part, continuous, or tabulating card stock
- Automatic deactivation when not in use
- Choice of four printer belts
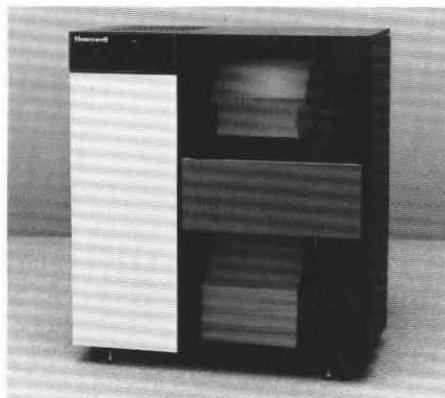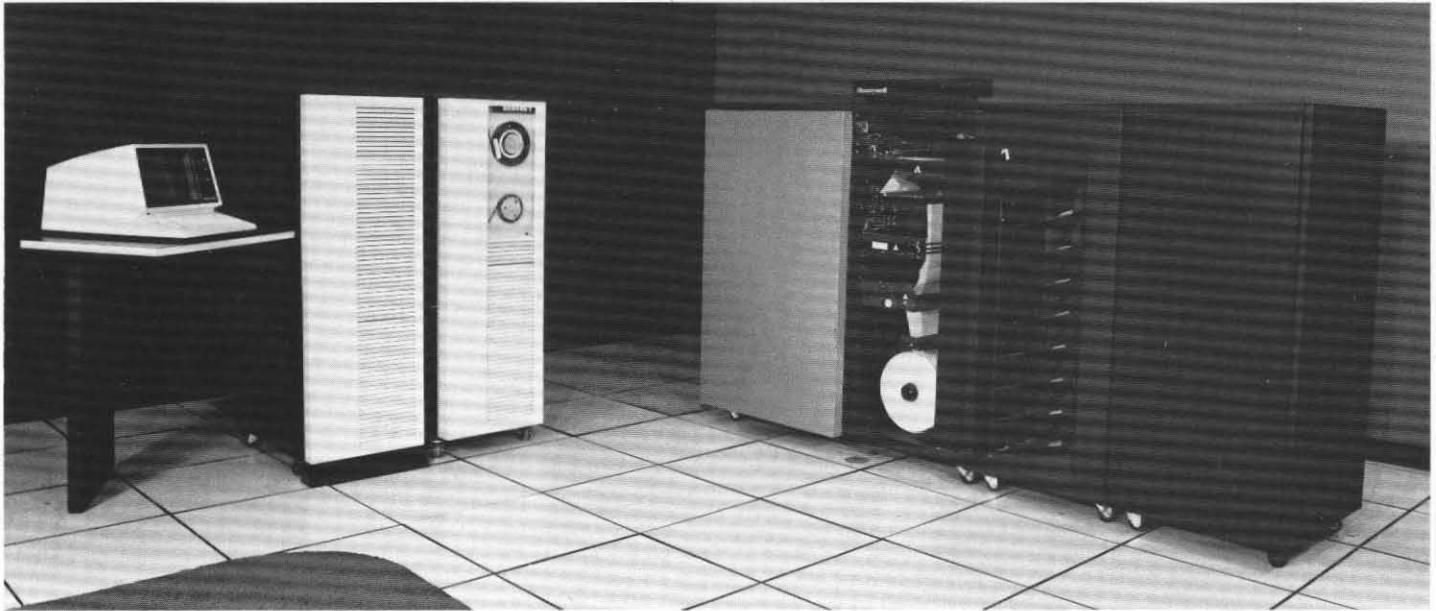
Offline Printer

Honeywell's Page Printing System represents an advance in high-speed, nonimpact computer printing. It produces high-quality, various-sized, finished documents that are cut, perforated, punched, collated, and addressed at speeds from 90 to 600 pages (8000 to 18,000 lines) per minute.

Electrographic printing allows both variable data and forms to be printed at the same time. Colored toners are available to customize the output and to reduce the need for colored paper.

Page Printing System (PPS)

PPS operates offline under the control of a preprogrammed Level 6 computer, reading print-image magnetic tape from the originating information processor and converting the tape codes to printed output.

Fixed information, such as letter-heads, logos, column headings, and vertical and horizontal lines, is formed electrostatically from a light-weight, easy-to-change metal format cylinder. Alternatively, multicolor preprinted forms, including information on the back side, can be used.

Expanded character sets are available to handle letter-writing applications and to allow simple forms to be drawn without the use of forms cylinders. The PPS also supports IBM-ATS textwriting systems.
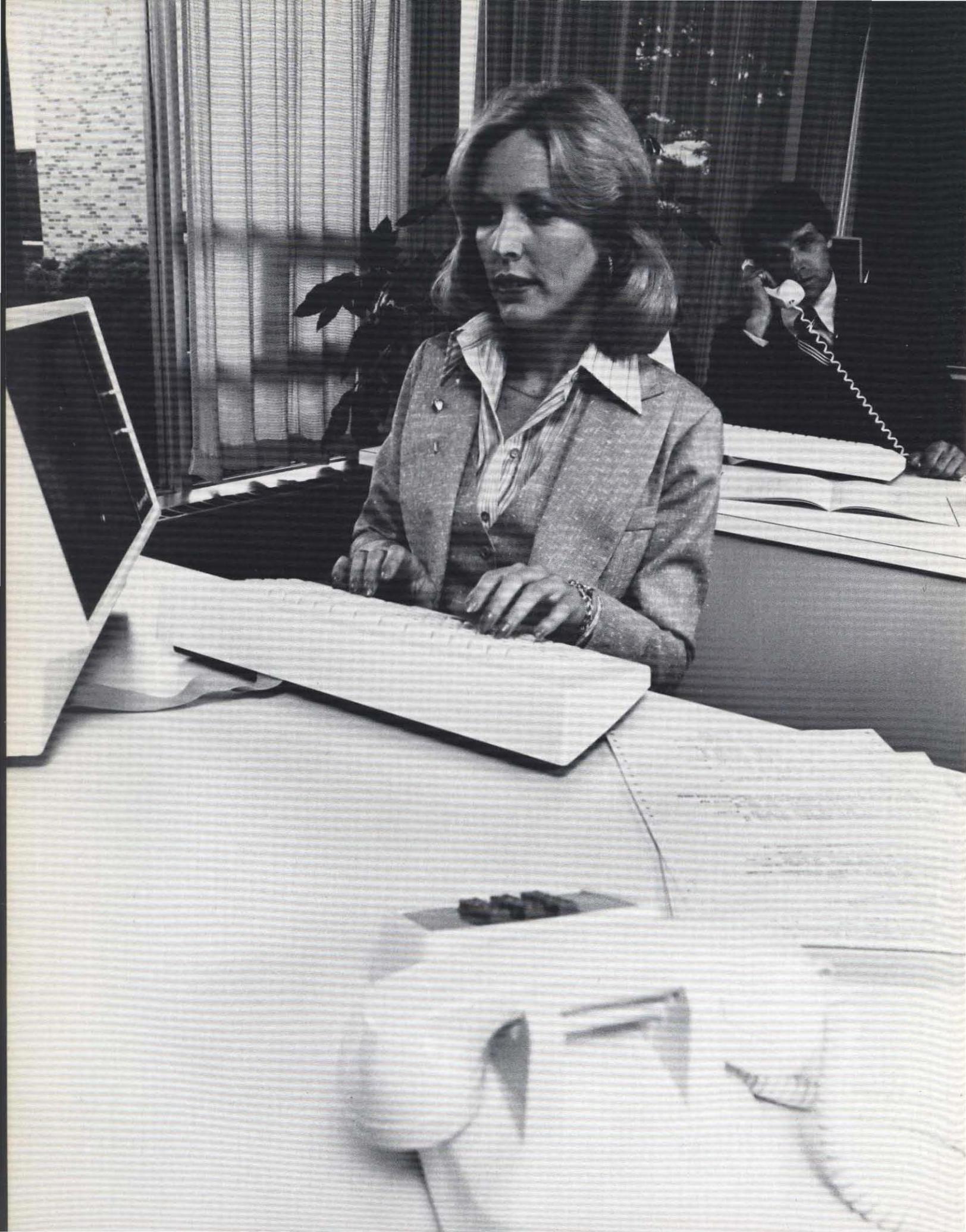
This is DPS 8/Multics: modular
hardware, compatible software,
flexibility within a Distributed
Systems Environment. Highly inter-
active, easily accesible, designed to
provide a utility-grade computer
service. DPS 8/ Multics is the
adaptive information management
system.

For answers to questions con-
cerning Multics systems, contact
your Honeywell Marketing
Representative.

Honeywell