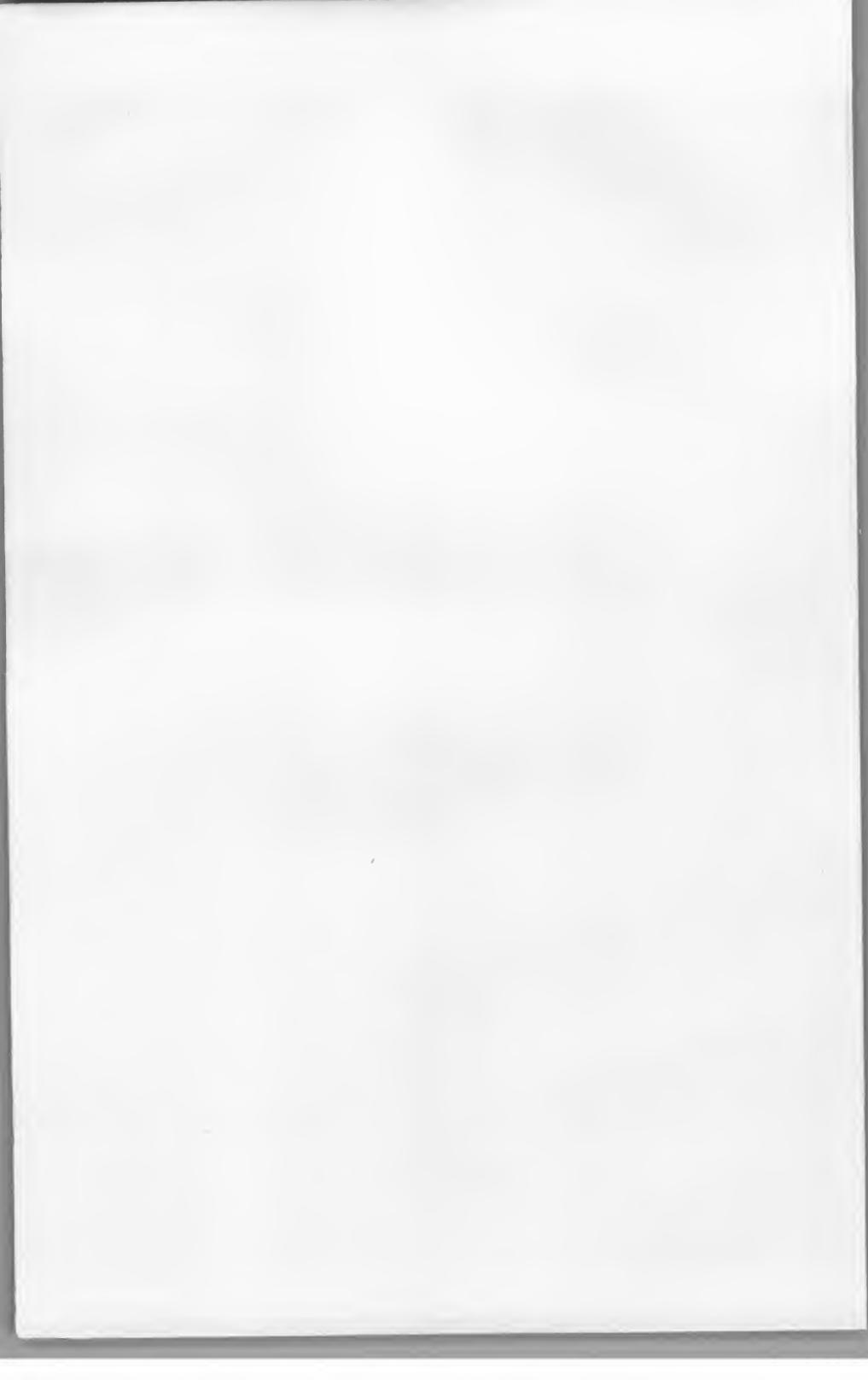


# ULTRIX Handbook

digital





## ULTRIX Handbook

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## Chapter 1 • ULTRIX Overview

### • Handbook Summary

The ULTRIX Handbook is divided into chapters that deal with each component of the operating system, ULTRIX compatibility and conformance with industry standards, and ULTRIX support services, including training and documentation. Appendices provide information on required and optional hardware and more information on standards bodies.

This chapter provides an overview of the ULTRIX operating system and the contents of this handbook.

### • General Description

The UNIX operating system, upon which Digital's ULTRIX operating system is based, was originally developed on a Digital PDP-7 computer by programmers searching for a better way to do their programming and documentation work. The result of their development efforts was a lean, clean operating system built around a powerful set of tools which could be combined to provide a complete working environment. The system supports many users at once, runs many tasks at once, and is interactive. It is ideally suited for software development, computer science applications, word processing, and publishing activities. The UNIX operating system is written in C programming language and is highly portable among processors.

Today, the Berkeley Software Distribution (BSD) V4.3, a major evolution of the original UNIX operating system, includes a hierarchical file system with demountable volumes, compatible devices and interprocess I/O, asynchronous processes, networking features, and over 200 tools and utilities. The ULTRIX operating system includes many of the features of BSD V4.3.

Along with the functionality of BSD V4.3, Digital has added many significant features to its ULTRIX operating system, including source-level compatibility with AT&T's UNIX System V, support for a full range of processors and devices, and new commands and programming languages.

Digital is committed to making its ULTRIX operating system compliant with standards in the industry. The ULTRIX operating system was the first POSIX-conforming operating system of its kind in the industry. Today, ULTRIX also conforms to Open Software Foundation (OSF) and X/Open specifications. Digital will continue to evolve ULTRIX to support new, formal international standards as they emerge.

## • Components of the ULTRIX Operating System

Figure 1-1 illustrates the activities for which ULTRIX software provides services and facilities. They include general use, compound document creation, networking and communications, system and resource management, data access management, software development, and multiple device interoperability. Chapters in this handbook address each of these areas in detail. A summary of each major functional area of the operating system follows.

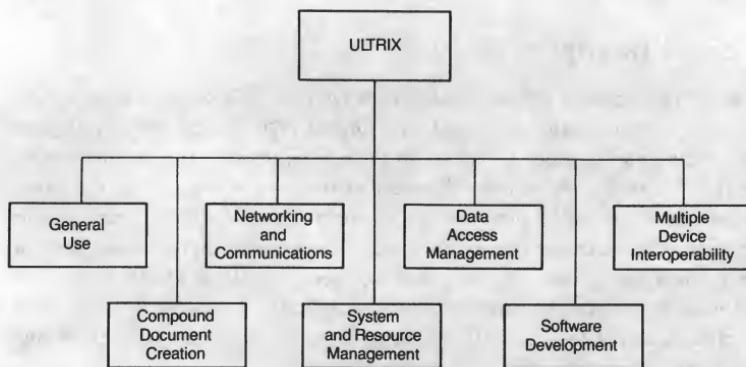


Figure 1-1 • Components of the ULTRIX Operating System

### General Use

General use includes the day-to-day tasks performed by most users, including sending and receiving mail, editing files, running applications, writing reports, developing code, and communicating with other systems. The ULTRIX software supports the traditional character-cell terminal and high-resolution windowing workstations. Within either of these environments, the ULTRIX operating system provides several supported command language interfaces called shells. In addition, workstation users have the facilities of the DECwindows Desktop Environment as part of the ULTRIX Worksystem Software. Spooled printing facilities are also provided. Hardware requirements for implementing an ULTRIX environment are summarized in Appendix A.

- *Character-Cell Terminals*

The base ULTRIX operating system supports most common hard-copy and video display terminals through a terminal server or direct connection. Alternatively, support exists with either the standard UNIX V7 terminal driver or the Berkeley terminal driver. Either driver can be selected and tailored by the user with the *stty* command. Terminals of differing capabilities are supported by the *termcap* database. The ULTRIX operating system also supports the terminal extensions defined by AT&T's System V Interface Definition (SVID).

- *Workstations and Graphical Terminals*

ULTRIX Worksystem Software (UWS) is the ULTRIX operating system package supplied for workstations. UWS supports both color and monochrome workstations and implements DECwindows software. DECwindows provides fast, reliable X servers, international keyboard support, a choice of programming languages, and a robust set of useful widgets in the X User Interface (XUI) toolkit. The XUI toolkit has been chosen as the basis of the Open Software Foundation's Motif software. With its intelligent window manager, DECwindows provides a consistent user interface for all applications. Digital is committed to supporting OSF/Motif as the primary user interface for DECwindows.

ULTRIX Worksystem Software can be installed on a nonworkstation server system used by remote workstations. Client workstations need not be the same type of processor as a server; ULTRIX servers can serve either DECstation or VAXstation workstations. Installation and management of UWS can be accomplished over a network using Remote Installation Services (RIS) or Diskless Management Services (DMS).

The ULTRIX Worksystem Software environment provides network transparent windowing; that is, an application can run on either the user's local workstation or a remote networked machine with no difference visible to the user. Thus, integrated systems can be implemented so that applications run where they will run most efficiently, while users interact with them on local workstations. DECwindows is also designed to provide easy integration of Digital systems with other desktop systems, such as those produced by IBM Corporation and Apple Computer, Inc.

#### **Compound Document Creation**

The ULTRIX operating system provides support for Digital's CDA (Compound Document Architecture), which is the backbone for creating, storing, and interchanging files that contain compound documents and their components.

A compound document is a document that contains a number of integrated components which may include text, graphics, and scanned images. With CDA, a compound document may also contain references to other CDA-compliant files which can be included as part of a document. These files can be edited, formatted, or otherwise processed. When the compound document is updated, these files are automatically updated as well.

CDA defines the format and content of compound documents while the ULTRIX software supports the handling of compound documents with tools for manipulating, displaying, and transferring these files. Support includes a provision for mailing compound documents through ordinary electronic mail systems without loss of content or formatting information.

#### **Networking and Communications**

ULTRIX has network extensions that make it ideally suited for the open system style of computing. ULTRIX networking capabilities provide the following general facilities: Internet network access provided via TCP/IP, Network File System (NFS), DECnet network access, UUCP facility, and Local Area Transport support. The Simple Network Management Protocol (SNMP) is provided as a protocol for network management.

Digital is committed to supporting the International Organization for Standardization (ISO) Open System Interconnection to ensure that ULTRIX remains an operating system for open system computing.

Distributed services that are available through ULTRIX include Yellow Pages (YP), the Berkeley Internet Name Daemon (BIND) service, Hesiod, Kerberos authentication service, Network Computing System (NCS), the internet time service (NTP), and mail facilities.

The VMS product, VMS/ULTRIX Connection, promotes resource sharing between ULTRIX or other implementations of UNIX operating systems and Digital's VMS operating system. With this product, VAX systems running VMS and VAXcluster systems can function as NFS servers and interoperate on TCP/IP-based networks.

#### **System and Resource Management**

ULTRIX software also includes extended system management and maintainability features such as Diskless Management Services (DMS), Yellow Pages, BIND, and Remote Installation Services (RIS) that simplify the tasks associated with its administration.

Resource management is enhanced by the fast, efficient local ULTRIX File System (UFS) and by virtual memory enhancements that provide full demand paging on remote and local files, demand-paged shared memory, and page locking.

#### **Data Access Management with ULTRIX/SQL**

A standards-compliant database engine and interactive structured query language are provided with the ULTRIX operating system. ULTRIX/SQL uses the industry-standard format SQL (Structured Query Language) for accessing databases and facilitating queries on databases for both customers and third-party database tools vendors.

#### **Software Development**

The ULTRIX operating system provides a broad variety of languages and tools for creating and maintaining high-quality, sophisticated software systems. In addition, leading independent software vendors' (ISVs) CASE tools are available to run with ULTRIX. The combination of Digital and ISV tools supports all aspects of software development and maintenance. These capabilities are valuable for developing applications for deployment on a range of hardware in a distributed, heterogeneous environment.

The operating system provides several supported command language interfaces, called shells. Shells provide simple and effective use of the system's resources, including command process creation, feeding the output from one process directly into another without intermediate file manipulation (piping), and the use of standard input and output "files" to minimize output redirection. They also provide portability among other environments based on UNIX operating systems. Because these shells are programmable, users can tailor features of the environment for the most efficient use.

Shells supported by the ULTRIX operating system include UNIX standard Bourne Shell (sh), C Shell (csh), K Shell (Ksh), and System V Bourne Shell (sh5). Users can select the shell best suited to their needs.

#### **ULTRIX for Digital's Full Range of VAX and RISC Processors**

ULTRIX runs on a full range of VAX and RISC processors, from the smallest desktop systems to the largest computers. Compatibility and adherence to standards lets the user write applications only once and then run them on machines of any size. For more information about minimum hardware requirements, refer to Appendix A.

To meet the performance demands of open system users, Digital has introduced our RISC (Reduced Instruction Set Computers) systems that run the ULTRIX operating system. These processors provide the balanced storage capability and high levels of service and reliability only available from a complete system vendor. Digital's RISC family of DECsystem and DECstation systems combines high speed and conformance to major industry standards with excellent price/performance. Applications are transportable between VAX and RISC ULTRIX.

#### • **Derivation of the ULTRIX Operating System**

Under license from AT&T, Digital's ULTRIX software is derived from BSD Version 4.2 of the UNIX operating system, with enhancements from BSD 4.3 and AT&T's UNIX System V.

The UNIX operating system was developed at AT&T's Bell Laboratories in the 1960s and was originally written in assembly language for a Digital PDP-7 computer. In the 1970s, it was ported to the PDP-11 computer and the C language, which was also developed at Bell Labs. During the same period, AT&T began to distribute the UNIX operating system to nonprofit organizations. In the early 1980s, after divestiture, AT&T began to market its version called UNIX, currently System V.

The University of California at Berkeley ported UNIX Version 7 to a VAX system in 1978, provided virtual memory support, and began to distribute its version as the Berkeley Software Distribution (BSD 3.2). Most implementations of UNIX operating systems on the market today, including Digital's ULTRIX, have some functionality of both Berkeley Software Distribution and AT&T's UNIX System V.

While the UNIX operating system is now widely accepted, it currently has multiple, incompatible versions. Standards efforts, for example POSIX, are being used in attempts to reconcile these various versions. The Open Software Foundation, with Digital as a founding member, was formed as a forum for advancing open system technology. X/Open, an international organization supported by Digital, is similarly focused on advancing open systems. Figure 1-2 illustrates the evolution of the UNIX operating system.

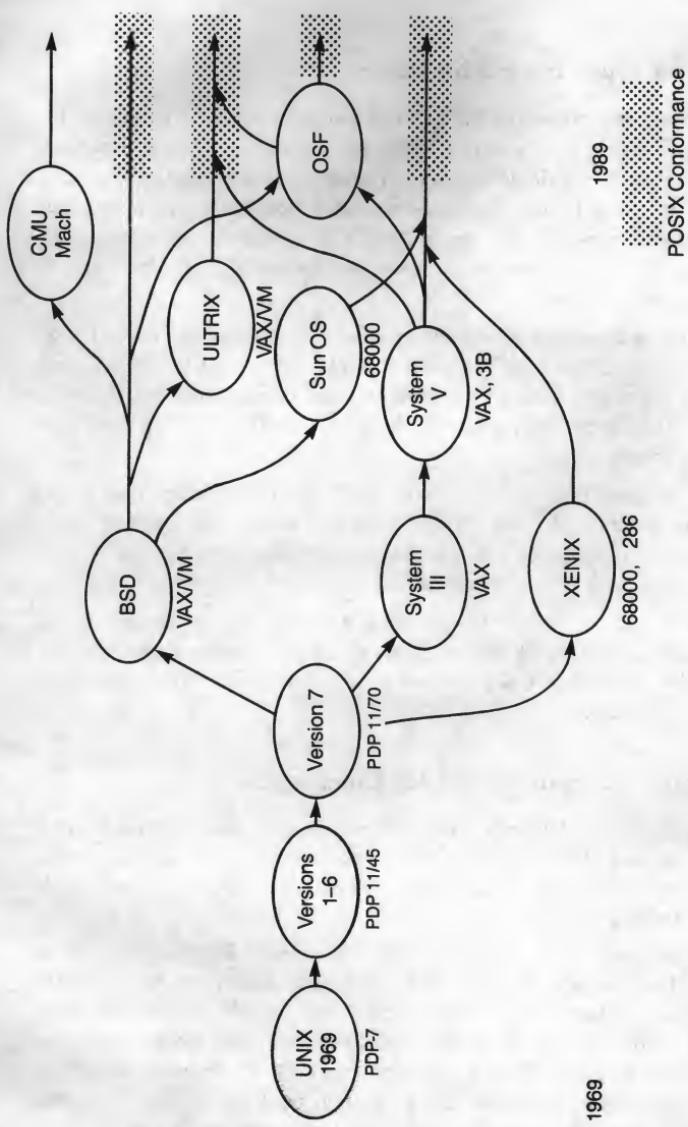


Figure 1-2 • Evolution of the UNIX Operating System

- **Support for Open System Standards**

Digital protects the customer's ULTRIX investment by adhering to and implementing open system standards in ULTRIX as they emerge. Digital is making ULTRIX the most standards-compliant operating system in the industry. Adherence to open system standards promotes portability of applications between systems from different vendors. An open system also frees users from dependence on a single supplier, so they can maximize their flexibility in using computing resources.

The ULTRIX operating system was the first major implementation of the UNIX operating system to meet IEEE Standard 1003.1 (POSIX), ISO 9945/1, and the United States government's National Institute of Standards and Technology FIPS 151-1. It currently supports draft 8 of the IEEE 1003.2 Shell and Utilities standards.

ULTRIX is designed in conformance with the X/Open Portability Guide Issue 3 base-level specifications and will be X/Open branded. The ULTRIX operating system is tracking OSF's Application Environment Specification as well as conformance with POSIX specifications.

Digital is an industry leader in delivering an operating system that spans international boundaries. ULTRIX supports an 8-bit international character set and complies with the X/Open internationalization profile (I18N) as well as ISO 8859 specifications.

- **Full Service for Systems and for Enterprises**

ULTRIX is backed by Digital's extensive service capabilities. Digital delivers complete solutions worldwide with industry-focused resources capable of providing strategic consulting, program management, and custom software, hardware, and training.

Digital service starts with top-down strategic Enterprise Planning to help set long-term direction, specify application needs, and deliver the best corporation-wide computing solution. Service for ULTRIX includes hotline telephone support, periodic software dispatches, and software update service. Additionally, Digital's Educational Services offers training to meet the needs of ULTRIX system users, managers, and programmers. This training covers the entire range of hardware and software configurations of Digital systems. Digital also offers worldwide system management services, including site planning, networking design and management, state-of-the-art predictive maintenance, and performance optimization.

## Chapter 2 • Compatibility and Industry Standards

### ▪ Chapter Overview

The ULTRIX operating system is compatible with other UNIX operating system implementations and with many industry standards. This chapter outlines compatibility with the following standards, specifications, and implementations.

- Open software standards and specifications, including IEEE POSIX 1003.1-1988/ISO 9945/1-1989, FIPS 151-1(1989), X/Open Portability Guide Issue 3, Base system, and XTI
- Network File System (NFS)
- Berkeley Software Distribution 4.2/4.3
- AT&T UNIX System V

Specific implementation of standards information presented in this chapter is organized in the same manner as it is in the referenced documents. In this handbook, the words *conformance* and *compliance* are used as defined by the POSIX standards work. *Conformance* is defined as satisfaction of all requirements of a given specification. *Compliance* is defined as satisfaction of all *measurable* requirements of a given specification.

### ▪ Standards and Independent Specifications

#### **Data Portability**

Digital achieves data portability with the ULTRIX operating system by supporting the ANSI SQL standard with ULTRIX/SQL, a runtime SQL relational database management system included with the base operating system.

#### **Application Portability**

Digital believes that portability can best be achieved by writing applications that conform to specifications such as those proposed by POSIX, X/Open, and the Open Software Foundation (OSF). The following sections describe adherence to these specifications and Digital's support of them.

#### **IEEE POSIX 1003.1/ISO 9945/1**

The ULTRIX operating system conforms with the IEEE standard 1003.1-1988/ISO 9945/1 Portable Operating System for Computer Environments (POSIX) specification, including the specifications of the POSIX Federal Information Processing Standard (FIPS 151-1).

When certification based on the National Institute for Standards and Technology's POSIX Conformance Test Suite (PCTS) is available, the ULTRIX operating system will be verified by an independent testing organization as a POSIX-conforming implementation and as conforming with POSIX FIPS.

Refer to Digital's ULTRIX POSIX Conformance Document for Digital's official statement of conformance. Refer to IEEE Standard 1003.1-1988 for POSIX conformance specifics.

#### X/Open and the Open Software Foundation

X/Open and OSF are not standards organizations but are organizations dedicated to developing and selecting standards formalized by ANSI, IEEE, ISO, and other standards bodies, specifically those specifications required for a complete open system. Both X/Open and OSF produce specifications defining an open system. These specifications are defined in the *X/Open Portability Guide* and OSF's *Application Environment Specification*. The specifications in these guides are very similar (see Table 2-1).

Table 2-1 • Summary of Open System Specifications of the OSF and X/Open Organizations

Open Software Foundation (Application Environment Specification)	X/Open (X/Open Portability Guide 3)
Operating System: POSIX 1003.1 X/Open	Operating System: POSIX 1003.1 Internationalization specification Interprocess communication
Languages: FORTRAN C Pascal COBOL Ada LISP BASIC	Languages: FORTRAN C Pascal COBOL Ada

**Table 2-1 • Summary of Open System Specifications of the OSF and X/Open Organizations (Continued)**

Open Software Foundation (Application Environment Specification)	X/Open (X/Open Portability Guide 3)
User Interface: X Window System Version 11 OSF/Motif	User Interface: X Window System Version 11
Graphics Library: GKS PHIGS	Graphics Library: Not specified
Networking Services: TCP/IP OSI XTI (X/Open Transport Interface)	Networking Services: XTI (X/Open Transport Interface)
Data Management: SQL	Data Management: SQL ISAM
	Terminal Interface
	Source Code Interchange

Digital's goal is to achieve X/Open branding as specified by the *X/Open Portability Guide* Issue 3. Our goal of targeting Issue 3 compliance is consistent with our goal of compliance with POSIX specifications because Issue 3 brings the X/Open base-level specifications into alignment with the POSIX standard.

Digital is also working to conform with OSF's Application Environment Specification for ULTRIX on both VAX and RISC systems. In most areas, conformance is either current or is committed for a definite target date.

#### **Summary Status of ULTRIX Support**

Table 2-2 summarizes for standards and independent specifications discussed in the section titled "Standards and Independent Specifications."

**Table 2-2 • ULTRIX Support of Standards and Independent Specifications**

Technology Area	ULTRIX Environment
Applications Portability	
POSIX	
ISO 9945-1	
IEEE 1003.1-1988	Y
FIPS 151-1	Y
IEEE 1003.2	
ISO 9945-2*	D
X/Open	
Portability Guide Issue 3	Y
Base system	
Graphics	
GKS ISO 7942-1985	Y
GKS-3D ISO 8805-1988	Y
PHIGS ISO 9592-1989	Y
Languages	
C ANSI X3.159-1989	D
FORTRAN ISO 1539-1980	Y
Pascal ISO 7185-1983	Y
COBOL ISO 1989-1978	Y
Ada ANSI/MIL Std. 1815A-1983	Y
Lisp (Common Lisp) ASC X3J13*	Y
Interoperability	
Interconnect	
OSI Suite*	D
X.400 CCITT-1984	D
TCP/IP	Y
X.25	D
Local Area Networks	
IEEE 802.3	Y

Key: Y = Yes, D = Under development, \* = Evolving standard

**Table 2-2 • ULTRIX Support of Standards and Independent Specifications (Continued)**

Technology Area	ULTRIX Environment
<b>Data Portability</b>	
Database	
SQL ISO 9079-1989	
ANSI X3.135-1986	Y
Data Interchange	
ODA ISO 8613-1989	Y
SGML ISO 8879-1986	Y
CGM ISO 8632-1987	Y
<b>User-Level Portability</b>	
Windowing	
X Window System	Y
ASC X3H3.6	
Toolkit/User Interface	
OSF/Motif	D

Key: Y = Yes, D = Under development, \* = Evolving standard

Refer to Appendix B for more information on standards bodies.

#### • Network File System (NFS)

The ULTRIX operating system includes licensed, fully conforming support for the Network File System (NFS), including lock manager/status monitor. These services have been tested against the corresponding services in SunOS Versions 3.0, 3.2, 3.4, and 4.0. ULTRIX also supports Yellow Pages service of SunOS Version 4.0.

#### • Berkeley Software Distribution, Versions 4.2 and 4.3

Because the ULTRIX operating system is based on BSD 4.2 with enhancements from BSD 4.3, there is a high degree of compatibility between them.

Specifically, shell script syntax is highly compatible with both the C shell and the Bourne shell and, in VAX C for ULTRIX, the vcc compiler generates BSD.0 format for object files. The ld linker can be used to link object files generated via vcc.

- **AT&T UNIX System V**

The ULTRIX operating system is compatible at the source code level with AT&T's System V Interface Definition (SVID) Issue 2 Volume 1. Source-level portability allows application programs written for the System V programming environment to run after being compiled and linked on an ULTRIX system. The ULTRIX software's compatibility with System V is based on SVID Issue 2 Volume 1. The degree of compliance with the SVID is listed in Table 2-3.

**Table 2-3 • ULTRIX Operating System Compatibility with SVID**

Interface Definition Description	ULTRIX Compatibility
<b>Volume 1 Part II, Base System:</b>	
Operating system services	Full
Error conditions	Full
Signals	Full
Other library routines	Full
Header files	Full
Environment variables	Full
System-resident data files	Full
Directory tree structure	Full
<b>Volume 1, Part III:</b>	
Kernel extensions	Full
<b>Volume 2, Parts II, III, IV, V, VI:</b>	
Base utilities extension	Full
Advanced utilities extension	Partial
Administration system extension	Partial
Software development extension	Partial
Terminal interface extension	Full

## Chapter 3 • The ULTRIX Base Operating System

### • Chapter Overview

An operating system is more than just a package of software. It is a set of components that work together to provide the basis of a computing solution. This chapter describes components of the ULTRIX base operating system.

### • The ULTRIX Environment

As mentioned in a previous chapter, ULTRIX was derived from the Berkeley Software Distribution (BSD 4.2). It contains many extensions from BSD 4.3 and System V Release 2. ULTRIX is packaged in two different ways:

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- ULTRIX
- ULTRIX Worksystem Software

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ULTRIX Worksystem Software (UWS) packages include all ULTRIX base system functionality and compatibility. They are intended to be installed and run on Digital workstation platforms. UWS is enhanced with Digital's X11-based window system. It includes Digital's X User Interface (XUI) end-user applications, application development tools, and X servers. Specific information about these enhancements is discussed in Chapter 4.

#### Compatibility

ULTRIX is binary compatible for programs compiled on VAX systems across the VAX product line and binary compatible for programs compiled on RISC systems across the RISC product line.

Applications developed using the X11 Tools and Libraries should require only minor modifications to be compatible with OSF's Motif software. Digital is committed to compatibility with Motif. Backward compatibility with ULTRIX is not warranted by Digital. However, ULTRIX V3.1 programs should run with little or no change on V4.0.

#### Symmetric Multiprocessing

ULTRIX includes symmetric multiprocessing (SMP) capabilities which increase the efficiency of multiprocessing systems. In general, system configurations have predictable performance scaling; for example, a four-processor system has performance of at least 380 percent for some SMP applications of a single processor. There is minimal single-processor performance impact of SMP.

With symmetric multiprocessing, multiple CPUs share a single memory-resident copy of the operating system. All CPUs can do all functions at the same time within the system kernel. Each CPU can perform system calls in kernel mode, scheduling, memory management, and file management.

- Application programs generally are unaffected by SMP. Support is included in the operating system to minimize the impact of SMP on existing device drivers. Debugging support is included to determine which CPU is executing a particular process.

If the kernel is initially built for growth, processors can be added or removed without rebuilding the kernel. This allows system management work to be minimized. The system automatically configures the number of available processors when it is booted. This allows easy addition or removal of CPUs.

### **File System**

ULTRIX software provides support for a single CPU to mount up to 96 RA disk drives. ULTRIX will support up to 3 HSC devices.

In the ULTRIX operating system, the buffer cache can be configured by the system manager. The cache can be set to any size from 10 percent to 90 percent of physical memory. Caching provides higher throughput through the file system. The configurable parameter can provide significant performance improvement for applications such as high I/O bound applications or those that are constantly updating a file.

The system manager can adjust other parameters, including the update interval run by the /etc/update program. This program constantly flushes or frees I/O buffers by asynchronously writing them back to disk. The system manager can adjust the update interval from 30 seconds to 10 minutes.

The ULTRIX file system is derived from the BSD 4.3 file system. The ULTRIX system organizes files based on a directory structure. A directory can contain files or other directories. All directories are descendants of a single master directory called a root directory.

In a networked system, ULTRIX support of the Network File System (NFS) allows for transparent point-to-point file access and full diskless boot functionality. NFS is designed to promote resource sharing by making information available to multiple systems. Diskless support in ULTRIX reduces overall investment, simplifies network administration, and enables users to simply log on without regard to system setup and management. More information about NFS can be found in Chapter 7.

The ULTRIX operating system also contains a generic file system (gfs) that allows other types of files to be transferred to the ULTRIX file system or NFS. Figure 3-1 illustrates the relationship among the ULTRIX file system, NFS, and the generic file system.

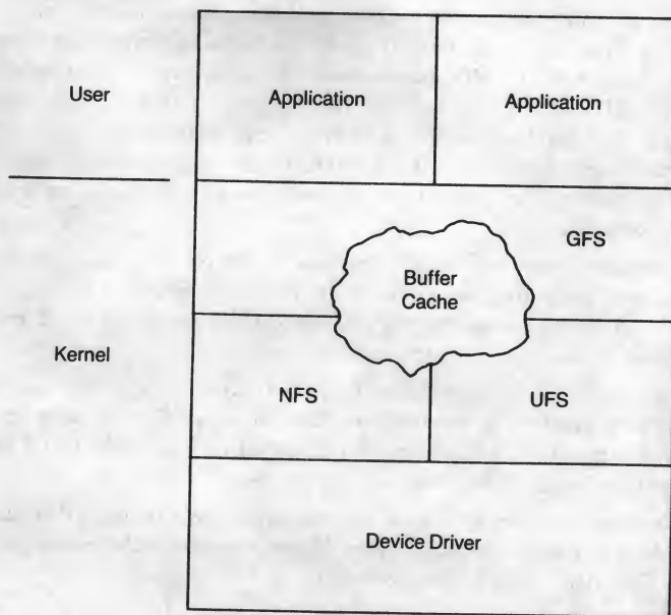


Figure 3-1 • ULTRIX File System

#### Virtual Memory Subsystem

ULTRIX software provides virtual address limits that allow system managers to configure the system to meet the needs of processes running on the system. Current versions of ULTRIX streamline the configuration process to allow more efficient use of disk space.

Physical memory support within ULTRIX is 512 MB on the VAX and 256 MB on RISC-based systems.

### Distributed System Services

Digital's strategy on distributed system services is to provide a complete set of software tools for creating and deploying distributed applications in local and wide area networks composed of systems running both ULTRIX and VMS and other vendor platforms.

As part of this strategy, the ULTRIX operating system includes an RPC (Remote Procedure Call) product based on Network Computing System (NCS). With RPC, ULTRIX can interact with a variety of other systems. Digital's RPC is a set of tools for heterogeneous distributed computing. Digital's RPC product consists of several components, including the RPC runtime library, the Network Interface Definition Language (NIDL), and the Location Broker. These components are written in portable C and are available in source format.

The Location Broker and the RPC runtime library provide running support for network computing and make up the Network Computing Kernel. The kernel and the NIDL compiler together support the development and implementation of distributed applications.

RPC runtime library is the backbone for NCS. It provides the system calls that enable local programs to execute procedures on remote hosts. It allows multivendor interoperability and provides improved resource utilization within the environment.

The Network Interface Definition Language (NIDL) is a compiler that generates client and server RPC stubs given the specifications of the remote procedure. The NIDL builds stubs automatically.

The Location Broker provides information about resources. It acts as a distributed naming service extended to the concept of an object where an object is a piece of data or an executable program on the network.

Digital's RPC product utilizes TCP/IP networking protocols.

Other aspects of ULTRIX distributed system services include the Kerberos authentication service which allows authentication among programs on a network; BIND, which distributes host files throughout the network; the Hesiod Name Service, an extension of BIND which allows centralized administration of host passwords, addresses, aliases, and other system management databases in a distributed manner; and the Network Time Protocol Service (NTP) which is used to synchronize the time on all machines on a network.

More information on distributed system services is available in Chapter 7, Networking and Communications Facilities.

### Security

Security can be measured by a specification called the Trusted Computer System Evaluation Criteria published by the National Computer Security Center. Classes of secure systems range from D-level trust (minimum protection) to A1-level trust (verified secure design). The ULTRIX operating system provides C2-level security (controlled access protection) features. This level of trust offers event auditing and audit trail analysis which allows the system to log each system call that a process makes. The data is stored in binary format. ULTRIX security also includes user identification, authentication, and authorization. User identification is assisted by the use of long passwords (up to 16 characters) which are stored in encrypted files, password aging to prevent reuse of passwords, and system-generated passwords. ULTRIX supports the Kerberos Authentication Service to provide two-way authentication of both a used and a remote node. Berkeley `kmem` and `tty` group protections are also included. These features can be disabled if they are not needed.



## Chapter 4 • ULTRIX Worksystem Software

### • Chapter Overview

This chapter describes the components of the ULTRIX Worksystem Software (UWS), the ULTRIX operating system as it is packaged for workstations that have graphics capabilities. The chapter includes a description of Digital's windowing environment, DECwindows, as well as information on support for OSF/Motif.

### • ULTRIX Worksystem Software

Digital workstations with graphics capability come equipped with ULTRIX Worksystem Software (UWS). The components of UWS are the ULTRIX operating system and DECwindows, Digital's implementation of the X Window System. Included with the DECwindows environment in UWS are the X Version 11 server, a window manager, a session manager, the ULTRIX User Executive, the User Interface Language (UIL), the *XUI Style Guide*, Adobe's Display PostScript, CDA support, and bundled graphical tools and utilities.

#### Windowing System

Researchers at MIT developed the X Window System for displaying and manipulating graphics and text applications simultaneously on a computer screen. The X Window System provides a single programming interface for distributed applications to be displayed on workstations that support bit-mapped graphics.

The X Window System has gained widespread industry acceptance because it provides a high-performance network protocol for windowing and graphics, and is also independent of workstation hardware and operating systems. Even more important is its "network transparency." With appropriate communications protocols, an application (written to use the X Window System user interface) can be displayed on a local or on a remote networked workstation, PC, or X window terminal.

The use of windows provides an efficient and user-friendly approach to using computer resources. With windows, the user can view output from multiple applications executing on different systems, in a variety of operating environments on the same screen. Many applications can be started simultaneously and kept running all day. The user can shift from application to application simply by moving a pointer device.

The overall architecture of DECwindows, Digital's implementation of the X Window System, is shown in Figure 4-1. As indicated by the "stairstep" shape of the application area in this figure, applications can call on services at whatever level of abstraction is required for the most effective implementation.

The DECwindows environment helps end users integrate their applications by providing a common user interface ("look and feel") for all applications. Since DECwindows is available with VMS and MS-DOS, as well as ULTRIX, it provides a common "look and feel" for users of any of Digital's major operating systems. The common look and feel lets users work more logically and intuitively and provides a degree of integration never before achieved.

The DECwindows architecture has several levels, from hardware and networks through operating systems, integration of data management and applications, and finally, specific applications. Software developers can work at any of these levels and easily integrate with Digital's architecture. Entering the architecture at the highest levels—at the applications integration or at the specific applications levels—achieves the tightest integration with other components of Digital's computing environment.

The architecture is flexible enough to work within the specifications of many industry-developed standards and powerful enough to provide the most cost-effective way to connect the entire enterprise. Application developers can also use the extension libraries to minimize the cost of supporting multiple graphics or windowing environments from a single application.

Digital's windowing architecture also lets end users and system developers access their applications, using many platforms from multiple vendors. Developers write applications only once; users can access those applications from any size system, anywhere in the enterprise.

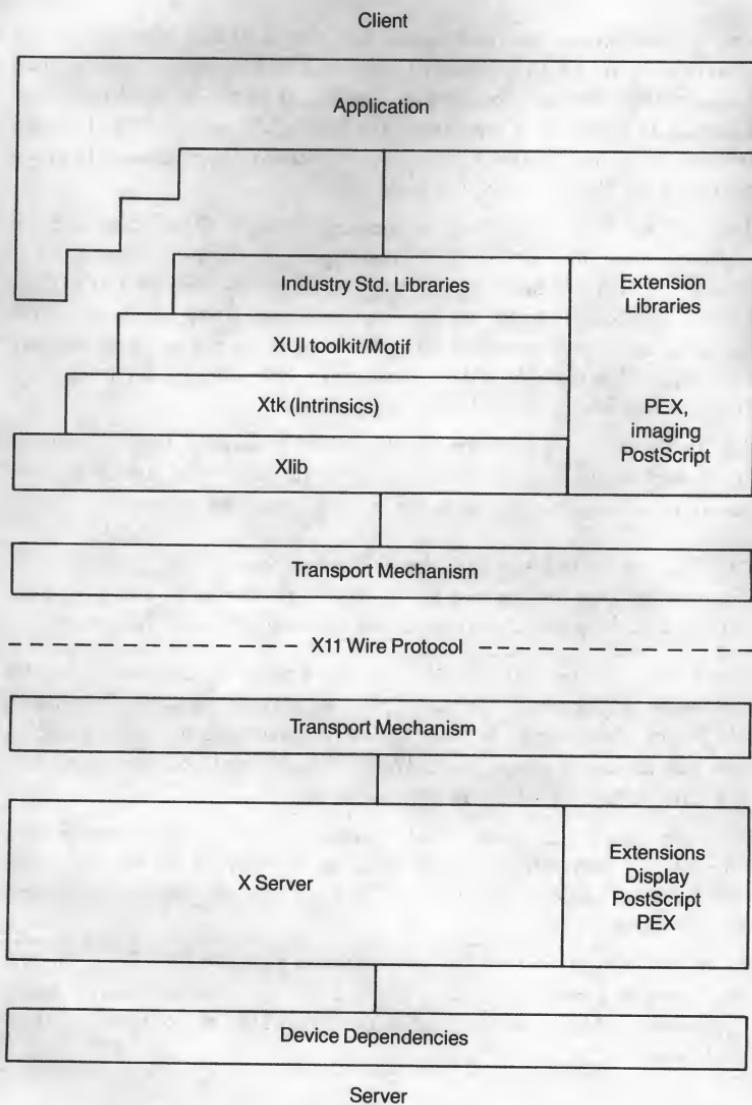


Figure 4-1 • DECwindows Architecture

The DECwindows environment will support the Motif user interface recently introduced by the Open Software Foundation. Motif represents a combination of leading technologies submitted by Digital and jointly by Hewlett-Packard Company and Microsoft Corporation. The Digital technology selected to form OSF/Motif consists of the XUI toolkit Application Programming Interface (API) and the User Interface Language (UIL).

The XUI software operates on a client-server model. The clients are the applications and the servers control the display. Applications designed to X Window System standards can run unchanged on any host with TCP/IP or DECnet connection capabilities between the system acting as client and the system hosting the server. An X server need not be the same type of hardware as the client. For example, a VAX X server can serve DECsystem clients, and a DECstation server can serve VAX system clients.

As Digital moves to embrace Motif, development work begun using the DECwindows XUI toolkit can continue to progress since toolkit features remain essentially the same in Motif as in DECwindows.

#### DECwindows Enhancements to the X Window System

The DECwindows architecture has all of the advantages of the X Window System, as well as the advantages of the following Digital enhancements:

- The X User Interface (XUI) toolkit provides a comprehensive set of tools for application development. The toolkit provides libraries containing 30 widgets. The toolkit also contains facilities for resource management, internationalization, and additional development. The XUI toolkit facilitates writing applications that follow the *DECwindows Style Guide*.
- The User Interface Language (UIL) separates the user interface from its function. UIL allows the interface layout to be modified quickly and easily. With UIL, a single application can support multiple user interfaces and natural languages.
- Digital's *DECwindows Style Guide* contains a set of guidelines for application developers that promotes ease of use and user interface consistency among applications. All applications developed by Digital conform to these guidelines.

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- An important part of the flexibility of UWS and DECwindows is provided by CDA, Digital's Compound Document Architecture. CDA, which is part of the ULTRIX base operating system, provides a method for creating, storing, and interchanging files that contain a number of integrated components, including text, synthetic graphics, scanned images, and external references to other CDA-compliant files which can be used as part of a document. With CDA, compound documents can be edited, formatted, or otherwise processed as simply as text-only documents.

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CDA products also support other types of information, including CAD databases and "live spreadsheet" data. Voice and full-motion video technologies will be incorporated into CDA in the future. In addition to applications developed by Digital, such as DECwrite, many CDA applications are under development by third-party vendors.

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- Additional programming languages include standard C and FORTRAN.
- Increased robustness is provided by X Validation Test Suites and Xlib checks for illegal parameters.
- Digital's Graphics Library Software includes DEC GKS-3D and DEC PHIGS.

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- *Graphics Libraries Software*

DEC GKS-3D implements the ISO GKS-3D standard. Conforming to level 2c of the standard, DEC GKS-3D provides full output capabilities, including workstation-independent segment storage (level 2) and full input capabilities (synchronous and asynchronous input at level c). DEC GKS-3D, as a development tool, is a solid base for portable, device-independent, three-dimensional graphics application development.

DEC PHIGS is Digital's implementation of the ANSI/ISO PHIGS standard for three-dimensional, device-independent graphics. The capabilities of DEC PHIGS go beyond those specified in the PHIGS standard. DEC PHIGS provides most of the functionality specified by the proposed PHIGS+ standard, as well as extensions to support "immediate mode" output and "posting to views."

DEC GKS-3D and DEC PHIGS are available as layered products on the ULTRIX operating system running VAX or RISC hardware.

Display PostScript has been integrated with X Window System servers through a joint effort of Adobe Systems, Inc., and Digital. In addition to being able to display a PostScript file on a screen, ULTRIX Worksystem Software allows integration of Display PostScript with an application.

Through extensions to X11, Display PostScript gives program developers the ability to use scaled or rotated text or images, world coordinates, and sophisticated color systems. In addition, a rich set of fonts is available.

The UWS also features PostScript Previewer which allows users to view a PostScript document before printing it.

Included in DECwindows is a set of base applications, listed below, useful to all workstation users:

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- Window manager
- Session manager
- Terminal emulators
- A CDA viewer
- An applications package, including:
  - mail
  - an editor
  - calculator
  - calendar
  - clock
  - notepad
  - paint
  - visual file comparator

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DECwrite, an application developed by Digital, is a compound document editor that combines word processing, desktop publishing, drawing, and data-charting capabilities. It is fully compliant with DECwindows and runs on both ULTRIX and VMS workstations. DECwrite is available as a layered product.

## Chapter 5 • Software Development in the ULTRIX Environment

### • Chapter Overview

Digital has a wide array of CASE tools for the ULTRIX operating system. The CASE environment for ULTRIX spans the entire software development process. These tools are available from Digital as well as a large number of independent software vendors (ISVs). The CASE tools are described in this chapter.

### • CASE Tools in the ULTRIX Environment

Digital's CASE (Computer-Aided Software Engineering) environment for ULTRIX provides tools for developing and maintaining timely, high-quality, complex software in a heterogeneous computing environment. It provides software engineers with tools and a project-control framework for designing, implementing, testing, and maintaining software. The environment also supports structured analysis and design techniques that enable software engineers to better model and understand a system's performance goals and implementation options. And ULTRIX software provides tools and filters that speed up software development by allowing code to be reused rather than reinvented.

As indicated above, Digital's CASE environment for ULTRIX supports each stage of the software development life cycle. This development life cycle is a concept used by many organizations to designate the series of stages that make up software development and maintenance. It typically includes requirements analysis, design, coding, testing, and maintenance.

The CASE environment relies upon standards to provide stability while retaining flexibility. Numerous components of the Digital CASE environment adhere to industry standards. ULTRIX supports POSIX, the IEEE open operating system interface, OSF specifications and the X/Open applications interfaces, as well as standard UNIX features. Standards provide a means to tie together tools that support the entire software life cycle and thus reduce redundancy, enhance communication, and promote sharing of common data.

Digital supports software development in its ULTRIX environment in four ways:

- The ULTRIX operating system which includes over 200 programming tools from UNIX operating systems
- ULTRIX Workstation Software (UWS) for workstations, which includes DECwindows for increased flexibility and interoperability

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- Digital CASE products, bundled with or optional for the ULTRIX operating system
- A large number of ISV RISC and VAX CASE products which provide tools for the entire range of the software development cycle

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Programming utilities for a UNIX operating system are fundamental to Digital's CASE offering for ULTRIX. The UNIX operating system was developed by and for software engineers and has many tools built in for program development. This bundled programming environment includes languages, editors, debuggers, execution profilers, testing utilities, source code control utilities, system builders, and documentation tools. Digital has made the ULTRIX programming environment even more powerful by enhancing many of its individual programming tools or by adding new ones.

DECwindows also adds capabilities to the ULTRIX programming environment. Digital has developed graphic interfaces for the popular debugger, dbx, the file compare utility, diff, and two editors. The mail utility, dxmail, has also been enhanced with a DECwindows interface.

## ▪ **Programming Languages**

The UNIX operating system is based on the C language. The ULTRIX environment supports portable C-language programming with the traditional Kernighan/Ritchie UNIX C compiler.

Also provided for VAX systems are Digital's VAX C compiler and enhanced libraries, which together may yield significant performance gains while providing the ability to generate code portable between ULTRIX and VMS systems. Programmers also can use Digital's optional VAX FORTRAN compiler for superior quality and performance.

VAX C and VAX FORTRAN programs are source compatible between VAX ULTRIX and VMS systems, provided they contain no system-specific dependencies. Programs written for the UNIX C compiler (pcc) are compatible between ULTRIX and other implementations of UNIX operating systems, provided they contain no system-specific dependencies.

Digital provides the language compilers listed in Table 5-1 to satisfy the needs of programmers. Digital also supplies a number of unsupported compilers and assemblers. See the technical summary of the document set AA-MG63B-TE for more information. Many compilers and assemblers supplied by other vendors can also be integrated into the ULTRIX environment.

**Table 5-1 • ULTRIX Operating System Programming Languages**

Language	Features
VAX C/ULTRIX (vcc)	Included with VAX ULTRIX systems. Extensions include those defined by proposed ANSI X3J11 standard; source compatible between ULTRIX and VMS systems.
C for RISC	C compiler included with RISC systems.
Portable C (pcc)	Common Usage C compiler.
VAX FORTRAN/ULTRIX	Source compatible between VAX ULTRIX and VMS systems. Part of the VAX Common Language Environment. Can call programs written in three VAX languages. Layered product for VAX ULTRIX systems.
FORTRAN/ RISC V2.0 (f77)	Available as a layered product for RISC ULTRIX systems.
VAX LISP (vaxlisp)	Full implementation of COMMON LISP except complex numbers and the INSPECT and ED functions. Available as a layered VAX ULTRIX product.
Lucid LISP	RISC implementation of common LISP. Available from ISV for fast LISP expert system-based development.
Pascal for RISC	Available as a layered product on RISC systems.
Assemblers	For VAX systems, the ULTRIX operating system provides the Berkeley VAX/UNIX assembler. On RISC systems, the assembler provided is the MIPS R2000 UNIX assembler, which is described in R2000 Architecture documentation.

There are also several compilers available from independent vendors for Digital ULTRIX systems.

**Table 5-2 • Compilers Available from Independent Vendors**

Language	Vendor/System Availability
Ada	Verdix, VAX only; Alsys, VAX only; Meridian, RISC only
APL	STSC, VAX only
C++ (preprocessor)	Oasys, VAX and RISC
COBOL	Austec, VAX only; ACCUCOBOL, VAX and RISC
Modula 2	OASYS, VAX only; ACE, VAX only

## • Program Development and Maintenance Tools

The ULTRIX operating system provides a large number of supported program development and maintenance tools. In addition, independent software vendors supply many more tools that run on ULTRIX systems. Figure 5-1 outlines the typical CASE development steps and selected ULTRIX tools available for each step. Each of these tools is briefly described in the following sections.

### Structured Analysis and Design

Below is a list of leading ISV analysis and design tools that run on ULTRIX workstations. Some of these products include:

- *teamWORK by Cadre Technologies, Inc.* This product supports structured analysis and design, realtime modeling, simulation, data modeling, and C code frame generation.
- *Software through Pictures by Interactive Development Environments, Inc.* This product supports structured analysis and design, realtime modeling, object-oriented design, data modeling, and Ada, C, and Pascal code frame generation.
- *Statemate by i-Logix, Inc.* This product supports analysis, requirements specification, and design verification for realtime systems.

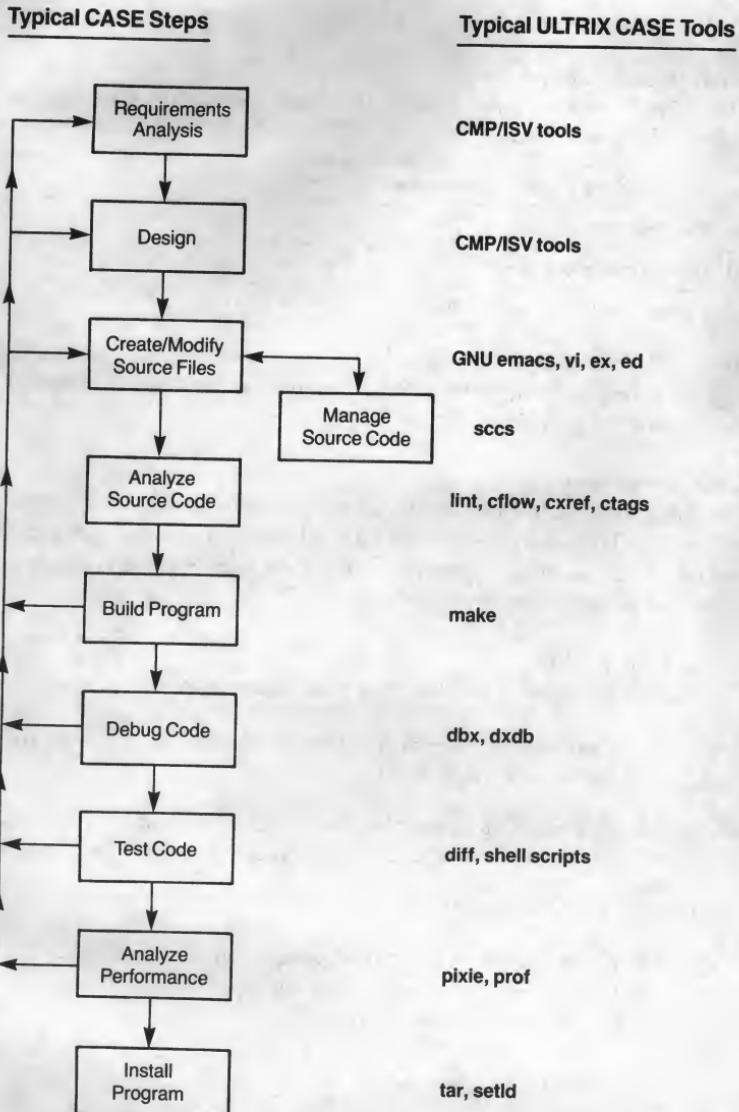


Figure 5-1 • CASE Environment for ULTRIX—Development Steps and Selected Available Tools

### **Create/Modify Source Files**

The ULTRIX operating system includes these tools, among others, for creating and modifying source files:

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- **vi**, standard 8-bit clean screen editor
- **ex**, alternate line editor
- **ed**, alternate line editor
- **GNU emacs**, public domain editor

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The ULTRIX operating system has a language-sensitive mode and EDT mode, interactive help facility, on-line tutorial, and on-line user manual. Extensive customization is possible.

### **Code Management**

For code management, ULTRIX software includes SCCS, Source Code Control System, which maintains source code files and complete histories of modifications. Old versions can be recovered and modified. Files in current use may be flagged to prevent inconsistent updates.

### **Source Code Analysis**

The following tools are available for use when source code analysis is needed:

**lint** detects elements of program files that are likely to contain bugs, are not portable, or are redundant.

**cflow** analyzes a group of C, assembler, and object files. Output is collected and a graph of external references is generated for display.

**cxref** builds cross-reference tables.

**ctags** makes a tag file for ex vi, or GNU emacs from the specified C, Pascal, and FORTRAN sources. A tag file gives the locations of specified objects in a group of files.

### **Program Build**

For program building, the **make** tool ensures consistent building of applications. The tool determines what recompiles are needed to generate the program by comparing dates of sources, objects, libraries, and executable code. In addition, **make** has macro and text substitution capabilities.

### **Debugging**

**dbx** is the source-level debugger provided with ULTRIX. It works with FORTRAN, C, Pascal, and assembly code. Capabilities include high-level and assembly language debugging, expression evaluation, stack tracing, breakpoints, single stepping, program state examination, and line-by-line variable tracing.

**dxdb** is a DECwindows enhancement to **dbx**. This debugger allows users to display C source program, and set, change, and examine values line by line.

### **Test Code**

The **diff** tool is a file comparator utility that handles graphics files.

Shell scripts are testing tools written in the shell interpretive language.

### **Performance Analysis**

The **pixie** tool provides analysis information based on invocation counting and basic block counting, reads an executable file, and partitions it into basic blocks. It also generates a file that lists the address of each block.

The **prof** tool analyzes one or more data files generated by FORTRAN and C language compilers by means of PC sampling. Results are generated as formatted listings which can indicate where to correct inefficient code, substitute better algorithms, or switch to assembly language.

### **Program Installation**

For program installation, **tar** is a tape archiver that saves and restores multiple files to and from a single archive.

The **setld** tool loads, unloads, and inventories software subsets.

- **Specialized Tools**

Several tools included in the ULTRIX operating system for specialized tasks are listed below:

- The **awk** tool supports pattern scanning and matching. It is customizable with a C-like language.
- The **lex** tool is a lexical analysis program generator. It is useful for building structures to parse specified grammar.
- The **yacc** tool converts context-free grammar into tables useful to compilers and parser.

- **New Programming Environments**

New, state-of-the-art programming environments that feature highly interactive, multiwindow coding, testing, and debugging features are now available on ULTRIX.

Saber-C by Saber Software, Inc., is an integrated programming environment for the C language.

SMARTsystem by ProCASE Corporation provides a sophisticated maintenance and development environment for C programming, including static analysis and incremental semantic system checking.

- **Additional Support for the Software Development Cycle**

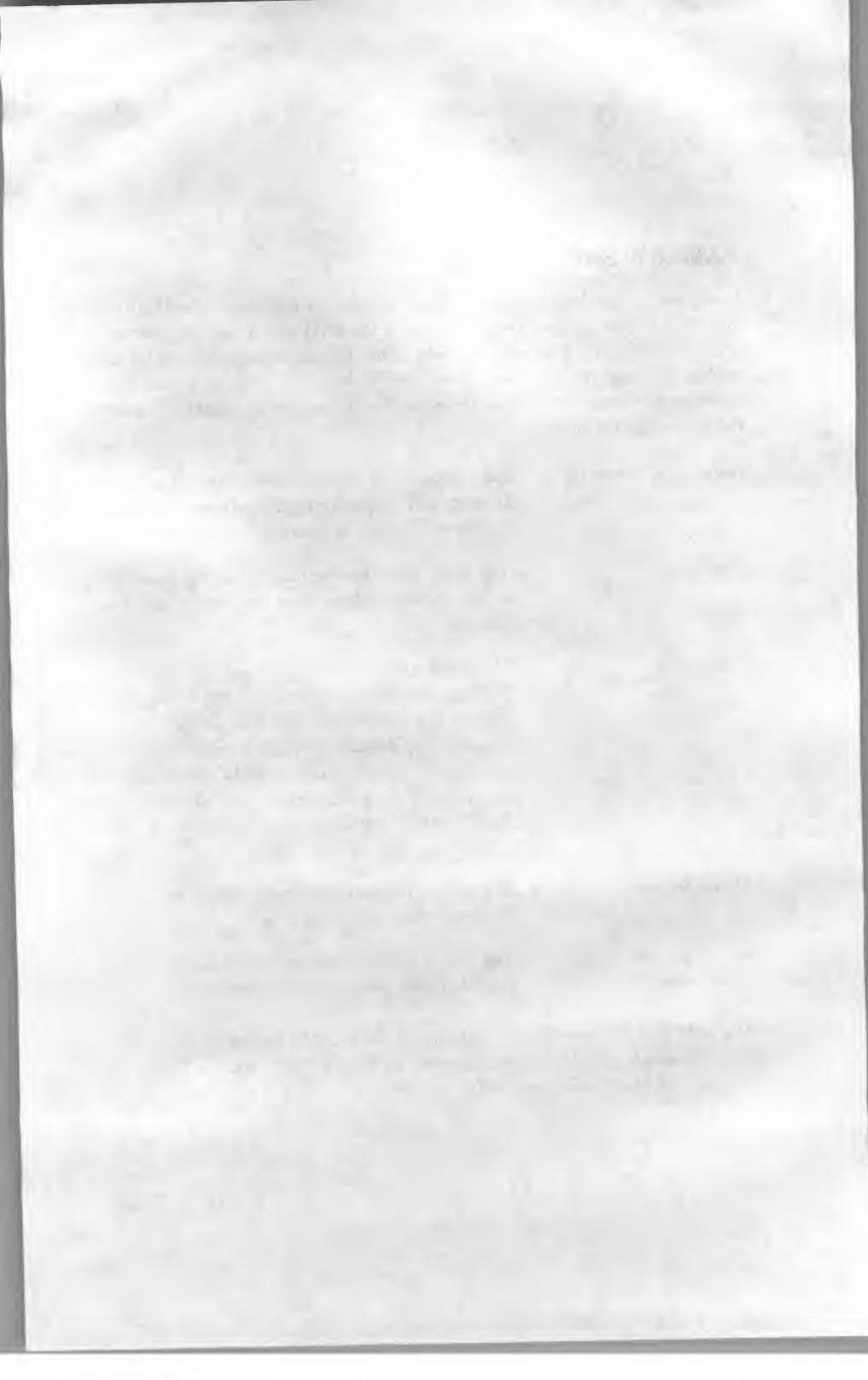
Additional CASE tools from Digital and ISVs are available for all aspects of the software development cycle. In addition to supporting the development of software for Digital systems, the CASE environment for ULTRIX can support a wide range of non-Digital microprocessors such as those from Motorola, Intel, and Zilog. Support for cross-development tools is available from ISVs, including Boston Systems Office, Inc., Tektronix, Inc., MDP Division, Microtec Research, Inc., Applied Microsystems Corporation, and Oasys, Inc.

- **Addition of Software by Users**

Users, vendors, and others who produce software for addition to the ULTRIX operating system can produce kits by using the **setld** tool to add to, subtract from, or modify the contents of product kits. Documentation is provided to explain the use of the **setld** utility and kit-building tools to install and maintain user-created software. Designing kits to use the **setld** utility ensures the following benefits:

Installation Reliability	Each program is verified immediately after transfer and is recoverable for reinstallation or in case of damage or deletion.
Flexibility	The <b>setld</b> utility can be used to choose subsets at installation, and to delete and later reinstall subsets.
Uniformity	The <b>setld</b> utility is an integral part of the ULTRIX installation architecture. Producing kits that are compatible with the <b>setld</b> utility ensures compatibility with future installations. In addition, <b>setld</b> kits can be installed on a server machine for network installation using the RIS utility, which provides Remote Installation Services.
Media Support	Kits can be built on any device supported by the <b>setld</b> utility.
Binary or Source-Level Distribution	Kits can be built containing source code, linkable object files, or binary images.

The **setld** utility is described in Section 8 of the *ULTRIX Reference Pages*. The tools for building **setld** kits are discussed in the *ULTRIX Guide to Preparing Software for Distribution on ULTRIX Systems*.



## Chapter 6 • Document Development and Production in the ULTRIX Environment

### ▪ Chapter Overview

Many of the tasks performed on or by computers result in the need to produce reports, presentations, or memos to share information. This chapter describes the tools that are available in the ULTRIX environment for development and production of such documents.

### ▪ Document Development and Production

The ULTRIX environment supports document production with a broad set of tools. Many of the CASE tools listed in Tables 5-1 and 5-2 are useful in the creation of both program source code and document files. In addition to these tools, the ULTRIX operating system provides editors and document processors specifically for the task of document creation and preparation. These tools include layered products such as DECwrite, a compound document processor for the DECwindows environment; Display PostScript, an imaging model for displaying both print and graphics; and Interleaf TPS, a third-party layout program widely used in the publishing industry.

ULTRIX also supports Digital's industry-leading CDA (Compound Document Architecture), which lets you link documents to other files or applications, and automatically updates documents whenever the source data changes.

### ▪ Editors

Both line-oriented and screen-oriented editors are provided by the ULTRIX operating system, including:

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- **ed** and **ex**—interactive line editors
- **sed**—stream editor
- **vi** and **emacs**—screen-oriented interactive editors
- **dxnotepad**—a DECwindows editor included with ULTRIX Worksystem Software

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## • Tools for Document Manipulation and Formatting

### ULTRIX Documentation Tools

Tools available as part of the ULTRIX operating system include:

- **roff, troff**—formats text to be printed by typewriter-like devices and line printers
- **eqn**—equation processor to format mathematical equations
- **tbl**—a preprocessor used for formatting tables
- **mptx**—a macro package for formatting a permuted index
- **ptx**—a command to generate the index created using the **mptx** macro
- **mu**—macros for creating ULTRIX books and documentation
- **macref**—assists in developing new macros and producing cross-reference listings of macro files

### DECwrite

For Digital workstations equipped with ULTRIX Worksystem Software (UWS), DECwindows and DECwrite provide sophisticated, flexible tools for creating compound documents containing a variety of information types.

DECwrite, a layered Digital product, is a flexible, WYSIWYG (what-you-see-is-what-you-get) program that incorporates text processing, drawing, and page composition. It can import and export material in a variety of formats to and from other applications and tools such as DECchart and DECpaint. DECchart provides capabilities for creating line, bar, and pie charts while DECpaint allows free-form illustrations to be created.

DECwrite is based on CDA which is part of the base ULTRIX operating system. Any DECwrite document can be printed on a PostScript laser printer or distributed electronically through the mail.

### Display PostScript

To display or print graphics, an application must have an imaging model. PostScript, one of the most popular, is available with the ULTRIX operating system. The addition of Display PostScript extends the PostScript imaging model to bitmap display systems, including Digital's workstations.

The ULTRIX Worksystem Software (UWS) implements the imaging models of both the X Window System and the Display PostScript system. Both define a coordinate system for imaging. By implementing Display PostScript as an extension of the X server, UWS applications can mix X and PostScript imaging calls even within a single window by using a single network connection.

The Display PostScript system consists of three main components: the PostScript interpreter, the client library, and a **pswrap** translation program.

In addition to the capabilities of X imaging, the Display Postscript system includes the following:

- A coordinate system that can be moved, rotated, and scaled
- Splines for complex curves
- Device-independent color model with dithered (approximated) colors
- Text that can be scaled and rotated
- Image operators for bitmaps (scaling, rotating, gray-scale manipulation)

#### Additional ULTRIX Tools for Document Manipulation

Additional tools included in the ULTRIX operating system which are valuable for document manipulation include:

- **Spell**—spelling checker.
- **Diction**—finds all sentences in a document that contain phrases from a database of bad or wordy diction.
- **Explain**—an interactive thesaurus for phrases found by the **diction** command.
- **Style**—analyzes surface characteristics of a document. The **style** command reports on readability, sentence length and structure, word length and usage, verb type, and sentence openers.
- **diffmk**—used to compare two document versions and mark the differences between them.
- **diff**—used to compare the contents of two files and list the differences.

- **awk**—a text scanning and processing language.
- **grep, egrep, fgrep**—search for lines matching in a pattern.
- **wc**—counts words, lines, and characters.
- **sort**—sorts and alphabetizes data.
- **comm**—compares sorted data.
- **uniq**—reports repeated lines in a file.

## ▪ Document Transport and Production

### **CDA (Compound Document Architecture)**

Digital's CDA (Compound Document Architecture) provides the backbone for creating, storing, and interchanging files that may contain a number of integrated components including text, graphics, scanned images, and external references to other CDA-compliant files which can be used as part of a document. These files can be edited, formatted, or otherwise processed as simply as text-only documents. CDA products also support other types of information, including CAD databases and live spreadsheet data. CDA provides for interchange of data types in a heterogeneous, distributed network.

The CDA converter library provides CDA-based conversion services. With the CDA converter library, users of CDA-compliant products convert data from many different formats to the Digital document interchange format (DDIF) and from DDIF to multiple alternative formats. This allows integration of text, data, and graphics as the user moves from one application to another.

The library works through a system of front- and back-end converters via the DECwindows LiveLink capability. One pair of converters is used for conversion to or from DDIF for each alternate format. (See Figure 6-1.)

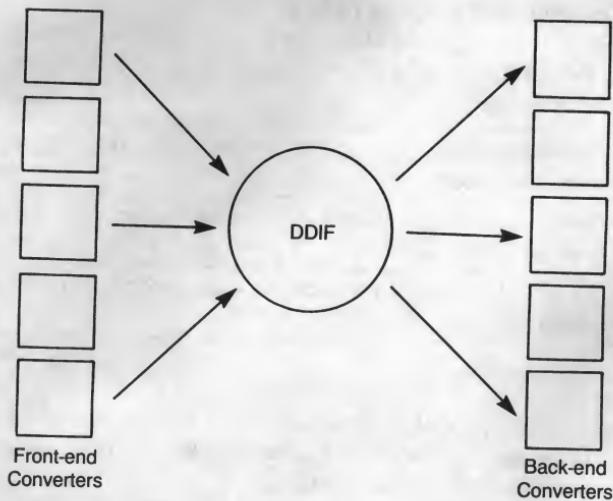


Figure 6-1 • CDA Converter Kernel

The CDA converter library provides a gateway to CDA for a variety of systems and support for most desktop applications. For example, a document created in IBM's DCA format can easily be incorporated into a DECwrite document along with spreadsheet information from a Lotus 1-2-3 spreadsheet and drawings from MacPaint.

In addition to invoking the CDA converters from the application levels, the following tools are available from the ULTRIX shell.

- **cdoc**—an alternative tool for translating between DDIF and other formats
- **dtoc** and **ctod**—tools for translating between DDIF and data object transport format (DOTS) which allows transportation for compound documents by mail

### Other Transport and Production Facilities

In addition to the capabilities of CDA, the ULTRIX operating system provides facilities for manipulating and transporting compound document files, including:

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- A DECwindows application for viewing compound documents (part of the DECwindows environment)
- **vdoc**—a terminal-oriented application for viewing character-cell representations of compound documents
- **TeX** and **LaTeX**—high-quality typesetting of text, especially text with mathematical content

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### Printing

Printers of differing capabilities are supported by the ULTRIX operating system. The print system for ULTRIX is based on BSD 4.3 print software and provides the following additional features:

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- Improved syntax for specifying filters in the file, particularly the ability to specify any filter as a pipeline, as well as a simple command.
- New output filters—two filters allow jobs to be submitted either to DECnet PrintServer hosts or to TCP/IP PrintServer hosts.
- Monitoring of print jobs—system reports when print jobs stall.
- **lpr**—the standard command to print; options allow the user to select data type, orientation, page size, input trays, lay-up, number-up, and output trays. The **lprsetup** tool allows simple printer setup.
- Jobs may be submitted to PostScript printers.

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Print jobs can be submitted to the ULTRIX V4.0 print system from systems running earlier versions of the ULTRIX print software or BSD print software on other vendors' hardware.

# Chapter 7 • Networking and Communications Facilities

## ▪ Chapter Overview

This chapter describes the networking facilities and distributed system services that are included in the ULTRIX operating system or are available as layered products.

## ▪ Networking Capabilities

The ULTRIX operating system and its bundled and layered products provide networking capabilities which use the following general facilities:

- Internet network access (TCP/IP)
- Network File System (NFS)
- Local Area Transport Support—LAT TELNET Gateway
- The VMS/ULTRIX Connection
- DECnet network access
- DECnet-ULTRIX Internet Gateway
- ULTRIX TCP/IP Services for PCs
- Internet Portal
- DECnet Router and X.25 Gateway
- DECnet/SNA ULTRIX 3270 and 2780/3780 Terminal Emulation
- Simple Network Management Protocol (SNMP)
- X/Open Transport Interface (XTI)
- Digital's RPC product—a port of NCS
- UUCP facility

Details on these facilities are found in the following sections.

### Products Included with the ULTRIX Operating System

#### ▪ *Internet Network Access (TCP/IP)*

The Internet is a collection of networks and gateways that uses a set of based protocols called the Internet Protocol Suite or TCP/IP to promote a single, heterogeneous virtual network environment. The protocols are based on Berkeley Software Distribution (BSD) 4.3.

The ULTRIX operating system supports Internet communications by using Transmission Control Protocol/Internet Protocol (TCP/IP) and User Datagram Protocol/Internet Protocol (UDP/IP) over an Ethernet Local Area Network (LAN). This support facilitates electronic mail, file transfer, remote execution, and remote login capabilities by using the TCP/IP applications protocols SMTP (for mail), FTP (for file transfer), NTP (to synchronize clocks), and TELNET (for remote login). Additional supported commands include the Berkeley r-commands. The software also supports reverse local address translations (arp) which are necessary to boot some diskless workstations.

- *ULTRIX Network File System (NFS) Support*

The ULTRIX operating system includes the Network File System (NFS). This facility is designed to promote resource sharing by making information available to multiple systems generally connected by an Ethernet LAN.

NFS permits file sharing among physically separate systems in a multivendor networking environment. A processor can export file systems to, or import file systems from, other processors running NFS. Individual subtrees also can be exported from a file system with export restrictions. To export a file from one system to another, a directory file must be available that lists systems that may be accessed, together with the parameters controlling access. Controlling parameters include the names of clients permitted access and access permissions on the files within the exported file systems. The exporting system or server plays a passive role in file sharing.

The administrator for a client machine can import a file system from any server machine that has granted access permission to the requesting client machine. A complete exported file system or any subtree of an exported file system can be imported by the client machine. Imported file systems are not copied to the client's own file systems but are accessed transparently by the use of remote procedure calls. Imported file systems appear to a user of the client system as resident in the client's local file system.

ULTRIX also provides an automount daemon, a lock manager, and status monitor with NFS. The automount daemon automatically mounts and unmounts directories and increases both efficiency and security. The NFS locking service (lockd) allows the user to create advisory locks on files and file regions on local and remotely mounted file systems.

File locking is a way to manage shared file access. The NFS locking service coordinates the dispersal of locks to local and remote file systems. The NFS status monitor (statd) monitors the status of the client and server sites in response to a request made for the local locking service. If a site failure is detected, the status monitor notifies the local locking service which then processes the recovery of the locked files or regions.

A facility to display Network File System statistics is also included with the ULTRIX operating system. The `nfsstat` command displays statistical information for the NFS and RPC interfaces in the kernel. It can also be used to reinitialize this information. The statistics are automatically reinitialized to zero each time the system reboots.

- **ULTRIX Local Area Transport (LAT) Support: LAT TELNET Gateway**

The ULTRIX operating system's Ethernet support includes Digital's Local Area Transport (LAT) protocol for terminal connection through DECserver terminal servers. DECnet includes a facility called the LAT TELNET Gateway. LAT service is activated and controlled by the `lcp` utility.

DECserver terminal servers provide a means to connect many terminals or dial-up modems to several different systems on an Ethernet LAN. They serve as a transparent link between a given terminal and one or more systems to which the terminal can be connected simultaneously. The user can switch from one session to another by issuing commands to the LAT.

Serial printers can also be connected to a LAT, thereby allowing them to be used by all the systems recognized by the LAT.

#### **VMS/ULTRIX Connection**

The VMS/ULTRIX Connection is a layered software product for the VMS operating system. This product promotes resource sharing and supports networking, file access, remote terminal access, and application development between VMS servers and the ULTRIX operating system or other UNIX operating system clients. The product allows ULTRIX and other implementations of UNIX operating systems to exploit the availability and reliability of VAXcluster systems that use industry-standard TCP/IP networking protocols. (See Figure 7-1.)

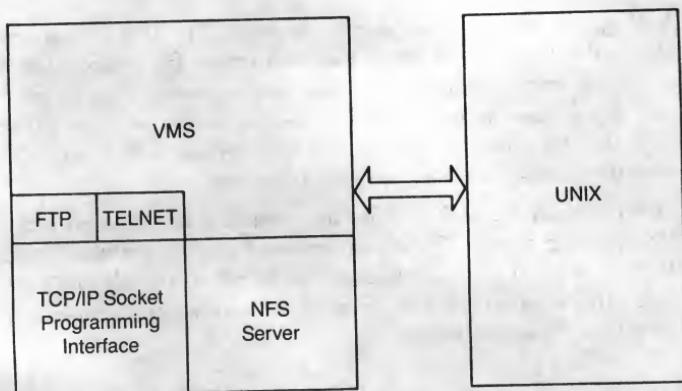


Figure 7-1 • VMS/ULTRIX Connection

Major features of the VMS/ULTRIX Connection are:

- Support for TCP/IP and other Internet networking protocols, including FTP and TELNET on VMS systems
- TCP/IP support for DECwindows with VMS V5.3 or above
- Programming support via the C language socket interface and QIO programming interface
- NFS server support on VMS systems for any UNIX operating system clients
- A system management interface for setting up and monitoring the communication and NFS environments
- New features include NCS, RIP, and BIND Resolver.

Digital's Remote Procedure Call product is a port of Apollo's Network Computing System (NCS). It provides a set of tools for building heterogeneous distributed applications.

Routing Information Protocol (RIP) will allow hosts running the VMS/ULTRIX Connection to discover network route information dynamically among machines on their local network.

Berkeley Internet Name Domain (BIND) is a host name and address lookup service for the Internet network. It allows client systems to obtain host names and addresses from BIND servers rather than from databases on local hosts. Only the client software (BIND Resolver) is implemented.

- *Network File System (NFS)*

The VMS/ULTRIX Connection supports NFS protocol specifications. NFS is an application layer protocol that provides clients with transparent access to remote file services. Current software supports an NFS server on VMS for UNIX operating system clients.

- *Client Access to VMS Files*

UNIX operating system clients can access VMS files stored in an RMS StreamLF format on the server. StreamLF files are analogous to the "Byte" stream files common on UNIX operating systems. Clients also can access other types of RMS files such as ISAM files. However, the ISAM structure and file contents will be passed to the UNIX operating system client in sequential bytes. A programmer must be aware of the specific ISAM structure to make use of the file contents on a UNIX operating system client.

- *Client Access to ULTRIX-Compatible Files*

The ULTRIX-compatible file system on VMS provides clients with the same file system functionality as an ULTRIX server. To the remote client, the VMS NFS server looks like a large ULTRIX file cabinet. The ULTRIX files are accessed according to the rules of the ULTRIX File System (UFS). UFS supports BSD 4.3 Fast File System semantics which are a superset of the SVID Issue 2, Volume 1 file system semantics. The UFS rules permit up to 255 levels of directory nesting and file names of 255 characters. VMS files visible to these ULTRIX file systems may also be accessed by applications executing on the VMS system.

#### **DECnet Access (Including the DECnet-ULTRIX Internet Gateway)**

DECnet software is an optional product for the ULTRIX operating system. DECnet is the collective name for the family of communications products (software and hardware) that allows Digital operating systems to participate in a network.

All systems connected to a DECnet network can communicate with one another without having to go through a central or master system. Any system in the network can communicate with any other system, not only with those systems to which it is directly attached. Network users can gain access to software facilities that do not exist on their own system and can communicate freely over the entire network. A DECnet network, therefore, provides the efficiency and flexibility of distributed networking.

The ULTRIX operating system runs the DECnet protocol as an end node, and serves as a gateway from ULTRIX and other systems running Internet protocols to systems in a DECnet network. The DECnet access facility called the DECnet-Internet Gateway, includes:

- Electronic mail (Mail-11 and SMTP protocol translation)
- Remote login (CTERM and TELNET protocol translation)
- File transfer (DAP and FTP protocol translation)

Supported DECnet commands are **dcat** (concatenate), **dcp** (copy), **dlogin** (virtual terminal), **dls** (directory listing), **drm** (remove), and **mail**. The use of wildcards is supported for file transfer operations, and file names are generated automatically on the target system if not specified explicitly.

Each generation of DECnet has been a pioneer in the direction of open communications. DECnet/OSI Phase V is the fifth generation of Digital's network architecture. Its two major goals are support for multivendor networking and support for networks over 100,000 systems.

The Digital Network Architecture supports proprietary protocols and OSI standard protocols and services, which users may implement based on their specific needs.

Digital will integrate the lower four levels of the OSI standard into DECnet first because their specifications are stable. At the upper levels, Digital's network management and high-performance routing algorithms, which are required to support very large networks, are technologically ahead of the standards in their current state. When draft standards for the upper layers of the OSI Reference Model are well defined and near full consensus, they will be incorporated into DECnet as well. The first DECnet/OSI products are expected to be available by mid-1990. The ULTRIX operating system will migrate to support these products.

The ULTRIX network offering is available in two kits. The ULTRIX kit contains the Internet protocol suite and applications as well as mop and lat. It also contains the DECnet-ULTRIX kernel modules. Integrating these modules into the ULTRIX kit enables consolidation of network code and facilitates portability to emerging OSI, OSF, and other standards. The integration effort also enhances architectural integrity and makes network management easier.

The DECnet-ULTRIX kit contains libraries, DECnet applications, and the DECnet/Internet application gateway.

### **UNIX/TCP/IP Services for PCs**

Digital resells two products under a Digital Distributed Software agreement with LOCUS Computing Corporation. Both connect ULTRIX hosts to DOS PCs using TCP/IP as the networking protocol suite.

LOCUS's PC-Interface (PCI) product allows an ULTRIX system to provide file and print services for DOS PCs connected to an Ethernet. It supports multiple UNIX operating system hosts and multiple drive capabilities, provides VT 220 and 100 terminal emulation, requires only 50K of memory on the PC, and provides data security through DOS and UNIX operating system standards for record locking and file permission.

LOCUS's PC Xsight product allows a PC to display X-window applications running on an ULTRIX operating system host. The PC becomes a powerful, cost-effective color X-terminal and off-loads graphics processing from the host.

### **Internet Portal**

The Internet Portal will benefit those customers who have an existing DECnet backbone network but have a growing need to connect TCP/IP hosts. The Portal takes the TCP/IP packet at the sending end, encapsulates it into a DECnet packet, sends it across the DECnet backbone where a receiving Portal removes the DECnet header, and sends the unaltered TCP/IP packet to its destination node.

The major intent of the Internet Portal is to provide TCP/IP network connectivity across a DECnet Phase IV backbone so that Internet LAN users can take advantage of the wide area services provided by DECnet.

### **DECnet Router and X.25 Gateway**

The DECnet Router and X.25 Gateway are software products that run on an Ethernet Communications Server hardware unit to provide DECnet routing functions for a network of one or more host computers via point-to-point links or CCITT X.25 Packet-Switching Data Network (PSDN) switched virtual circuits. The DECnet Router and X.25 Gateway implement Phase IV DECnet routing and network management and require DECnet-ULTRIX and the presence of a VMS load host. The software runs on VAX computers only.

### **DECnet/SNA ULTRIX Terminal Emulators for IBM 3270 and IBM 2780/3780 Systems**

The DECnet/SNA product set provides a system connecting DECnet and SNA networks that can be used by a wide variety of Digital-supplied access routines running under VMS, MS-DOS, and ULTRIX operating system environments.

The DECnet/SNA ULTRIX Terminal Emulator for IBM 3270 is a layered software product that allows users of a VT terminal, or system in a VT mode on suitably configured ULTRIX systems in a DECnet environment, to interactively access IBM mainframe applications. Access to these applications is gained via any of the DECnet/SNA gateway products. A VMS-based load host is required.

A DECwindows version of this emulator is also available for the Digital workstation environment. Emulation function and features are similar to the non-DECwindows product.

The IBM 2780/3780 Terminal Emulator is part of the ULTRIX operating system package that allows the ULTRIX terminal (VAX only) to emulate a 2780 or 3780 IBM terminal. This terminal emulator uses a Binary Synchronous Communications (BSC) protocol to send and receive files across a communications line connected to an IBM system that supports 2780/3780 devices.

### **Simple Network Management Protocol (SNMP)**

Simple Network Management Protocol (SNMP) is a manager/agent (client/server) protocol for network management. It is an interim network management strategy adopted by the Internet until the Common Management Information Protocol (CMIP) and the CMIP on TCP/IP (CMOT), the long-range management solution, are completed and adopted by standards agencies.

With SNMP, every system runs the agent software which is a daemon that answers requests from the manager software such as system name, uptime, load statistics, routing tables, network counters, and local address translations. ULTRIX software supports the agent portion of SNMP software in its base system. Agent software is also included in the Internet Portal. The manager portion of the software is available as a separate service.

### X/Open Transport Interface (XTI)

ULTRIX supports the X/Open Transport Interface library (XTI) which is part of the X/Open Portability Guide Issue 3. XTI is a library that provides a common programming interface for the UDP, TCP, and, in the future, TP4 transports. It will provide easy migration of applications as networks evolve from TCP/IP to the OSI of the future. XTI does not replace the session or transport layer of the OSI model. Rather it is an interface between them. In addition to providing the runtime library, the following Internet applications from Digital will be based on XTI: FTP, TELNET, and SMTP. XTI works in either the BSD or System V environment.

### Digital's RPC Product

Digital's RPC (Remote Procedure Call) product, a port of NCS, distributes both the data and the capabilities of an application to heterogeneous computers and operating systems on a network. The major components of NCS included in ULTRIX are the Remote Procedure Call (RPC), the Network Interface Definition Language Compiler, and the Location Broker. RPC is a mechanism developed to distribute applications, allow multivendor interoperability, improve resource utilization, and provide application independence from the communication subsystem.

Structure programming techniques have encouraged applications to be built using subroutines with well-defined interfaces. In an NCS distributed application, the application calls a stub which masquerades as the local subroutine. The stub then packages the data and passes it via the RPC runtime to another stub on a remote machine which in turn unpackages it and passes it to the real subroutine.

The stub is created using the Network Interface Definition Language compiler (NIDL). The developer feeds the subroutine interface definition into the NIDL compiler. The compiler generates the C source code stub that is used by the target machine C compiler to create the stubs.

The location broker provides a mechanism for the system administrator to register the subroutines on a server so that the client stub can find them. The Network Computing System is a complete solution to distributing processes which makes it economical to write future applications. (See Figure 7-2.)

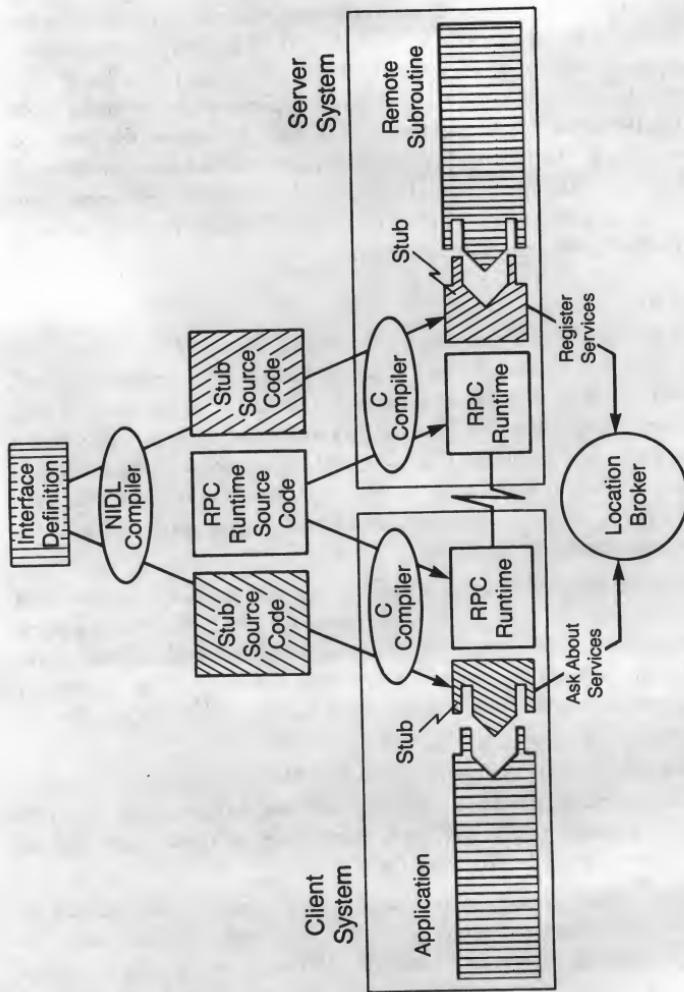


Figure 7-2 • Digital's RPC Network Computing Summary

Digital's RPC is currently layered on a TCP/IP network. ULTRIX will interact with NCS on VAX systems running NCS on VMS software, as well as Apollo, IBM, Hewlett-Packard, and other systems using licensed NCS from Apollo.

#### **UNIX-to-UNIX Copy Facility (UUCP)**

The UUCP facility is a series of programs that permit communication between ULTRIX systems or any UUCP systems. Files can be transferred and remote commands can be executed over dial-up or hardwired communication lines. Files transferred in this manner are created in a spool directory for processing by the UUCP daemons. If the transfer includes executable commands, the commands are executed in batch mode and the command, data, and work files are deleted from the spool directory. All Digital's currently supported autodialing modems work with the UUCP facility.

Part of the UUCP facility is the **tip** utility, which establishes a full-duplex connection to another system, thus providing virtual terminal access to the remote system. The **tip** utility also provides ASCII file transfer.

### **• Distributed System Services**

These distributed services are available to ULTRIX users: Yellow Pages, BIND, Hesiod, Kerberos, and Mail Facilities. Each of these services is described in the following sections.

#### **Yellow Pages Service**

The Yellow Pages (YP) service implements common databases for information such as user name and passwords, and network domains. These databases are shared among systems in a network by using the capabilities of NFS. The service is implemented so that a single system is the YP server at any given time. If that system fails, another system can take over the server function.

#### **BIND**

The Berkeley Internet Name Daemon (BIND) service is a host name and address lookup system for information on large distributed networks which use the Internet protocol. It may supplement or replace the host lookup provided by YP.

The ULTRIX BIND service is based on Berkeley's BIND service. It divides a network into a hierarchy of domains, subdomains, and zones. It eliminates the need for a central clearinghouse for name and address information and allows each domain to maintain control authority for its particular area. BIND has a hierarchy of servers that know how to communicate with each other when information is requested from a different area. The service caches information and thus can increase throughput.

#### **Hesiod Name Service**

The Hesiod Name Service allows centralized administration of the password, host, alias, and other system management databases and sharing of such information in a distributed fashion. The name service is based on BIND and can completely replace YP. Hesiod alone is designed to provide applications with a rapid, low-overhead naming service in which a query returns no more than a few matches. The name service uses the Kerberos authentication service when it is needed for authentication.

#### **Kerberos Authentication Service**

The Kerberos Authentication Service allows for one-way or mutual authentication. This is accomplished in a client/server fashion where there is a Kerberos server. The service uses "tickets" for authentication. Each ticket is double encrypted and time sensitive. The service is based on the Data Encryption Standard (DES).

#### **Mail Facilities**

The ULTRIX system provides extensive mail facilities in both workstation and character-cell environments. On a workstation, the DECwindows interface to mail provides an integrated environment for transferring, editing, and filing messages. On a terminal, a command line interface provides similar features.

In addition to UUCP and Internet mailing services provided by the operating system, layered products such as ULTRIX Mail Connection (see next page) provide connectivity between ULTRIX systems, UNIX systems, and MAILbus with its associated gateways and user agents.

Several mail user agents are supplied with the ULTRIX software, notably MH, based on the Rand 6.5 message handler and UCB mail which is derived from the Berkeley Software Distribution. Both user agents consist of a collection of single-purpose programs to send, receive, save, and retrieve messages. They support distribution lists, aliases, and message forwarding instructions, as well as provide notification of new mail, either synchronously or asynchronously.

MH is more powerful than UCB mail because it offers advanced folder handling and message selection facilities. MH commands can also be freely interspersed with other shell commands to allow the user to read and answer mail while performing other tasks.

The message transfer agent provided with ULTRIX is sendmail, and it is responsible for directing both incoming and outgoing messages to the appropriate network or address.

#### • **ULTRIX Mail Connection**

The ULTRIX Mail Connection is a layered product that provides enhanced mail services. It allows users to exchange mail easily between the ULTRIX and UNIX mail domains and the MAILbus gateways and user agents. It does this via a direct link with VAX Message Router. Features include:

- Electronic mail interchange with Digital ALL-IN-1 mail for VMS, MS-DOS, X.400, Telex, IBM PROFS, and IBM Snads
- Enhanced facilities over those provided with the base system, MH
- Address lookup facility on Message Router's DDS (Distributed Directory Services)
- Support for sending CDA documents, as DDIF and DOTS
- Choice of MH interface: either the standard command line interface or the graphical-based interface, **dxmail**, which provides a windows-oriented, easy-to-use mail interface similar in look and feel to other DECwindows applications

The ULTRIX Mail Connection provides a means for the ULTRIX user to communicate easily and freely with users on a variety of mail systems.

Figure 7-3 illustrates the integration of various mail systems to the ULTRIX Mail Connection.

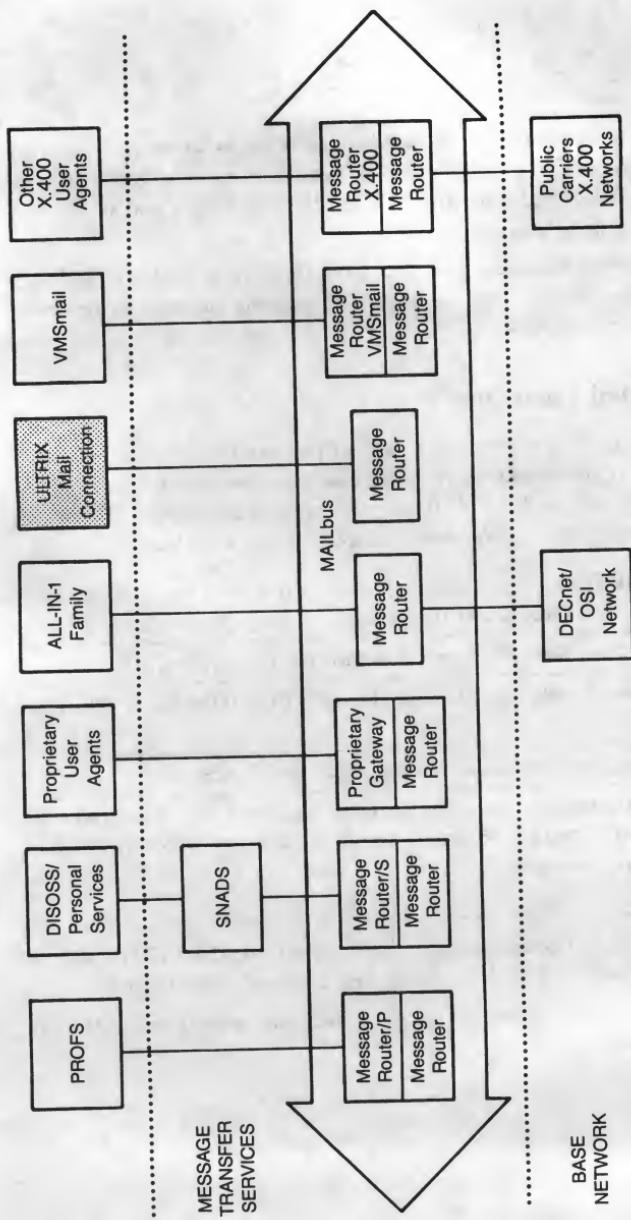


Figure 7-3 • The ULTRIX Mail Connection

## Chapter 8 • Data Access Management with ULTRIX/SQL

### • Chapter Overview

ULTRIX/SQL is an integration of an industry-standard SQL (Structured Query Language) and a Relational Database Management System (RDBMS) engine for accessing databases and facilitating queries on databases for both customers and third-party database tool vendors. The integration of industry-standard SQL and RDBMS allows for the development of portable applications on ULTRIX that use standards-compliant SQL. ULTRIX/SQL is packaged and licensed with the ULTRIX operating system.

### • ULTRIX/SQL Base System

The ULTRIX/SQL base system contains many features and benefits:

- An ULTRIX/SQL RDBMS engine allows the data format to be hidden from the user. It also allows enhanced data access/manipulation/recovery capabilities.
- An interactive SQL monitor allows databases to be created and/or manipulated using only the base system. It provides on-line language and help tables.
- Remote database access enables database tables to be shared among multiple ULTRIX systems using either DECnet or TCP/IP.
- Tools for the Database Administrator (DBA) and tools for optimization allow the DBA to tune for performance in such areas as lock management, buffer management, and storage structure.
- ULTRIX/SQL also contains advanced DBA and end-user documentation, including on-line manual pages and a cross-reference table for standards-compliant syntax.

### ULTRIX/SQL Administration

ULTRIX/SQL administration is handled by the System Administrator and the Database Administrator.

Tasks of the Database Administrator (DBA) include:

- Creating databases and tables
- Granting data access to users
- Checkpointing and recovering journaled databases

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- Restructuring and optimizing data tables
- Moving database tables (transparent to applications)

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Tasks of the System Administrator include:

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- Authorizing individual database users
- Granting special privileges to users
- Creating alternate data areas
- Restoring databases from system backup
- Monitoring RDBMS servers and sessions

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## ▪ **ULTRIX/SQL Application Development**

ULTRIX/SQL applications can be written in C, FORTRAN, and Ada using embedded language extensions (ESQL). Applications are run through the precompiler to generate standard C, FORTRAN, and Ada source code from SQL constructs. After being compiled and linked, the executable code can communicate with the server.

An embedded SQL runtime in the ULTRIX base operating system means that software houses that develop applications using ULTRIX/SQL do not need to buy an RDBMS license or pay a royalty fee for its use.

ULTRIX/SQL is supported by a variety of third-party tools for development of portable and distributed applications.

## ▪ **Basic Command Features of ULTRIX/SQL**

Basic command features of ULTRIX/SQL allow the ability to do the following:

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- Create tables from data or other tables
- Insert, delete, and update data
- Select data fields (with constraints)
- Create views (table projections)
- Grant or restrict data access in views or tables
- Use various data types: integer, float, char, date, and money

---

- Advanced Command Features of ULTRIX/SQL

Advanced features of ULTRIX/SQL allow for networking or remote access to distributed databases on homogeneous systems from ULTRIX to ULTRIX, from ULTRIX to VMS via Rdb remote access, and from ULTRIX to other UNIX operating systems via other operating system gateways. A single node can also be used to monitor multiple projects' data, and a user can read or write to remote databases, as shown in Figure 8-1.

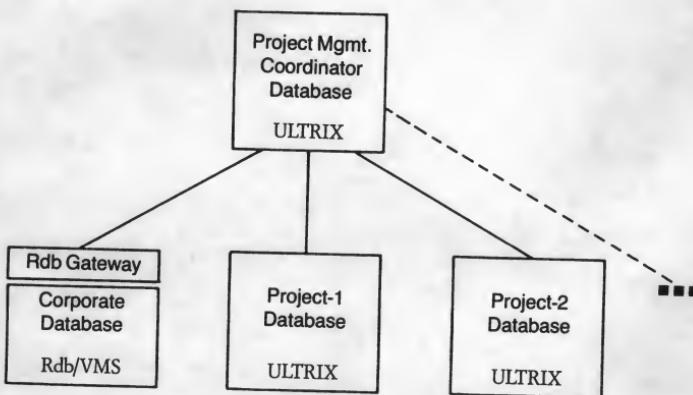


Figure 8-1 • ULTRIX/SQL Networking Example

Other advanced command features include use of the following:

- Integrity constraints: type, value, and range restrictions
- Multi-table joins (using select)
- Multi-query transactions
- Dynamic SQL commands such as prepare, execute, describe, and sqlda

Backup and recovery are also included as advanced features of ULTRIX/SQL.

- **Layered Products Available on ULTRIX/SQL**

Several layered products are optional on ULTRIX/SQL. Embedded SQL precompilers for C, FORTRAN, and Ada with translators to and from ULTRIX/SQL and VAX/SQL for C and FORTRAN are available. Rdb remote access from the ULTRIX/SQL environment, and several front-end tools from third-party vendors, including INGRES, INFORMIX, and FOCUS, are also optional.

## Chapter 9 • System Management

### • Chapter Overview

Digital has added an extensive set of tools and services to the ULTRIX environment to provide effective system management. These tools ease many system management tasks, from initial installation through day-to-day maintenance and occasional crash recovery. They also make dedicated system installation and management experts unnecessary. This set of tools is described in this chapter.

### • Installation and System Generation

The ULTRIX operating system includes enhanced installation and operating system generation facilities.

The consolidated ULTRIX distribution kit is segmented into a base ULTRIX system and workstation components, which are always loaded, and a number of software segments (called subsets), which may be loaded optionally. For more information on software subsets, refer to the technical summary for ULTRIX V4.0 documentation set, No. AA-MG63B-TE.

ULTRIX subsets contain executable programs and linkable object modules. It is not necessary to build the operating system from sources. Software installation is highly automated. Software subsets are loaded automatically through a utility program called `setld`. The `setld` utility loads, unloads, and inventories subsets. For installing subsets, the `setld` utility displays a list of the subsets available to be installed. The user can select any or all of the subsets for installation, depending on the availability and size of disk space. This utility can also execute the Installation Verification Programs (IVPs) for products that have them.

Several installation options reduce management requirements as well as hardware and support costs. The ULTRIX Diskless Management Service (DMS) is available to create and manage a diskless environment. Remote Installation Service (RIS) is also available for installation and modification of software over a network. DMS and RIS provide support for multiple architectures and most ULTRIX versions.

## • **System Generation and Modification**

Operating system generation is handled by a kernel generation program called **doconfig**. System generation is interactive for functions such as the configuration of devices and optional operating system features and automated kernel build.

System verification can be performed using system exerciser programs located in the **usr/field** disk area. Changing system setup in response to configuration changes is simple and fast.

Line printer spoolers are set up by using an interactive tool called **lprsetup**, which has on-line help and provides default answers to questions about modifying the system's printer setup. The utility handles remote and local printers.

The UUCP (UNIX-to-UNIX copy) facility uses a similar setup tool called **uucpsetup**. Local area network can be set up through **netsetup**. These tools avoid the need for direct editing of terminal, printer, or network control files.

The **nfssetup** command is an interactive facility that allows users to set up or modify NFS on their systems. NFS provides support for sharing ordinary files and directories in a multivendor networking environment (see Chapter 7). The **nfssetup** command allows you to either enable or disable the NFS locking service.

The Yellow Pages (YP) service provides a network lookup service consisting of databases and processes (see Chapter 7). The **ypsetup** command is an interactive facility that allows users to set up YP services on their systems. It sets up a default YP domain name and the nature of the YP environment (master server, slave server, or client), and places several administrative files under YP control.

The BIND (Berkeley Internet Name Daemon) server translates host names to network addresses. Host names can be easily resolved at other locations without maintaining multiple copies of the host's database (see Chapter 7). The **bindsetup** command sets up the BIND service on a system and places host name and address resolution under BIND control. This command can be used to set up a system as a primary, secondary, or caching server, or as a client.

Each system administrator will maintain a database service selection file, **/etc/svc.conf**. The **/etc/scv.conf** file allows an administrator to select the desired services on a per-database basis. This file must be modified when adding or removing a naming service such as Yellow Pages or BIND. Modifications to the services selection file are made either with an editor or via the **svcsetup** command. All changes take effect immediately.

## ▪ System Administration

The ULTRIX operating system includes the following system administration facilities:

- The operator service utility, **opser**, helps the system operator to perform administrative functions such as system startup and shutdown, file system backups, and file system consistency checks.
- The line printer control utility, **lpc**, enables the system administrator to monitor, start, and stop printer queues.

File system creation and maintenance utilities include:

- **mkfs** and **newfs** for creating file systems
- **mount** and **umount** for mounting and unmounting file systems
- **fsck**, **icheck**, **dcheck**, **ncheck** for checking file system integrity
- **dump**, **restore**, **rdump**, and **rrestore** for backing up and restoring file systems
- **du**, **df**, and **quo** for monitoring file system usage

General system monitoring utilities:

- **cpustat** for monitoring CPU statistics
- **iostat** for reporting I/O statistics
- **vmstat** for monitoring memory usage
- **umonitor** for monitoring UUCP system status
- **ps** and **pstat** for monitoring process and system status
- **arp**, **ifconfig**, **netstat**, **ruptime**, and **rwho** for monitoring TCP/IP network status
- **nfsstat** for displaying network file system statistics
- **ac**, **accton**, and **sa** for monitoring login and system accounting

- **Saving and Restoring Files**

Along with the **rdump** and **rrestore** facilities, the **tar** utilities save and restore individual files or selected directory subtrees using magnetic tape or floppy disks. In addition, the **tar** utility saves and restores empty directories and special files, and supports multivolume archives. The ULTRIX **tar** utility supports the POSIX-specified USTAR format.

- **ANSI-Compatible Archiving**

The **ltf** utility (labeled tape facility) is similar to the **tar** utility. However, it writes and reads tape volumes using formats that are compatible with ANSI Versions 3 and 4, thereby permitting information exchange with VMS and other operating systems whose tape formats comply with the ANSI standards.

- **Maintainability**

The ULTRIX operating system kernel is enhanced to provide recovery from many hardware error conditions. The software includes the following maintainability enhancements to ease the system administrator's job for tasks such as error logging and crash recovery.

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- Device and memory error logging system, including:
  - Kernel and device driver error gathering scripts
  - Error logging daemon (elc)
  - Error logging housekeeping command (eli)
  - Error log report generator (uerf)
- Crash dump facility that can write a crash dump to disk
- Disk media error support services, including the ability to statically replace bad blocks and drivers that dynamically replace bad blocks
- Stand-alone initialization and verification programs
- Diagnostic and exerciser programs

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## Chapter 10 • Integrating the Digital and Non-Digital Operating Environments

### • Chapter Overview

This chapter briefly describes Digital's strategy for delivering a unified software environment that allows new and existing applications to share information and resources with each other regardless of the systems on which the applications run. Network Application Support (NAS) services are available to ULTRIX users whose enterprise network is made of heterogeneous systems and devices, whether they are from Digital or other vendor systems.

### • Network Application Support (NAS)

Although the ULTRIX operating system running on an appropriate platform may be the system of choice for an enterprise, many customers will have or may wish to acquire equipment that uses UNIX or other non-ULTRIX operating systems. To provide maximum interoperability, functionality, and investment protection, Digital has developed Network Application Support (NAS) services to allow access to applications from any of these systems running on a network.

NAS is a comprehensive set of applications services that allows software applications to integrate well with one another across a distributed environment of multivendor systems. These services answer the need for access, communication, and information/resource sharing capabilities across a network of different desktop devices and server systems.

The foundation of Network Application Support services is the NAS architecture, which defines the architectural specifications and Application Programming Interfaces (APIs). The APIs separate applications from all system-specific dependencies, thereby providing portability and interoperability.

### • NAS Built on Open Standards

A key goal of NAS is to implement and expand upon strategic industry software standards to provide open access to specifications. For example, the Application Programming Interfaces (APIs) that facilitate the development and delivery of integrated applications are based in general on a superset of the Open Software Foundation's APIs. By building NAS services on industry standards, Digital can assure our customers of long-term growth, compatibility, and flexibility. Table 10-1 lists NAS services and the relevant standards that they meet.

**Table 10-1 • NAS Services and Relevant Standards**

Service	Relevant Standards/Specifications
<b>Applications Access:</b> Windowing Services	X Window System (endorsed by X/Open) ANSI X3H3.6 (in process) OSF/Motif (IEEE 1201 in process)
Forms Services	FIMS (Form Interface Management System: ISO SC22/WG18)
Terminal Services	ANSI X3.64
Graphics Services	GKS (ISO 7942 and ANSI X3.124) PHIGS (ANSI X3.144)
Application Control Services	Emerging: Remote Procedure Call (NCS/RPC, OSF RFT, EMCA 127, ISO DIS 10148, ANSI X3T5); IEEE 1003.4, IEEE 1003.8
<b>Communications and Control:</b> Messaging Services	CCITT X.400
EDI Services	ANSI X12, EDIFACT
<b>Information/Resource Sharing:</b> Compound Document Services	ODA/DDIF (ISO 8613) SGML (ANSI X3.143, ISO 8879) Abstract Syntax Notation (ASN.1 - ANSI X3T2, ISO 8824-5)
Data Access Services	SQL (ISO, ANSI X3.135)

**Table 10-1 • NAS Services and Relevant Standards (Continued)**

Service	Relevant Standards/Specifications
Repository/Dictionary Services	Emerging: Information Resource Dictionary Services (ANSI X3.138, ISO TC97)
File Sharing Services	Network File System (de facto; IEEE 1003.8 in process)
Print Services	ECMA/ISO Print Systems Interconnect, PostScript (de facto)
Operating System Interface: POSIX	IEEE 1003.1; 1003

#### • Multivendor Support

Network Application Support services are provided on Digital's VMS or ULTRIX system software, residing on VAX or DECsystem computers acting as server systems. NAS delivers common applications services transparently across a TCP/IP or DECnet network.

Digital provides NAS services for VT terminals, DECwindows terminals, and IBM 3270 terminals attached to systems running the VMS or ULTRIX operating systems, for ULTRIX and VMS DECwindows workstations, for MS-DOS and OS/2 personal computers, and for Apple Macintosh systems.

Digital's Personal Computing Systems Architecture (PCSA) is being expanded to integrate PCs into Digital/OSI networks over DECnet-ULTRIX and TCP/IP, using ULTRIX-based server systems.

PCSA provides a framework for integrating personal computers into an organization's total information system to enable different types of users to share information, large system resources, and network services across the entire organization. PCSA for ULTRIX will allow MS-DOS, OS/2, and Apple Macintosh PC clients to take advantage of file and print sharing and other Network Application Support services provided by VAX and RISC-based servers running ULTRIX.

- **System Software**

Digital offers a choice of operating environments: ULTRIX or VMS, and provides a high level of integration between systems. Both ULTRIX and VMS environments were designed to support distributed computing and share common hardware, networking, languages, information management, and NAS capabilities.

The Remote System Manager (RSM) is a VMS layered product that allows VMS to provide system initialization, software distribution, and backup/restore services to an ULTRIX workstation.

## Chapter 11 • Support Services

### ▪ Chapter Summary

This chapter describes support services which Digital makes available to users of the ULTRIX operating system. These services include consulting, ongoing software and hardware support, and training.

### ▪ Introduction

Digital delivers complete solutions worldwide with industry-focused resources capable of providing strategic consulting, program management, and custom software, hardware, and training.

Starting with strategic enterprise planning, Digital helps the customer set long-term direction, specify application needs, and deliver the best corporation-wide computing solutions. In addition, Digital offers hotline telephone support, periodic software dispatches, and software update service.

Digital delivers the widest spectrum of worldwide system management services, including site planning, networking design and management, education, standard and predictive preventive maintenance, and performance optimization.

Digital offers training to help users become proficient quickly at powerful workstation tools like windowing, graphics, file manipulation, and human interfaces.

The following sections provide a closer look at three of Digital's most important service areas: Enterprise Services, ongoing support services, and training services.

### ▪ Enterprise Services

Digital's Enterprise Services is a significant new addition to Digital's broad service offerings. Through Enterprise Services, Digital helps customers leverage their investment in technology and people. Digital makes a major commitment to providing total solutions integration, including systems, services, and support. Digital also accepts full program management responsibility for implementing enterprise-wide integrated systems, including coordinating the work of third-party vendors.

Next, Digital builds a working relationship between our program managers and customers. This helps customers use information more effectively in managing their enterprise. To this end, Digital applies its vast experience gained from managing multimillion-dollar programs worldwide, and Digital takes the lead in assuring that performance meets the original plan.

### **The Enterprise Services Process**

Just as your enterprise achieves success through proven processes, Digital's Enterprise Services are based on proven approaches, methodologies, and expertise in four major areas.

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- Planning—Enterprise planning begins with Digital's consultants. Through its alliances with other premier consulting organizations, Digital builds a team of professionals who are experts at understanding the customer's business and vision. This team helps to match strategic business planning with information technology opportunities, while keeping organizational and personnel implications in perspective.
- Design—Once Digital understands the customer's corporate vision, Digital helps develop a custom blueprint for integrating the enterprise. The blueprint is more than a design of an information system; it focuses on the use of high-level strategies to develop organization, information, and solution architectures that show how to accomplish enterprise integration objectives.
- Implementation—With a comprehensive blueprint, the customer begins to recognize the intricacies and complexities involved throughout the process. Digital implements the total program carefully, efficiently, on time, and on budget, with the appropriate hardware and software customization and multivendor integration.
- Management—The ongoing management of the enterprise requires expertise for all systems, including business, technology, and human resources. Digital can provide fully integrated support and service management systems to contribute to the customer's success.

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### Ongoing Support Services

Digital provides a full range of software services for the ULTRIX operating system. The services described in this chapter may not be available in all geographic areas. For complete information on the services provided by specific areas, contact the local Digital sales office.

Following are some of the areas in which Digital offers support services:

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- **System Startup Service Packages**

System startup service packages are available with various levels of service. The services provided with these packages can include:

- Installation of the ULTRIX software: Customer Services installs the software on Digital hardware at the customer's site.
- Training on the ULTRIX software: Digital works with the customer to determine what training is needed and the most beneficial way to provide it. Topics covered can range from how to use ULTRIX commands to system management of ULTRIX systems.
- Software maintenance service and technical assistance

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- **Support Services**

Digital provides a variety of ULTRIX support services, including:

- Scheduled preventive maintenance

An assigned specialist at Digital's Customer Support Center provides support by scheduling service delivery, reporting on performance, and resolving critical problems to maximize the availability of the software.

- Telephone support

Support will be provided to resolve problems by fixing them, by providing temporary solutions until permanent solutions are put in place, or by escalating as necessary to provide solutions.

- On-site remedial support

If the Customer Support Center or remote resources cannot resolve a critical problem, then a specialist will visit the site to determine the solution.

- Access to software information and service delivery networks

The Digital Software Information Network (DSIN) is available by dial-up connection to view problem solutions that have been entered into a database maintained by Digital for this purpose.

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- **Support Services (Continued)**

- **Software performance reports (SPRs)**

Customers can report problems with the ULTRIX software. Every SPR receives a response, and solutions are entered into the DSIN database.

- **DISPATCH**

The *DISPATCH* newsletter, which reviews solutions or work-arounds to current SPRs, is available quarterly.

- **Software media and documentation updates for each new release**

These updates are covered by a monthly charge and are distributed as kits.

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- **Digital Training Services**

- ULTRIX Operating System Training**

Digital's training service organizations offer a wide range of high-quality instructional programs and courses. This service enables customers to make the most effective use of their training dollars before and after their systems are installed.

ULTRIX training is flexible, complete, and productive. Offered in text-based, video-based, lecture/lab, and seminar formats, courses cover the entire range of today's hardware and software configurations for Digital systems running the ULTRIX operating system.

ULTRIX training courses include:

**Lecture/Lab Courses**

EY 2040E	Introduction to Computer Systems
EY A767E	ULTRIX Utilities and Commands
EY 1925E	C Programming
EY 2286E	Utilizing ULTRIX Features from C
EY 9239E	VAX System V Disk Shadowing
EY 9240E	VAX System V Maintenance
EY 9241E	VAX System V Performance Management
EY 9243E	VAX System V Configuration and Installation
EY D540E	DECwindows Programming I

**Seminar Courses**

EY 5297E	ULTRIX Internals
EY 2255E	The C Programming Language—Application Development
EY 6791E	Advanced C Programming Clinic and Data Structures
EY D548E	UNIX and ULTRIX Systems Overview
EY D547E	A VMS User's Guide to UNIX
EY D546E	OSF/Motif Programming for the DECwindows Programmer
EY 9236E	DECwindows Technical Overview
EY-2257E	Comprehensive Overview of the UNIX Operating System

**Self-Paced Instructional Courses**

EY-2228-PO	Introduction to UNIX Operating Systems
EY-2230-PO	Shell Programming for Users
EY-2231-PO	Shell Programming for Programmers
EY-2232-PO	Text Processing on UNIX Systems
EY-2233-PO	Prototyping UNIX Software Applications
EY-2234-PO	Programming Productivity: Using Advanced UNIX Software Utilities
EY-2237-PO	Utilizing ULTRIX Features with C
EY-2669-SP/VH/VU	Introduction to Computer Systems
EY-8290-VH/VU	Introduction to PostScript Programming
EY-A897E	ULTRIX System Management
EY-A896E	ULTRIX Utilities and Commands
EY-C170-MT/TK	Using ULTRIX User Executive and DECwindows Desktop Applications—VAX Systems
EY-A899E-MT/TK	Using ULTRIX User Executive and DECwindows Desktop Applications—RISC Systems
EY-C169E-MT/TK	Introduction to DECwindows Systems—VAX/ULTRIX
EY-A898E-MT/TK	Introduction to DECwindows Systems—RISC/ULTRIX
EY-8256E-MT/TK	Programming X Version 11 in the ULTRIX DECwindows Environment

For further information on ULTRIX training, contact your local Digital Sales Representative.

Seminars and instructor-led courses can be delivered at customer sites, particularly for customers with large-scale and multi-user training needs. On-site instruction provides the added benefit of allowing users to learn one subject or more, together with their colleagues, on their own system(s).

#### **Custom Training Programs/Consulting Services**

Programs and consulting services are provided for customers who need custom training programs that integrate people and technology. The Comprehensive Training Solutions Group provides many types of custom training programs for managers, office professionals, technical staff, factory-floor personnel, and others.

Offerings include computer-based training, computer-based interactive video, and consulting and analysis services. Digital's training services can perform a needs analysis for a specific job or group of jobs, or a broader training analysis that examines an entire organization's training needs. From these analyses, recommended training programs can be developed and implemented.

For example, a custom training program could be planned for a job-integrated training application for the factory floor. It could use graphics and interactive video, advanced seminars for managers, or computer-based training for office personnel. Another program might create a training network based on the customer's computer network to allow many users to access courses or databases simultaneously.

Whether computer-based training, computer-based interactive video, lecture-based training, linear video, or seminars, the highest quality custom training is delivered in the most appropriate format.

Training consulting is available for customers who wish to develop or upgrade their own training. Digital provides consulting to assist in all phases of planning and implementation, such as facilities design/construction, equipment selection and installation, instructional design/production, and professional staff development.

## • Digital Press

Digital Press, the publishing entity of Digital's Educational Services group, produces practical, timely books for today's computer community. Digital Press serves the computer professional and academic and business communities with publications on computer-related subjects that appeal to the general interests or specific needs of these communities.

Written by leading authorities and practitioners in the computer field, Digital Press books provide accurate, up-to-the-minute information on computer technology. They address the real-world interests of computer professionals, including managers, programmers, system designers, and business users, and they meet the academic needs of students as well as instructors. Whatever their computer interests, readers find Digital Press books useful and stimulating.

For information on ordering through Digital Press, call 1-800-343-8321.



## Appendix A • Hardware Requirements

This appendix describes the minimum hardware needed to run the ULTRIX operating system. Refer to the ULTRIX Software Product Description (SPD) for a complete listing of maximum configurations and supported hardware. The minimum configuration required to run the ULTRIX operating system is a processor with memory, a console terminal, and a system disk. An Ethernet network connection can be substituted for the system disk.

### • Processors

The ULTRIX operating system is fully supported on most Digital processors, including MicroVAX, VAX, VAXserver, VAXstation, and DECsystem RISC processor systems. The ULTRIX Worksystem Software is fully supported on all DECstation workstations. For a current list of supported processors, refer to the ULTRIX SPD.

### • Memory Requirements

For any nonworkstation VAX processor, except the VAX 3500 and 3600 systems, the minimum memory requirement is 6 MB for VAX and 8 MB for RISC systems. For any VAXstation system except the VAXstation 3500 and 3600 systems, the requirement is 6 MB. The VAX and VAXstation 3500 and 3600 systems require 8 MB. The minimum memory requirement for any DECstation system is 8 MB.

### • Console Terminal

One ASCII console terminal is required. On VAXstation or DECstation equipment, the console terminal can be the workstation's screen. Terminals that do not accept lowercase characters are not supported as the console terminal.

### • System Disk

The base ULTRIX operating system requires approximately 48 MB of storage on the system disk. Of this space, approximately 8 MB are for the root files, and 40 MB are for the /usr files. The ULTRIX Worksystem Software requires approximately 126 MB of storage on the system disk. Of this space, approximately 8 MB are for the root files, and 118 MB are for the /usr files.

Additional system disk storage must be allocated for swap space, based on memory size. If the system memory is 10 MB or less, 20 MB must be allocated for swap space. If the memory is larger than 10 MB, swap space must be twice the memory size. On RISC systems, the default disk partition layout provides the correct amount of swap space. For RISC workstations not booted over a network, the minimum disk configuration is an RZ55.

On VAX systems, system support is provided for disk adapters and devices that communicate using Digital's Mass Storage Control Protocol (MSCP), for some UNIBUS disks, and for some SCSI disks. RISC systems provide support for MSCP and for SCSI but not for UNIBUS devices. Not all supported disks are large enough to store the root and /usr files with sufficient space remaining for swap space; refer to the SPD for a list of disks that can be used as system disks.

All optional subsets included with the ULTRIX kit require approximately 100 MB of disk storage, but this space need not be on the system disk.

#### • Software Load Device

Systems must be configured with a supported software load device. This includes either a compact disc reader (CDROM), Digital's CompacTape cartridge devices (TK50, TK70), or a Digital 1600 BPI 9 track reel-to-reel tape. VAXstation and DECstation systems may be configured without the software load device, if software installation is performed via a network, from an existing ULTRIX system set up to support Remote Installation Services (RIS).

#### • ULTRIX CI/HSC Support

ULTRIX supports configurations that use computer interconnect (CI) hardware. A configuration may consist of a single node, or a maximum of 16 nodes, where a node is defined as being either a VAX processor or a mass storage server. No more than two mass storage servers are permitted in a CI environment. Support is provided only for a homogeneous (ULTRIX) CI environment.

A mass storage server is a free-standing, high-speed, intelligent server designed to the specifications of the Digital Storage Architecture and known as the Hierarchical Storage Controller (HSC).

## Appendix B • Information on Standards Bodies

Digital encourages you to become more involved in the standards process. For more information, contact the relevant standards body listed below.

For **IEEE POSIX Drafts**, contact:  
Computer Society Standards  
Telephone: (202) 371-0101

For **IEEE Standards**, contact:  
IEEE Computer Society  
Telephone: (714) 821-8380

For **ANSI Standards**, contact:  
ANSI  
Telephone: (212) 642-4900

For **Open Software Foundation**, contact:  
11 Cambridge Center  
Cambridge, Mass, 02142  
Telephone: (617) 621-8700

For **X/Open**, contact:  
1750 Montgomery Street  
San Francisco, Cal. 94111  
Telephone: (415) 773-5383 or  
Apex Plaza  
Forbury Road  
Reading, Berkshire, UK RG1 1AX  
Telephone: 44 734 508311

For **X Window Consortium**, contact:  
Bob Sheifler  
M.I.T.  
Telephone: (617) 253-0628



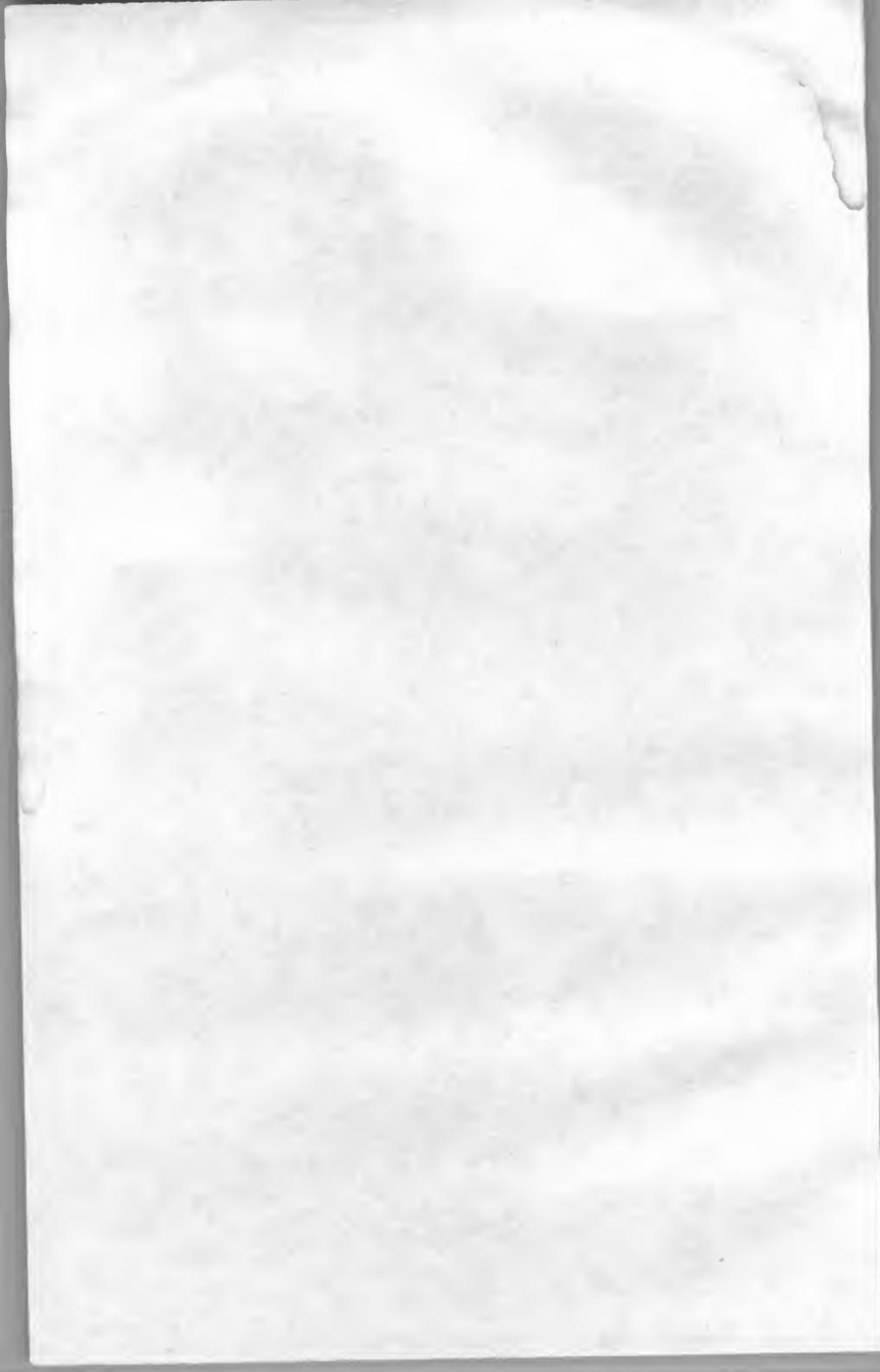














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