

ULTRIX-11™
Software Technical Description


Order No. AA-X342B-TC

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ATTACHMENT: "7th Edition UNIX Summary"

SOFTWARE TECHNICAL DESCRIPTION

1.0 INTRODUCTION

This document describes the ULTRIX-11 software product to help prospective customers to make an informed decision concerning purchasing an ULTRIX-11 system. This software description answers the most commonly asked concerns about the ULTRIX-11 operating system, such as:

- Number of users
- Licensing
- Hardware configuration requirements
- Disk media requirements
- Product features

1.1 WHAT IS ULTRIX-11?

The ULTRIX-11 system is the 16-bit member of DIGITAL's ULTRIX family of UNIX products. The ULTRIX-11 V2.0 software is the second version of Digital's 16-bit UNIX[†] product. The first version was the V7M-11 V1.0 software. The ULTRIX-11 V2.0 software is enhanced in the following areas:

- New hardware support: J11 micro-processor, disks, tapes, and communications devices
- New software features: the C shell with job control, an in-kernel floating point simulator, and the Source Code Control System (SCCS)
- Performance improvements: disk partitioning, overlapped seeks, and mapped buffers
- Improved installation procedures: ease of installation, a system acceptance test
- Improved documentation

The ULTRIX-11 software product consists of the following: the ULTRIX-11 operating system and utility programs, several languages, program development tools, and complete documentation.

[†] UNIX is a trademark of AT&T Bell Laboratories.

The ULTRIX-11 operating system is an enhanced version of the V7M-11 V1.0 software, which is based on UNIX Time-Sharing System, Seventh Edition (V7). In addition, the ULTRIX-11 system includes numerous enhancements, bug fixes, and additional features.

The following documentation is supplied with the ULTRIX-11 software:

ULTRIX-11 Programmer's Manual, Volumes 1, 2A, and 2B
An Introduction to Display Editing with vi
An Introduction to the Source Code Control System
An Introduction to the C Shell
Screen Updating and Cursor Movement Optimization
ULTRIX-11 Programmer's Guide
ULTRIX-11 Software Technical Description
ULTRIX-11 Installation Guide
ULTRIX-11 System Management Guide

The ULTRIX-11 system runs on memory-managed PDP11 processors, supports a wide range of peripheral devices, and is fully supported by DIGITAL. This support includes the following: hardware maintenance by Digital Field Service, warranty, telephone support, product updates, a software dispatch, and software consultation for application development. You can install the ULTRIX-11 software yourself or you can purchase installation from Digital Software Services.

1.2 HOW IS THE ULTRIX-11 SOFTWARE DISTRIBUTED?

The ULTRIX-11 software is distributed on four types of media: magnetic tape, RL02 disk packs, RC25 disk cartridge, or RX50 5-inch floppy diskettes. Each distribution kit includes the set of manuals described in section 1.1. Each distribution kit supports a subset of the possible system disks. Use table 1.1 to match the type of load media with your system disk and select the appropriate distribution kit for your system.

TABLE 1.1

<u>Load Media</u>	<u>System Disks</u>
RX50	RD51/RD52
RL02	RL02
RC25	RC25
MAGNETIC TAPE	RL01/2 RC25 (fixed disk) RK06/7 RP02/3 RP04/5/6 RM02/3/5 RA60/RA80/RA81

1.2.1 Magnetic Tape Distribution

The magnetic tape distribution is available at 800 BPI for use with the TM11 and TM02/3 magnetic tape controllers, or at 1600 BPI for use with the TS11, TU80, TSV05, and TM03 controllers. The 1600 BPI distribution tape cannot be used with the TM02 tape controller due to the lack of the auto density select feature.

The distribution magnetic tape contains a boot program and other standalone programs, a dump/restore image of the ULTRIX-11 root file system and of the /usr file system, and the ULTRIX-11 OPTIONAL FILES in tape archive (tar) format.

The standalone programs load the ULTRIX-11 file systems onto the system disk for you. You use the tar command to load the OPTIONAL FILES as required. The root file system contains the ULTRIX-11 binaries. The /usr file system holds the following: user libraries, user binaries, UUCP, various administrative files, SCCS, Fortran 77, and software development tools. The OPTIONAL FILES include: the games programs (/usr/games), the on-line manuals (/usr/man) from the ULTRIX-11 Programmer's Manual, Volume 1, and the UNIX documents (/usr/doc) from the ULTRIX-11 Programmer's Manual, Volumes 2A and 2B.

1.2.2 RL02 Distribution

The RL02 distribution consists of a root and /usr disk pack, and an OPTIONAL FILES disk pack. The root and /usr disk contains the ULTRIX-11 root and /usr file systems and the standalone programs. The contents of these file systems are the same as the magnetic tape distribution. The OPTIONAL FILES disk contains: the games (/usr/games), on-line manual pages (/usr/man), and the UNIX documents (/usr/doc). To

facilitate loading, the OPTIONAL FILES are provided in both tar format and an ULTRIX-11 file system containing the files.

1.2.3 RC25 Distribution

The RC25 distribution consists of a single RC25 disk cartridge containing: the boot and standalone programs, the root and /usr file systems, and the optional files. The root and /usr file systems are the same as the magnetic tape distribution. The optional files are the same as the RL02 distribution, but are supplied in tar format only. You use the standalone programs to copy the RC25 distribution onto the RC25 fixed disk, which then becomes the system disk.

1.2.4 Micro/PDP-11 Distribution

To allow convenient loading on the Micro/PDP-11, the ULTRIX-11 distribution has been repackaged. The Micro/PDP-11 distribution consists of 30 RX50 5-inch floppy diskettes.

TABLE 1.2

Number of Diskettes -----	Contents -----
1	BOOT and standalone programs
6	ROOT file system
3	/USR file system
3	SYSGEN files
1	USEP
11	OPTIONAL SOFTWARE
1	GAMES
4	ON-LINE MANUALS

The standalone programs load the root and /usr file systems and the system generation files onto the RD51 or RD52 Winchester disk for you. These file systems contain only the basic ULTRIX-11 software, those files required to operate the system. You use the Optional Software Load command (OSLOAD) to load the items of optional software needed for your installation. This scheme allows you to optimize file storage on the Winchester disk.

The UNIX documents files (/usr/doc) are not supplied with the RX50 distribution. These documents are supplied in hardcopy. The documents files are available on RX50 diskettes by contacting the Digital Telephone Support Center.

1.3 HOW IS THE ULTRIX-11 SOFTWARE LICENSED?

The ULTRIX-11 software is licensed for use on a single CPU according to the number of users. You obtain this single use binary license directly from DIGITAL. No other licenses

are required. There are two classes of licenses: for 1-16 users and for 1-32 users. The 16-user license is available on magnetic tape, RL02, RC25, and RX50 media. The 32-user license is available on magnetic tape only. The 16-user license cannot be upgraded to 32 users. Refer to the ULTRIX-11 Software Product Description for ordering and licensing information.

For licensing purposes, a user is defined as any terminal that is available for user logins, that is, has a login process running. This lets you connect as many communications ports to the system as the hardware can support, with the restriction that only 16 (or 32) of those ports may be available for users to log in. Printer ports and dialout lines do not count as users. This is an important difference between the ULTRIX-11 software and V7M-11, which controlled the number of users by limiting the number of communications ports.

2.0 HARDWARE REQUIREMENTS

The ULTRIX-11 software supports a wide range of PDP-11 processors and peripherals. The information in this section should be used to verify that the customer's existing or proposed hardware configuration is supported by the ULTRIX-11 software.

2.1 ULTRIX-11 SUPPORTED HARDWARE

The following tables list the processors, peripherals, and the degree of ULTRIX-11 support. The processors are separated into two groups: processors with separate Instruction and Data space and processors without separate Instruction and Data space. This division is done mostly for convenience, although it reflects the two versions of the ULTRIX-11 kernel.

The separate I and D space kernel for the larger processors is listed in Table 2.1, and the overlay kernel used with the smaller processors is listed in Table 2.2.

Use this key to read the tables:

Key:

- F Fully supported device. When pertaining to disks, this indicates the disk can be the system disk. Regarding magnetic tapes, it can be the distribution load device.
- S Supported as a user device only. When pertaining to disks, this indicates the disk cannot be the system disk, but can be used for user file storage. Regarding magnetic tapes, it cannot be the distribution load device, because this device cannot handle full size reels.
- O Obsolete device. A driver is provided, but the device is not supported. Digital does not recommend use of this device. Digital provides no warranty, and does not accept SPRs for this device.
- N Not supported.

Table 2.1
ULTRIX-11 Hardware Support on Separate I & D Processors

Processor		11/44	11/45	11/55	11/70	11/73 *11
Memory	*1	256KB	256KB	256KB	256KB	256KB
Clocks:						
KW11-L	*2	F	F	F	F	F *10
KW11-P		F	F	F	F	N
Floating Point	*15	FP11F	FP11B FP11C	FP11B FP11C	FP11C FP11B	*16
Console Terminal		*3	*3	*3	*3	*3
Disk Drives:						
RK05		S	S	S	S	N
RL01/2	*13	F	F	F	F	F
RX50		S	S	S	S	S
RD51/RD52		N	N	N	N	F
RC25		F	F	F	F	F
RK06/7		F	F	F	F	N
RM02		F	F	F	F *4	N
RM03/5		N	N	N	F	N
RP02/3		F	F	F	F *4	N
RP04/5/6		F	F	F	F	N
RA60		F	F	F	F	N
RA80/RA81		F	F	F	F	N
RX02	*12	S	S	S	S	S
ML11		S	S	S	S	N
RS03/4		O	O	O	O	N
Tape Drives:						
TM11-TS03		S	S	S	S *4	N
TM11-TU10/TE10		F	F	F	F *4	N
TS11	*5	F	F	F	F	N
TU80	*5	F	F	F	F	N
TSV05	*5	N	N	N	N	F
TK25	*5	N	N	N	N	S
TM02/3-TU77		F	F	F	F	N
TM02/3-TU16/TE16		F	F	F	F	N
TC11-TU56		N	N	N	N	N

Table 2.1
 ULTRIX-11 Hardware Support on Separate I & D Processors
 (Continued)

Line Printers:

LP11	*14	F	F	F	F	N
Printer port	*17	F	F	F	F	F

Communication Devices:

DL11	*6	F	F	F	F	F
DZ11		F	F	F	F	N
DZV11/DZQ11		N	N	N	N	F
DH11		F	F	F	F	N
DM-11BB	*7	F	F	F	F	N
DHV11		N	N	N	N	F
DHU11		F	F	F	F	N
DN11		O	O	O	O	N
DU11		O	O	O	O	N

SECTION 2

Table 2.2
ULTRIX-11 Hardware Support on Non-Separate I & D Processors

Processor		M11 *8	11/23+ *9	11/24	11/34	11/40	11/60
Memory	*1	256KB	256KB	256KB	256KB	256KB	256KB
Clocks:							
KW11-L	*2	*10	*10	F	F	F	F
KW11-P		N	N	F	F	F	F
Floating Point	*15	KEF11 FPF11	KEF11 FPF11	KEF11 FPF11	FP11A	None	FP11E
Console Terminal		*3	*3	*3	*3	*3	*3
Disk Drives:							
RK05		N	N	S	S	S	S
RL01/2	*13	F	F	F	F	F	F
RX50		S	S	S	S	S	S
RD51/RD52		F	F	N	N	N	N
RC25		F	F	F	F	F	F
RK06/7		N	N	F	F	F	F
RM02		N	N	F	F	F	F
RM03/5		N	N	N	N	N	N
RP02/3		N	N	F	F	F	F
RP04/5/6		N	N	F	F	F	F
RA60		N	N	F	F	F	F
RA80/81		N	N	F	F	F	F
RX02	*12	S	S	S	S	S	S
ML11		N	N	S	S	S	S
RS03/4		N	N	O	O	O	O
Tape Drives:							
TM11-TS03		N	N	S	S	S	S
TM11-TU10/TE10		N	N	F	F	F	F
TS11	*5	N	N	F	F	F	F
TU80	*5	N	N	F	F	F	F
TSV05	*5	F	F	N	N	N	N
TK25	*5	S	S	N	N	N	N
TM02/3-TU77		N	N	F	F	F	F
TM02/3-TU16/TE16		N	N	F	F	F	F
TC11-TU56		N	N	N	N	N	N

Table 2.2
 ULTRIX-11 Hardware Support on Non-Separate I & D Processors
 (Continued)

Line Printers:

LP11	*14	N	N	F	F	F	F
Printer Port	*17	F	F	F	F	F	F

Communications Devices:

DL11	*6	F	F	F	F	F	F
DZ11		N	N	F	F	F	F
DZV11/DZQ11		F	F	N	N	N	N
DH11		N	N	F	F	F	F
DM11-BB	*7	N	N	F	F	F	F
DHV11		F	F	N	N	N	N
DHU11		N	N	F	F	F	F
DN11		N	N	O	O	O	O
DU11		N	N	O	O	O	O

Notes:

- *1 The ULTRIX-11 operating system will operate with a minimum of 192KB of memory. However, 256KB is the practical minimum memory size. Some large programs, such as vi and f77, may not run on 192KB systems. The ULTRIX-11 operating system supports up to 3.75MB (4MB - I/O page) of main memory. A minimum of 512 KB of memory is required to take full advantage of the mapped buffer feature (average 15% system performance improvement).
- *2 The DL11-W includes a KW11-L clock.
- *3 You can use most terminals as the system console, but a terminal that can produce hard copy output is recommended. You cannot use upper case only terminals as the console terminal. If you use LA120 as the system console, you should disable the auto disconnect feature.
- *4 These devices are not normally configured on the PDP11/70.
- *5 Only a single TS11/TU80/TSV05/TK25 tape drive is supported.
- *6 DL11 includes all versions of the DL11 used as single line units. It also includes the DLV11 on Q bus processors, and the second single line unit supplied with the Micro/PDP-11, PDP11-23, PDP11/23 PLUS, PDP11/24 and PDP11/44.
- *7 Modem control option for the DH11.
- *8 M11 is short for the KDF11-B version of the Micro/PDP-11. This is a PDP11/23 PLUS processor.
- *9 This column applies to the PDP11/23 as well as the PDP11/23 PLUS.
- *10 The system must have a 60 HZ clock that can be enabled/disabled via bit six of the CLOCK CSR at address 777546. The Micro/PDP-11 and PDP11/73 processors include the 60 HZ clock.
- *11 PDP11/73 refers to the KDJ11-A micro-processor module and Micro PDP11/73 system (KDJ11-B), used in Q bus systems. If the KDJ11-A is used to replace a PDP11/23 PLUS, such as the Micro/PDP-11, a multifunction module containing a bootstrap must also be provided. The single line unit for the system console must also be provided. The MXV11-BF multifunction module may be used, but it is not recommended because its on-board memory

is non-parity memory.

- *12 One dual RX02 drive is supported, 18 bit addressing only. On Q22 bus processors, the RX02 can only be accessed via the ULTRIX-11 buffered I/O mechanism. The physical (RAW) I/O system cannot be used to access the RX02.
- *13 For the RL01, two drives are required. For the RL02, two drives are recommended.
- *14 The LP11 line printer driver supports only a single unit.
- *15 The ULTRIX-11 operating system kernel floating point simulator allows programs that execute floating point instructions to run on processors without floating point hardware. However, floating point hardware is highly recommended for intensive floating point applications and/or where performance is a factor.
- *16 The PDP11/73 (KDJ11-A) includes the floating point instruction set in the micro-code. Do not use the KEF11 or FPF11.
- *17 Printer port refers to a printer, such as the LA120, LA100, or LA50 connected to a port on one of the supported communications devices.

2.2 ULTRIX-11 NON-SUPPORTED HARDWARE

UNIX Seventh Edition (V7) contains full or partial support for several hardware devices that the ULTRIX-11 software does not support. The ULTRIX-11 software does not support these devices because there is no device driver, the device is obsolete, or device support cannot be verified.

The ULTRIX-11 software does not support the following devices:

CR11, DJ11, PC11, DC11, RF11, TC11

- No ULTRIX-11 device drivers are available for these devices.

DN11, DU11, RS03/4

- The V7 drivers for these devices have been updated to function with the ULTRIX-11 operating system kernel. However, these devices are not supported by DIGITAL and their use is not recommended.

C/A/T Phototypesetter Interface (DR11-C driver)

- This device operates on non-DIGITAL supplied hardware and is not supported. The V7 C/A/T driver has been updated to function with the ULTRIX-11 operating system kernel. The ULTRIX-11 kernel supports the C/A/T (DR11-C) driver only to the extent that it delivers characters written to the file /dev/cat to the output cable of the DR11-C. Actual connection and operation of the phototypesetter is the customer's responsibility.

2.3 MINIMUM HARDWARE CONFIGURATION

The ULTRIX-11 software requires a minimum hardware configuration consisting of a processor, clock, memory, disk, and in some configurations, a magnetic tape. Use the following guidelines to ensure that ULTRIX-11 software supports your proposed or existing hardware configuration.

- Processor

Refer to Table 2.1 and Table 2.2 to verify if the ULTRIX-11 software supports the processor, the processor has sufficient memory, and has a clock. The processor must have memory management.

- Disk

The configuration must include at least one of the

fully supported disks from Table 1.1 or Table 1.2. The ULTRIX-11 software requires two drives if the system disk is an RL01. When the entire ULTRIX-11 distribution is loaded, it nearly fills two RL01 disk packs, one RL02 disk pack, or one RK06 disk pack. Although you can salvage some disk space by not loading unnecessary files (such as the documents and games programs), the amount of user file space is severely limited. For the RL01 disk, DIGITAL recommends three drives. For the RL02 and RK06 disks, DIGITAL recommends two drives.

- **Magnetic tape**

The configuration should include one of the fully supported magnetic tapes from Table 1.1 or Table 1.2. The type of magnetic tape controller dictates the density of the ULTRIX-11 distribution tape: 800 BPI for the TM11 and TM02/3, or 1600 BPI for the TS11, TSV05, TU80, and TM03 (not TM02).

- **Communications**

The configuration should include a communications interface with enough lines to support the maximum number of simultaneous users on the system.

2.4 OPTIONAL EQUIPMENT

The following guidelines can be useful in selecting optional equipment.

- **Cache Memory**

Cache memory is desirable to improve processor performance. The PDP11/44, PDP11/60, PDP11/70, and PDP11/73 processors are equipped with cache memories; the remaining processors are not. The PDP11/34 has an optional KK11-A cache.

- **Floating Point Processor**

The ULTRIX-11 kernel does not require or use floating point. However, some system commands, such as iostat, accounting, and the debugger, do use floating point. The floating point hardware requirement depends on the amount of floating point operations the user's programs execute, and the performance requirements of those programs.

An optional floating point simulator can be configured into the ULTRIX-11 kernel. This simulator allows programs that require floating point support to run on a processor without floating point hardware. The performance of the simulator should be sufficient for the

ULTRIX-11 utility programs. The simulator performance for user programs is application dependent. For floating point intensive applications DIGITAL recommends the floating point hardware.

The Micro/PDP-11, PDP11/23, and PDP11/24 processors have two floating point options: The KEF11-AA (a floating point chip installed to the processor module), and the FPF11 (a floating point processor on a separate module). The FPF11 is the faster option.

- Disks

There are several factors you should consider when determining how many disk drives your system requires. These include the number of users, the number and size of their files, and any data base requirements (the amount of required disk capacity). Multiple disk drives are convenient for copying disks, and are mandatory for file system backups when the configuration does not include a magnetic tape. If you require very high availability, multiple disk drives should be considered, because disks are the most likely system component to fail. Multiple drive systems usually continue to operate when one disk fails.

- Magnetic tape

DIGITAL recommends your hardware configuration include a magnetic tape for file system backup and restore operations, receiving ULTRIX-11 software updates, and information interchange with the UNIX software user community. Multiple tape drives are generally not necessary, unless you need to copy magnetic tapes directly.

- Line Printer

The need for a line printer depends on the type of work to be done on the system, and is an optional feature.

- Communications Devices

You can include additional communications interfaces in the hardware configuration. However, you must consider the following limiting factor: the number of terminals available for logins is limited to the 16 or 32 users specified in the ULTRIX-11 software license. For example, if you purchase a 16-user ULTRIX-11 sublicense, up to 16 communications ports can have a login process running. The ULTRIX-11 operating system enforces this restriction. Communications ports used to drive printers and UUCP/TIP dialout lines do not count as users.

2.5 CONFIGURING FOR THE NUMBER OF USERS TO BE SUPPORTED

The 16 or 32 user limit in the ULTRIX-11 license agreements is for licensing purposes only. The actual number of users depends on the hardware configuration and other factors. The following descriptions define the number of simultaneous interactive users a ULTRIX-11 system can support on various hardware configurations.

For this discussion, a user is an ULTRIX-11 program development job mix, such as edits, compiles, debugging, and nroff text processing. The number of users ULTRIX-11 supports depends on the hardware configuration and the type of work the users are performing. If every user is editing, the number increases; if the users are all running nroff, the number decreases. Response time requirements also affect the number of users.

- Micro/PDP-11 (11/23+ processor)

The Micro/PDP-11 with the 11/23+ processor and 256KB of memory supports two users; with 512KB of memory, it supports four users. Increasing the Micro/PDP-11 memory size beyond 512KB is beneficial when users are running either a large number of subprocesses or very large subprocesses.

User file storage space on the RD51 (10 megabyte) disk is limited. For two or more users, DIGITAL recommends the RD52 (30 megabyte) disk or a second RD51 disk.

- Micro/PDP-11 (11/73 processor)

The Micro/PDP-11 with the 11/73 processor and 256KB of memory supports three users; with 512KB of memory it supports six users. With an RD52 disk and 512KB of memory, the Micro/PDP-11/73 supports up to eight users. Increasing the memory size improves the system's performance. The Micro/PDP-11/73 with an RC25 as the system disk and one megabyte of memory supports up to 16 users.

User file storage space on the RD51 (10 megabyte) disk is limited. For two or more users, DIGITAL recommends the RD52 (30 megabyte) disk or a second RD51 disk. For eight or more users, DIGITAL recommends the RC25 (dual 26 megabyte) disk.

- PDP11/23, PDP11/23+, and PDP11/24

Any of these processors configured with dual RL02 disks and 256KB of memory can support two users. With 512KB of memory, these processors support up to four users.

- PDP11/34 and PDP11/40

The PDP11/40 with 256KB of memory supports from four to six users, depending on the type of disks used. The PDP11/34 with 256KB of memory supports four users with dual RL02 disks, six users with dual RK07 disks, or eight users with an RM02 or RP04/5/6 disk. Adding the KK11-A cache memory to the PDP11/34 improves system performance and increases the number of users.

- PDP11/60

The PDP11/60 with 256KB of memory supports six users with dual RL02 disks, eight users with dual RK07 disks, and ten users with an RM02 or RP04/5/6 disk.

- PDP11/44

The PDP11/44 with 256KB of memory and dual RL02 disks supports five users, and with 512KB of memory it supports seven users. The PDP11/44 with 512KB of memory and dual RK07 disks supports up to 10 users. The PDP11/44 with 768KB of memory and an RM02 or RP04/5/6 disk supports 14 users.

- PDP11/45 and PDP11/55

Either processor with 256KB of memory can support 10 users with dual RK07 disks, or 16 users with RM02 or RP04/5/6 disk.

- PDP11/70

The PDP11/70 with 512KB of memory and a single RM03/5 or RP04/5/6 supports 20 users. A fully configured PDP11/70 with additional memory and disk drives supports 30 users.

Performance Improvements

Performance deteriorates as the amount of swapping increases. You can increase system performance by adding more memory to reduce swapping. Using a fast disk such as the ML11 for the swap device also increases performance. Locating the root, swap, and /tmp file systems on separate disk controllers improves system I/O throughput. Placing the /tmp file system on a fast disk improves the performance of the C compiler and nroff.

2.6 DEVICE ADDRESS/VECTOR ASSIGNMENTS

The system clock, disk, magnetic tape, and console terminal must be configured for the standard address and vector assignments. Since DIGITAL ships all systems with these

devices at the standard address and vector, this should not concern the customer. You can configure other devices, such as communications interfaces and secondary disks, to any desired address and vector. You can change the device address and vector assignments at system generation time. However, for communications interfaces, you must sequentially address and vector multiple units of the same type. Table 2.3 shows the addressing of three DH11 units, each with modem control:

TABLE 2.3

Device	Unit	Address	Vector
DM11-BB	0	770500	300
	1	770510	304
	2	770520	310
DH11	0	760020	320
	1	760040	330
	2	760060	340

These devices normally follow DIGITAL's floating address and vector rules, which are fully supported by the ULTRIX-11 software. If you configure multiple DH11 interfaces and not every DH11 unit has modem control, you should address the units with modem control first, followed by the units without modem control. This lets the DH11 device driver correctly associate each DH11 unit with its modem control unit.

If the system has multiple MSCP disk controllers (UDA50, KLESI, RQDX1, RUX1), only one of them will be at the standard address of 172150. You can use the ULTRIX-11 boot program's CSR command to enter the CSR address if the system disk controller is not at the standard address. This lets you install the ULTRIX-11 software on an MSCP disk that is not at the standard address. DIGITAL recommends that the system disk controller be at the standard address for more convenient bootstrap operation.

3.0 DISK MEDIA REQUIREMENTS

Traditionally, UNIX operating systems require all disk media to be completely free of hard errors. Soft errors were tolerated in most cases. The ULTRIX-11 software supports the DIGITAL standard bad block replacement strategy for most of the larger disks. In most cases, this eliminates the requirement for error free media. The following paragraphs define the ULTRIX-11 disk media requirements:

- RK05, RL01, RL02, RX02, and RX50

The ULTRIX-11 software does not support bad block replacement for these disks, so the media must be free of bad blocks. The RK05, RX02, and RX50 disks are small enough to usually be free of bad blocks. DIGITAL recommends using the RL01-EF and RL02-EF (hard error free disk packs) for the RL01/2 disk drives.

- RD51 and RD52

The controller for these disks implements controller initiated bad block replacement. The controller automatically detects bad blocks and reverts each bad block to a replacement block. This makes the disk media appear to be error free to the operating system.

- RP02 and RP03

The ULTRIX-11 software does not support bad block replacement for these disks. The media must be hard error free. The RP03-PX disk pack meets this requirement.

- RK06/7, RM02/3/5, and RP04/5/6

The ULTRIX-11 software fully supports bad block replacement for these disks, so the media need not be hard error free. However, the number and location of bad blocks can adversely affect system performance. The ULTRIX-11 software includes standalone programs which format and surface verify these disk packs. These standalone programs aid in determining the affect of any bad blocks on system performance. Refer to section 4.8, Disk Bad Block Replacement, for more information.

- RC25, RA60, RA80, and RA81

These disks contain a factory initialized bad block replacement file to make the media appear error free to the operating system. These disks also use an error correction mechanism to enable the operating system to warn the system manager a disk block is going bad before it becomes unreadable.

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The controllers for these disks implement cooperative bad block replacement. The software and the hardware cooperate to replace bad blocks. The ULTRIX-11 system includes programs that initialize the disk during installation to ensure that all bad blocks have been replaced and lets the system manager replace any bad blocks that occur during normal system operation.

4.0 ULTRIX-11 SOFTWARE FUNCTIONAL DESCRIPTION

The ULTRIX-11 software is the second release of V7M-11, which is based on the UNIX Time-Sharing System, Seventh Edition (V7) and includes most features of that software. Refer to the attached Summary for a description of those V7 features. The following functional description covers only the enhancements that distinguish the ULTRIX-11 software from V7, and the V7M-11 V1.0 software.

4.1 THE ULTRIX-11 SOFTWARE IS CUSTOMER INSTALLABLE

ULTRIX-11 design, packaging, and documentation allow it to be installed by any customer with a basic knowledge of computer systems. The ULTRIX-11 software is designed to be completely field reconfigurable from binaries. It requires no source code files to regenerate the operating system. The ULTRIX-11 documentation describes the procedures to configure a system to run the software, install the software in the system, and manage the system after the ULTRIX-11 software becomes operational.

One of the major improvements in the ULTRIX-11 software compared to V7M-11 is the automated system installation and initial setup. The ULTRIX-11 software installation is automated by two interactive programs: system disk load (SDLOAD) and initial setup (SETUP). The SDLOAD program is used only with the magnetic tape and RX50 distributions. The RL02 and RC25 distributions come with the software already loaded.

To install the software, you boot the distribution media, answer questions about the system configuration, then the autoinstall programs take over and install the ULTRIX-11 software. After the autoinstall completes, you generate a new ULTRIX-11 kernel to match your hardware configuration and setup user accounts.

You use the ULTRIX-11 System Acceptance Test (USAT) and the User-mode System Exerciser Package (USEP) to verify whether the system hardware and the ULTRIX-11 software are functioning properly.

4.2 ULTRIX-11 SYSTEM ACCEPTANCE TEST (USAT)

The ULTRIX-11 System Acceptance Test verifies that the operating system and its major subsystems are functioning properly. USAT performs the following tests:

- "AWK TEST" The awk test is a short script which generates a table of temperature conversions. Temperatures for Celsius, Fahrenheit, and Kelvin are computed for the Kelvin temperature range 0 to 500 degrees, in 5-degree Kelvin increments. The resulting table, 100

lines long by 3 columns wide, is compared with a file containing a known, correct temperature table. The test fails if the temperature tables do not match.

- "BC TEST" The bc test calculates the value of e, the base of natural logarithms, to 50 decimal places. The resulting output is compared with the known, correct value of e. The test fails if the two values do not match.
- "DC TEST" The dc test generates a list of temperatures. Celsius, Fahrenheit, and Kelvin temperatures are printed for temperatures ranging from 5 to 400 degrees Kelvin, in 5-degree Kelvin increments. This file of temperatures is 240 lines long, one temperature per line. The test output is compared with a file containing a known, correct version of the temperature list. The test fails if the temperature lists do not match.
- "C COMPILER TEST" The C compiler test compiles a C program using the cc flags -s -O, which generates a table of temperature conversions. Temperatures for Celsius, Fahrenheit, and Kelvin are computed for the Kelvin temperature range 0 to 500 degrees, in 5 degree Kelvin increments. The resulting table, 100 lines long by 3 columns wide, is compared with a file containing a known, correct temperature table. The test fails if the temperature tables do not match.
- "DOC PREP TEST" The document preparation test runs a variety of editing commands. The test procedure uses copy, ed, diff, spell, nroff, grep and ex on various files.

Initially, a 300-line file containing 5541 bytes of text is copied using cp. The text editor ed then is invoked, and the word 'newproc' is substituted for the word 'proc' throughout the file (20 substitutions). A comparison is made between this file and the original version using the diff command. The output is compared with a file containing the known, correct differences between the two files.

Spell is run on the file, and the output is compared with a file containing the known, correct spell list. The file is sent through nroff, and the output is compared with a file containing a known, correct nroff output. Grep -v is used to redirect all lines not containing the word "Printed" in them. Finally, the editor ex is invoked, and 'newproc' is substituted for 'proc' throughout the file (20 substitutions). The document preparation test fails if any of the test commands fail.

- "F77 COMPILER TEST" The Fortran test compiles a Fortran program using the F77 compiler, which generates a table of temperatures. Celsius, Fahrenheit and Kelvin temperatures are printed for the Kelvin temperature range 0 to 500 degrees, in 5-degree Kelvin increments. The resulting 100-line table of temperatures is compared with a file containing a known, correct version of the output. The test fails if the temperature tables do not match.
- "LEARN TEST" The learn test simulates a learn session in order to verify that learn is functional. Learn is run starting with lesson 5.1a (the section on files) and continues for six lessons (up to lesson 6.2a). The output from a prearranged list of responses is compared with a file containing the known, correct responses given by learn. The test fails if the output files do not match.
- "LEX TEST" The lex test is a short test to insure that lex is functioning. A lex script compresses multiple blanks and converts uppercase input to lowercase. The input file is the output generated by a ps -alx command. The lex-generated C program is compiled and executed using the prearranged input file. Output is compared with a file containing the known, correct output. The test fails if the output files do not match.
- "LINT TEST" Lint is run on a file containing known lint errors, and the output is compared with a known, correct lint-generated error list. If the two error lists do not match, the test fails and an error message is printed.
- "PCC TEST" The pcc test is a test of the Portable C compiler. A program, which generates a table of temperatures, is compiled using pcc and then executed. Celsius, Fahrenheit, and Kelvin temperatures are printed for the Kelvin temperature range 0 to 500 degrees, in 5-degree Kelvin increments. The resulting 100 line table of temperatures is compared with a file containing a known, correct version of the output. The test fails if the temperature tables do not match.
- "SED TEST" The sed test runs sed (stream editor) on a short file. The input file is a listing generated by a ps -alx command. Blanks, as well as the digits 0 and 1, are replaced with <null> characters throughout the file (814 substitutions). The output file then is compared with a file containing the known, correct output. The sed test fails if the two output files do not match.
- "YACC TEST" The yacc test generates a table of

temperature conversions. Celsius, Fahrenheit, and Kelvin temperatures are printed for the Kelvin temperature range 0 to 500 degrees, in 5-degree Kelvin increments. The resulting 100-line table of temperatures is compared with a file containing a known, correct version of the output. The test fails if the temperature tables do not match.

- "SYSTEM STATS" This test checks such things as memory usage, process status, and free disk space. The commands included are: who, ps, pstat, memstat, bufstat, iostat, and df. The output is sent to a logfile which is printed following the completion of the entire usat test script.

4.3 AUTOMATED SYSTEM GENERATION

ULTRIX-11 system generation is accomplished with an interactive program called SYSGEN. The SYSGEN program automates system generation by:

- Prompting for information about the configuration
- Creating a file describing the configuration
- Making the ULTRIX-11 kernel based on that file
- Guiding the customer through the installation of the new ULTRIX-11 kernel.

The SYSGEN program can also list, print, and remove configuration files and can print a list of the devices supported by ULTRIX-11, along with their ULTRIX-11 device mnemonics. The SYSGEN program includes extensive on-line help messages to guide the customer through the system generation process.

4.4 SYSTEM TUNING

The ULTRIX-11 software uses a set of parameters to define the size of the disk I/O buffer cache and other kernel internal data structures, such as the process and inode tables. You can change the values of these parameters at system generation time without recompiling any source code modules. The SYSGEN program contains default values for these parameters, or you can specify a value for any or all of the parameters at system generation time. The parameter values become part of the system configuration file.

4.5 PROCESSOR AND PERIPHERAL DEVICE SUPPORT

Because the ULTRIX-11 software supports a very wide range of processors and peripheral devices, you can tailor the system hardware configuration to match an application closely. See

Table 2.1 and Table 2.2 for a detailed listing of all supported hardware. The ULTRIX-11 software also supports the DIGITAL Storage Architecture (DSA) disks which use the Mass Storage Control Protocol (MSCP). This architecture allows new DSA disks to be supported with only minimal changes to the software device driver.

4.6 Vi Editor

The ULTRIX-11 system includes version 3.7 of the vi screen editor from the University of California at Berkeley, 4.1 Berkeley Software Distribution. Under the ULTRIX-11 software, the vi editor runs on any supported processor. The LISP code has been removed from the vi editor and is not supported. The ULTRIX-11 version of vi supports the TAGS feature, which was not supported by vi under V7M-11.

4.7 TERMINAL ENABLING EDITOR (TED)

The TED command lets you enable terminals and set terminal characteristics without knowing how to use a text editor. Previously, enabling terminals required editing files and possibly sending a signal to the init process. The TED command has safeguards against such errors as disabling the user's current login terminal and creating multiple entries for the same terminal.

4.8 OVERLAID TEXT KERNELS

Due to the size of the kernel, V7 only supports processors with separate Instruction and Data space. The kernel consists of two major segments, the text segment and the data segment. The text segment contains the PDP-11 instructions executed when the kernel is running. The data segment consists of the data structures the PDP-11 instructions reference.

If the processor has the separate I and D space feature, the memory management hardware maps the text and data segments separately. A processor without separate I and D space maps the text and data as a single segment, thus limiting the size of the kernel. For processors with separate I and D space, the kernel can be as large as 64KB of text and 48KB of data. For processors without separate I and D space, the size of the kernel is limited to a total of 48KB.

The V7 kernel can be forced to fit into the 48KB of address space available on processors without separate I and D space. However, this leaves no space available to support any users. To resolve this, the ULTRIX-11 system uses the text overlay kernel with mapped buffers. The overlay kernel is implemented with memory resident overlays which use dynamic remapping of the kernel text space. The overlay kernel also maps the disk I/O buffer cache outside kernel

address space.

The text overlay and mapped buffer schemes lets the ULTRIX-11 software support any reasonable hardware configuration on processors without separate I and D space. V7M-11 used a separate I and D space version of the kernel for processors with this feature. The ULTRIX-11 software also uses a separate I and D space kernel, but with text overlays and mapped buffers. This allows for even larger kernels on separate I and D processors.

4.9 OVERLAID TEXT USER PROCESSES

The lack of separate Instruction and Data space imposes a 64KB size limit on user processes. This size limitation would prevent several of the larger user programs such as vi, f77, awk, lex, and others, from executing on processors without separate I and D space. The ULTRIX-11 software has a user overlay mechanism to allow these programs to run without separate I and D space. For extremely large programs like the vi editor, the ULTRIX-11 software employs user overlays on processors with separated I and D space.

You can apply this overlay scheme to customer generated applications. The generation of overlaid user processes is fully documented. The ULTRIX-11 V2.0 software makes the user program overlay mechanism easier to use, and this is further enhanced by improved documentation.

4.10 SYSTEM PERFORMANCE IMPROVEMENTS

The ULTRIX-11 software includes performance improvements over V7M-11. The RL02 and RD51/RD52 disk drivers have been partitioned to reduce seek time to the swap area. Queue sorting and overlapped seeks have been added to the RL02 driver. On systems with a memory size of 512Kb or larger, an average 15% increase in overall system performance is achieved by the use of an improved disk I/O buffer caching scheme and mapped buffers. These features are based on the University of California at Berkeley 2.9 BSD software.

4.11 GENERAL DISK DRIVERS

The V7M-11 software required a separate copy of the disk driver for each disk controller. The ULTRIX-11 software has two general disk drivers. The HP driver supports up to three MASSBUS disk controllers. The RA driver supports up to three Mass Storage Control Protocol (MSCP) disk controllers. The general disk drivers allow support of multiple disk controllers without the overhead of multiple copies of the disk driver.

The MASSBUS controllers are:

RH11 - up to eight drives (RM02, RP04, RP05, RP06, ML11).
 RH70 - up to eight drives (RM02, RM03, RM05, RP04, RP05,
 RP06, ML11).

The MSCP controllers are:

UDA50 - up to four drives (RA60, RA80, RA81).
 KLESI - up to two RC25 units (2 drives per RC25 unit).
 RQDX1 - up to four drives (RX50, RD51, RD52).
 RUX1 - up to four drives (RX50).

The general MSCP disk driver supports three controllers, but only one of each type; that is, only one UDA50, KLESI, RQDX1, or RUX1.

4.12 DISK BAD BLOCK REPLACEMENT

The ULTRIX-11 system uses a bad block replacement strategy for the larger disks. Refer to section 3.0, Disk Media Requirements, for a description of the disk types supported by bad block replacement. The ULTRIX-11 bad block replacement software includes three standalone programs: the quick bad block scan program (bads), the MSCP disk initialization program (rabads), and the (dskinit) program for initializing non-MSCP disks supported by the bad block replacement software.

You use the bads program to scan the disk media quickly and identify any existing bad blocks, or to print the contents of the factory recorded bad block file.

You use the dskinit program to format the disk media and perform a complete surface verification with multiple test data patterns. The dskinit program also adds any bad blocks to the factory-recorded bad block file, or creates the bad block file if it does not already exist.

You use the rabads program to initialize the MSCP disks to insure that all bad blocks have been replaced before the software is installed. You also use rabads to replace dynamic bad blocks, blocks that go bad during normal system operations.

The ULTRIX-11 disk drivers are modified to read the bad block file and automatically replace any bad block. This bad block replacement is transparent to the operating system and the users. For the MSCP disks, the hardware does the bad block revectoring instead of the software driver.

Bad blocks in frequently-accessed areas of the ULTRIX-11 file system (such as the I-list and swap area), can have a negative impact on system performance. That is, each bad

block replacement operation involves a seek to the end of the disk to access the replacement block. ULTRIX-11 bad blocking includes a bad block status command (badstat) to monitor and display the number of replacements performed on each bad block. This command also lets the system manager assess the effect of bad block replacements on system performance.

4.13 UNIBUS MAP ALLOCATION

The V7 kernel allocates the entire UNIBUS map for each I/O transfer. This allows only a single device to use the map at any one time. The ULTRIX-11 system uses a more efficient UNIBUS map allocation algorithm, allowing several devices to use the map concurrently. This increases the amount of UNIBUS device I/O overlap and, therefore, system I/O throughput. This change is required when using fully buffered disk controllers such as the UDA50.

4.14 ASSIGNABLE TTY STRUCTURES

V7M-11 used assignable TTY structures to limit the number of active users to the number specified in the binary sublicense agreement. The ULTRIX-11 software employs a less restrictive method of enforcing the number of users limit. The ULTRIX-11 software assigns TTY structures automatically. The user no longer needs to be concerned about TTY structure assignments.

4.15 TTY CONTROL CHARACTERS AND TERMINAL DRIVER

DIGITAL has modified the ULTRIX-11 TTY driver to allow setting the terminal control characters with the stty command. This can improve erase and kill processing for video terminals. If desired, you use the stty command to set the standard control characters. The default control characters are now <CTRL/C> for interrupt, <DELETE> for erase, and <CTRL/U> for kill.

The ULTRIX-11 system lets you select either the standard V7 terminal driver or the new terminal driver, on a per user basis. The new terminal driver is the University of California at Berkeley 2.9 BSD terminal driver, used with the C shell and job control software.

The ULTRIX-11 software includes the getty table (/etc/gettytab) and terminal capabilities data base (/etc/termcap) from the University of California at Berkeley 2.9 software. These features allow the system to accommodate the characteristics of a wide variety of different terminal types.

4.16 LPR - LINE PRINTER SPOOLER

The ULTRIX-11 software includes an improved line printer spooler. The spooler includes the printer capabilities file (/etc/printcap) from the University of California at Berkeley 2.9 BSD software. The /etc/printcap file lets you specify the characteristics of multiple printers from a single control file. The spooler supports one printer on an LP11 parallel interface and additional printers on communications ports (DH11, DZ11, etc.). The spooler includes commands to show the line printer queue and delete jobs from the line printer queue.

4.17 C SHELL WITH JOB CONTROL

The ULTRIX-11 software includes the C shell with job control from the University of California at Berkeley 2.9 BSD software. The C shell is a command language interpreter with C-like syntax and a command history mechanism. The C shell also supports Bourne shell commands and syntax. The job control facility allows users to suspend processes, place them in the background or foreground, and monitor their status.

4.18 SPECIAL FILES

The operating system requires some special files in order to access devices. For V7, you must create these file individually using the mknod command. The RP06 disk requires 16 of these special files for each drive. The msf (Make Special Files) command has been added to the ULTRIX-11 software to allow creation of all the special files for a device with a single command.

4.19 FILE SYSTEM TABLE

The ULTRIX-11 software includes a file system table (/etc/fstab) containing the names of the system and user file systems and the directory names where the system and user file systems are mounted. All system commands requiring file system names as input have been modified to use the names in fstab as the default file system names. These commands include fsck, df, quot, mount, and umount. Also, the -a option is added to the mount and umount commands to allow mounting and dismounting all file systems with a single command.

4.20 USER-MODE SYSTEM EXERCISER PACKAGE (USEP)

The User-mode System Exerciser Package (USEP) consists of a collection of user-mode exerciser modules to exercise the hardware using the ULTRIX-11 operating system. There are USEP modules for the processor, memory, floating point, disks, magnetic tapes, communications interfaces, and the

line printer. USEP runs under the control of the System Exerciser Control Program (sysx). The system manager uses sysx to create an exerciser script file, start and stop the exercisers, and monitor USEP while it is running.

The DIGITAL Field Service engineer can load ULTRIX-11 and USEP from a magnetic tape onto a scratch disk and analyze hardware failures using an operating system identical to the one normally used by the customer on that hardware.

The ULTRIX-11 software includes an enhanced USEP that exercises the new hardware supported by the ULTRIX-11 operating system. The sysx program has been enhanced to provide better control of the exerciser programs and improved help messages.

4.21 ERROR LOGGING

The ULTRIX-11 error logger collects information about system and device errors when they occur and saves the information in the error log file for later analysis. The ULTRIX-11 error logging system consists of four major components:

- The error log initialization program (eli) performs such house-keeping functions as saving the error log file, zeroing the error log file, enabling and disabling error logging, and printing the size of the error log file.
- The ULTRIX-11 kernel and device drivers gather error information and save it in the kernel error log buffer.
- The error log copy process (elc), a background process, copies error log records from the kernel buffer into the error log file.
- The error log print program (elp) formats the error log data and generates error reports.

The error logging system has been updated to include support for new devices supported by the ULTRIX-11 operating system.

4.22 CRASH DUMP ANALYZER

The ULTRIX-11 software takes a crash dump by writing an image of all the processor's memory to the crash dump device. The crash dump device can be magnetic tape, RX50 diskettes, or the swap area on the system disk.

The crash dump analysis program (cda) extracts all available information concerning the crash from this memory image and formats it into a crash dump analysis report. The cda report provides information about unlogged errors, hardware traps (panic traps), the memory usage map, I/O buffer cache

usage, and active processes. The program also dumps many of the operating system's internal data structures.

4.23 MAINTAINABILITY IMPROVEMENTS

The ULTRIX-11 kernel is more fault tolerant and provides improved error information when a fault occurs. The ULTRIX-11 kernel contains a large number of bug fixes and the documentation explains system and device error messages.

4.24 SOURCE CODE CONTROL SYSTEM

The SYSTEM III Source Code Control System (SCCS) and the SCCS interface program from the University of California at Berkeley 4.2 BSD software are included in the ULTRIX-11 system. The ULTRIX-11 source code is developed under SCCS control.

4.25 SYSTEM V COMMANDS

The following commands have been ported from the AT&T UNIX SYSTEM V release to the ULTRIX-11 software:

```

cpio      - Copy file archives
cut       - Cut selected fields from a file
dcopy    - Copy file system for optimum access
ed        - Text editor
paste,   - Merge same lines of several files
labelit  - Label file system volumes
volcopy  - Copy file systems with label checking

```

4.26 OPERATOR SERVICES PROGRAM

The operator services program provides an interface between the operating system and the system operator. Operator services enables the operator to perform the following functions:

- Obtain on-line help
- Shutdown the system to single-user mode
- Restart multiuser mode operation
- Halt the processor
- Run file system consistency checks
- Perform file system backups
- Escape to a shell and execute ULTRIX-11 commands

4.27 SYSTEM MANAGEMENT COMMANDS

ULTRIX-11 includes several commands designed to aid the system manager with monitoring the system and maintaining the file system. You use the file system debugger (fsdb) to more safely modify or repair the ULTRIX-11 file system. You use the ipatch command to dump and/or modify an inode. The iostat disk and CPU usage commands have been vastly improved. The bufstat command displays the status of the I/O buffer cache. The memstat command prints a map of the usage of all memory on the system.

4.28 PLOT LIBRARY

The UNIX V7 plot library has been updated to support the VT 240 and VT241 terminals in Tektronix 4014 emulation mode.

4.29 TAPE ARCHIVER COMMAND

The ULTRIX-11 software includes an improved version of the tar command. The tar command now saves or restores empty directories and special files. The meaning of the p flag has changed: it now specifies that files will be extracted with the mode as written on the tape instead of the mode indicated by the current user's umask. The new tar command is compatible with tapes written by previous versions of tar and vice versa.

4.30 MAIL SYSTEM

The ULTRIX-11 software improves the mail system by implementing the mail front end (mail command) from the University of California at Berkeley 2.9 BSD software.

4.31 TIP - REPLACES CALL UNIX COMMAND (cu)

The tip command enables an ULTRIX-11 system to connect to another computer system. The tip command provides a virtual terminal facility from the ULTRIX-11 system to a remote system. It also allows for the transfer of ASCII text files between the ULTRIX-11 system and a remote UNIX system. It connects to the remote system with a hardwired direct connection, a direct connect with dedicated modems, or over a telephone line using a DIGITAL DF02-AC or DF03-AC auto call modem. The DF02-AC operates at 300 bits per second; the DF03-AC bit rate is switch selectable to 300 or 1200 BPS. The tip virtual terminal facility supports bit rates of 110, 150, 300, 1200, 2400, 4800, and 9600 bits per second. The tip command reliably transfers text files at speeds up to and including 2400 bits per second on all processors. Speeds up to 9600 bits per second can be used on faster processors, such as the 11/73 (J11).

The original cu command from V7 is included in the ULTRIX-11

system as `cu_v7`. This command is obsolete and is not supported. The version of `cu` from V7M-11 is also retained in the ULTRIX-11 system as `cu_v7m`. This command is supported but its use is not recommended. The `tip` command supports the `cu` user interface, so the user can enter `cu` commands and `tip` emulates `cu`.

The `tip` command was ported to ULTRIX-11 from the University of California at Berkeley 2.9 BSD software.

4.32 ADDITION OF USER WRITTEN DEVICE DRIVERS

The ULTRIX-11 system provides for adding up to four user-written device drivers. This is accomplished with four prototype device drivers containing all of the functions and definitions required to interface with the operating system. The user edits the code for the new device driver into one of the prototype files and uses the `sysgen` program to configure the new device into the ULTRIX-11 kernel.

The ULTRIX-11 user driver interface has been greatly improved to provide a more complete interface to the kernel. The user driver interface now includes a much more detailed description of how to write a driver and interface it to the kernel.

4.33 IMPROVED UUCP

The ULTRIX-11 system includes a vastly improved version of UUCP, which contains all currently known bug fixes. ULTRIX-11 also includes the UUCP Administrator's Guide, which simplifies the installation and administration of the UUCP software. The ULTRIX-11 software now uses `sethostname` and `gethostname` calls to implement the system's UUCP name.

4.34 FLOATING POINT SIMULATOR IN THE KERNEL

The V7M-11 software implemented floating point simulation by linking a floating point simulator library to each program that needed to execute floating point instructions. This method was slow and increased the size of the programs.

On the ULTRIX-11 system, you configure the floating point simulation code into the kernel if the processor does not have floating point hardware. This simulator provides a 50% speed increase in floating point instruction execution, compared to the user level floating point simulator library. The in-kernel floating point simulator allows all system and user programs that require floating point support to run on processors without the floating point hardware.

For applications involving intensive floating point calculations or requiring high floating point performance, the floating point hardware is recommended.

4.35 ULTRIX-11 NON-SUPPORTED SOFTWARE

The following features/programs from UNIX V7 are not included in the ULTRIX-11 software:

- CRYPT Command
- Packet Driver
- Multiplexed Files
- DC11 Device Driver
- TC11 Device Driver
- RF11 Device Driver

All forms of encryption and decryption have been removed from the ULTRIX-11 software, with the exception of the one way password encryption algorithm. This allows the ULTRIX-11 software to be shipped outside the United States of America without the special export license required if the encryption software were included. Customers located in the United States can obtain a kit for the reinstallation of the encryption software by contacting the DIGITAL Telephone Support Center.

ULTRIX-11 contains the following V7 software, but this software is not supported:

- bas - BASIC interpreter
- C/A/T - Phototypesetter interface
- cu - Call UNIX command (original version)
- factor - Factor a number
- m4 - Macro processor
- primes - Generate large primes
- ratfor - Rational Fortran interpreter
- pkopen(3) - Packet Driver Simulator
- DN11 driver
- DU11 driver
- RS03/4 driver
- Multi-volume file systems
- Versatec printer-plotter software
- All games
- On-line manuals (/usr/man)
- UNIX documents (/usr/doc)
- troff and associated macro packages

These software features are included in the ULTRIX-11 software and should function as in V7. The ULTRIX-11 system does not support these features. Software performance reports will be accepted but are handled on a best effort basis. That is, there is no guaranteed response.

The on-line manuals (/usr/man) are updated with each new ULTRIX-11 release. Software performance reports are handled on a best effort basis. The UNIX documents (/usr/doc) are not updated with new releases. These are the UNIX documents from V7. Software performance reports are not accepted for

the UNIX documents.

The troff phototypesetter text processing software is included and functions as in V7. It is currently not supported, but this could change in a future release. Software performance reports are handled on a best effort basis.

The ULTRIX-11 distribution includes the following non-supported software:

- m11 - MACRO-11 Assembler
- l11 - Linker
- macxrf - Cross reference

Software performance reports are handled on a best effort basis.

7th Edition UNIX — Summary

September 6, 1978

Bell Laboratories
Murray Hill, New Jersey 07974

A. What's new: highlights of the 7th edition UNIX† System

Aimed at larger systems. Devices are addressable to 2^{31} bytes, files to 2^{30} bytes. 128K memory (separate instruction and data space) is needed for some utilities.

Portability. Code of the operating system and most utilities has been extensively revised to minimize its dependence on particular hardware.

Fortran 77. F77 compiler for the new standard language is compatible with C at the object level. A Fortran structurer, STRUCT, converts old, ugly Fortran into RATFOR, a structured dialect usable with F77.

Shell. Completely new SH program supports string variables, trap handling, structured programming, user profiles, settable search path, multilevel file name generation, etc.

Document preparation. TROFF phototypesetter utility is standard. NROFF (for terminals) is now highly compatible with TROFF. MS macro package provides canned commands for many common formatting and layout situations. TBL provides an easy to learn language for preparing complicated tabular material. REFER fills in bibliographic citations from a data base.

UNIX-to-UNIX file copy. UUCP performs spooled file transfers between any two machines.

Data processing. SED stream editor does multiple editing functions in parallel on a data stream of indefinite length. AWK report generator does free-field pattern selection and arithmetic operations.

Program development. MAKE controls re-creation of complicated software, arranging for minimal recompilation.

Debugging. ADB does postmortem and breakpoint debugging, handles separate instruction and data spaces, floating point, etc.

C language. The language now supports definable data types, generalized initialization, block structure, long integers, unions, explicit type conversions. The LINT verifier does strong type checking and detection of probable errors and portability problems even across separately compiled functions.

Lexical analyzer generator. LEX converts specification of regular expressions and semantic actions into a recognizing subroutine. Analogous to YACC.

Graphics. Simple graph-drawing utility, graphic subroutines, and generalized plotting filters adapted to various devices are now standard.

Standard input-output package. Highly efficient buffered stream I/O is integrated with formatted input and output.

Other. The operating system and utilities have been enhanced and freed of restrictions in many other ways too numerous to relate.

† UNIX is a Trademark of Bell Laboratories.

B. Hardware

The 7th edition UNIX operating system runs on a DEC PDP-11/45 or 11/70* with at least the following equipment:

128K to 2M words of managed memory; parity not used.

disk: RP03, RP04, RP06, RK05 (more than 1 RK05) or equivalent.

console typewriter.

clock: KW11-L or KW11-P.

The following equipment is strongly recommended:

communications controller such as DL11 or DH11.

full duplex 96-character ASCII terminals.

9-track tape or extra disk for system backup.

The system is normally distributed on 9-track tape. The minimum memory and disk space specified is enough to run and maintain UNIX. More will be needed to keep all source on line, or to handle a large number of users, big data bases, diversified complements of devices, or large programs. The resident code occupies 12-20K words depending on configuration; system data occupies 10-28K words.

There is no commitment to provide 7th edition UNIX on PDP-11/34, 11/40 and 11/60 hardware.

C. Software

Most of the programs available as UNIX commands are listed. Source code and printed manuals are distributed for all of the listed software except games. Almost all of the code is written in C. Commands are self-contained and do not require extra setup information, unless specifically noted as "interactive." Interactive programs can be made to run from a prepared script simply by redirecting input. Most programs intended for interactive use (e.g., the editor) allow for an escape to command level (the Shell). Most file processing commands can also go from standard input to standard output ("filters"). The piping facility of the Shell may be used to connect such filters directly to the input or output of other programs.

1. Basic Software

This includes the time-sharing operating system with utilities, a machine language assembler and a compiler for the programming language C—enough software to write and run new applications and to maintain or modify UNIX itself.

1.1. Operating System

- UNIX The basic resident code on which everything else depends. Supports the system calls, and maintains the file system. A general description of UNIX design philosophy and system facilities appeared in the Communications of the ACM, July, 1974. A more extensive survey is in the Bell System Technical Journal for July-August 1978. Capabilities include:
 - Reentrant code for user processes.
 - Separate instruction and data spaces.
 - "Group" access permissions for cooperative projects, with overlapping memberships.
 - Alarm-clock timeouts.

*PDP is a Trademark of Digital Equipment Corporation.

- Timer-interrupt sampling and interprocess monitoring for debugging and measurement.
- Multiplexed I/O for machine-to-machine communication.
- DEVICES All I/O is logically synchronous. I/O devices are simply files in the file system. Normally, invisible buffering makes all physical record structure and device characteristics transparent and exploits the hardware's ability to do overlapped I/O. Unbuffered physical record I/O is available for unusual applications. Drivers for these devices are available; others can be easily written:
 - Asynchronous interfaces: DH11, DL11. Support for most common ASCII terminals.
 - Synchronous interface: DP11.
 - Automatic calling unit interface: DN11.
 - Line printer: LP11.
 - Magnetic tape: TU10 and TU16.
 - DECtape: TC11.
 - Fixed head disk: RS11, RS03 and RS04.
 - Pack type disk: RP03, RP04, RP06; minimum-latency seek scheduling.
 - Cartridge-type disk: RK05, one or more physical devices per logical device.
 - Null device.
 - Physical memory of PDP-11, or mapped memory in resident system.
 - Phototypesetter: Graphic Systems System/1 through DR11C.
- BOOT Procedures to get UNIX started.
- MKCONF Tailor device-dependent system code to hardware configuration. As distributed, UNIX can be brought up directly on any acceptable CPU with any acceptable disk, any sufficient amount of core, and either clock. Other changes, such as optimal assignment of directories to devices, inclusion of floating point simulator, or installation of device names in file system, can then be made at leisure.

1.2. User Access Control

- LOGIN Sign on as a new user.
 - Verify password and establish user's individual and group (project) identity.
 - Adapt to characteristics of terminal.
 - Establish working directory.
 - Announce presence of mail (from MAIL).
 - Publish message of the day.
 - Execute user-specified profile.
 - Start command interpreter or other initial program.
- PASSWD Change a password.
 - User can change his own password.
 - Passwords are kept encrypted for security.
- NEWGRP Change working group (project). Protects against unauthorized changes to projects.

1.3. Terminal Handling

- TABS Set tab stops appropriately for specified terminal type.
- STTY Set up options for optimal control of a terminal. In so far as they are deducible from the input, these options are set automatically by LOGIN.

- Half vs. full duplex.
- Carriage return + line feed vs. newline.
- Interpretation of tabs.
- Parity.
- Mapping of upper case to lower.
- Raw vs. edited input.
- Delays for tabs, newlines and carriage returns.

1.4. File Manipulation

- CAT Concatenate one or more files onto standard output. Particularly used for unadorned printing, for inserting data into a pipeline, and for buffering output that comes in dribs and drabs. Works on any file regardless of contents.
- CP Copy one file to another, or a set of files to a directory. Works on any file regardless of contents.
- PR Print files with title, date, and page number on every page.
 - Multicolumn output.
 - Parallel column merge of several files.
- LPR Off-line print. Spools arbitrary files to the line printer.
- CMP Compare two files and report if different.
- TAIL Print last *n* lines of input
 - May print last *n* characters, or from *n* lines or characters to end.
- SPLIT Split a large file into more manageable pieces. Occasionally necessary for editing (ED).
- DD Physical file format translator, for exchanging data with foreign systems, especially IBM 370's.
- SUM Sum the words of a file.

1.5. Manipulation of Directories and File Names

- RM Remove a file. Only the name goes away if any other names are linked to the file.
 - Step through a directory deleting files interactively.
 - Delete entire directory hierarchies.
- LN "Link" another name (alias) to an existing file.
- MV Move a file or files. Used for renaming files.
- CHMOD Change permissions on one or more files. Executable by files' owner.
- CHOWN Change owner of one or more files.
- CHGRP Change group (project) to which a file belongs.
- MKDIR Make a new directory.
- RMDIR Remove a directory.
- CD Change working directory.
- FIND Prowl the directory hierarchy finding every file that meets specified criteria.

- Criteria include:
 - name matches a given pattern,
 - creation date in given range,
 - date of last use in given range,
 - given permissions,
 - given owner,
 - given special file characteristics,
 - boolean combinations of above.
- Any directory may be considered to be the root.
- Perform specified command on each file found.

1.6. Running of Programs

- SH The Shell, or command language interpreter.
 - Supply arguments to and run any executable program.
 - Redirect standard input, standard output, and standard error files.
 - Pipes: simultaneous execution with output of one process connected to the input of another.
 - Compose compound commands using:
 - if ... then ... else,
 - case switches,
 - while loops,
 - for loops over lists,
 - break, continue and exit,
 - parentheses for grouping.
 - Initiate background processes.
 - Perform Shell programs, i.e., command scripts with substitutable arguments.
 - Construct argument lists from all file names satisfying specified patterns.
 - Take special action on traps and interrupts.
 - User-settable search path for finding commands.
 - Executes user-settable profile upon login.
 - Optionally announces presence of mail as it arrives.
 - Provides variables and parameters with default setting.
- TEST Tests for use in Shell conditionals.
 - String comparison.
 - File nature and accessibility.
 - Boolean combinations of the above.
- EXPR String computations for calculating command arguments.
 - Integer arithmetic
 - Pattern matching
- WAIT Wait for termination of asynchronously running processes.
- READ Read a line from terminal, for interactive Shell procedure.
- ECHO Print remainder of command line. Useful for diagnostics or prompts in Shell programs, or for inserting data into a pipeline.
- SLEEP Suspend execution for a specified time.
- NOHUP Run a command immune to hanging up the terminal.
- NICE Run a command in low (or high) priority.

- KILL Terminate named processes.
- CRON Schedule regular actions at specified times.
 - Actions are arbitrary programs.
 - Times are conjunctions of month, day of month, day of week, hour and minute. Ranges are specifiable for each.
- AT Schedule a one-shot action for an arbitrary time.
- TEE Pass data between processes and divert a copy into one or more files.

1.7. Status Inquiries

- LS List the names of one, several, or all files in one or more directories.
 - Alphabetic or temporal sorting, up or down.
 - Optional information: size, owner, group, date last modified, date last accessed, permissions, i-node number.
- FILE Try to determine what kind of information is in a file by consulting the file system index and by reading the file itself.
- DATE Print today's date and time. Has considerable knowledge of calendric and horological peculiarities.
 - May set UNIX's idea of date and time.
- DF Report amount of free space on file system devices.
- DU Print a summary of total space occupied by all files in a hierarchy.
- QUOT Print summary of file space usage by user id.
- WHO Tell who's on the system.
 - List of presently logged in users, ports and times on.
 - Optional history of all logins and logouts.
- PS Report on active processes.
 - List your own or everybody's processes.
 - Tell what commands are being executed.
 - Optional status information: state and scheduling info, priority, attached terminal, what it's waiting for, size.
- IOSTAT Print statistics about system I/O activity.
- TTY Print name of your terminal.
- PWD Print name of your working directory.

1.8. Backup and Maintenance

- MOUNT Attach a device containing a file system to the tree of directories. Protects against nonsense arrangements.
- UMOUNT Remove the file system contained on a device from the tree of directories. Protects against removing a busy device.
- MKFS Make a new file system on a device.
- MKNOD Make an i-node (file system entry) for a special file. Special files are physical devices, virtual devices, physical memory, etc.

- TP
- TAR Manage file archives on magnetic tape or DECtape. TAR is newer.
 - Collect files into an archive.
 - Update DECtape archive by date.
 - Replace or delete DECtape files.
 - Print table of contents.
 - Retrieve from archive.
- DUMP Dump the file system stored on a specified device, selectively by date, or indiscriminately.
- RESTOR Restore a dumped file system, or selectively retrieve parts thereof.
- SU Temporarily become the super user with all the rights and privileges thereof. Requires a password.
- DCHECK
- ICHECK
- NCHECK Check consistency of file system.
 - Print gross statistics: number of files, number of directories, number of special files, space used, space free.
 - Report duplicate use of space.
 - Retrieve lost space.
 - Report inaccessible files.
 - Check consistency of directories.
 - List names of all files.
- CLRI Preemptorily expunge a file and its space from a file system. Used to repair damaged file systems.
- SYNC Force all outstanding I/O on the system to completion. Used to shut down gracefully.

1.9. Accounting

The timing information on which the reports are based can be manually cleared or shut off completely.

- AC Publish cumulative connect time report.
 - Connect time by user or by day.
 - For all users or for selected users.
- SA Publish Shell accounting report. Gives usage information on each command executed.
 - Number of times used.
 - Total system time, user time and elapsed time.
 - Optional averages and percentages.
 - Sorting on various fields.

1.10. Communication

- MAIL Mail a message to one or more users. Also used to read and dispose of incoming mail. The presence of mail is announced by LOGIN and optionally by SH.
 - Each message can be disposed of individually.
 - Messages can be saved in files or forwarded.

- CALENDAR Automatic reminder service for events of today and tomorrow.
- WRITE Establish direct terminal communication with another user.
- WALL Write to all users.
- MMSG Inhibit receipt of messages from WRITE and WALL.
- CU Call up another time-sharing system.
 - Transparent interface to remote machine.
 - File transmission.
 - Take remote input from local file or put remote output into local file.
 - Remote system need not be UNIX.
- UUCP UNIX to UNIX copy.
 - Automatic queuing until line becomes available and remote machine is up.
 - Copy between two remote machines.
 - Differences, mail, etc., between two machines.

1.11. Basic Program Development Tools

Some of these utilities are used as integral parts of the higher level languages described in section 2.

- AR Maintain archives and libraries. Combines several files into one for housekeeping efficiency.
 - Create new archive.
 - Update archive by date.
 - Replace or delete files.
 - Print table of contents.
 - Retrieve from archive.
- AS Assembler. Similar to PAL-11, but different in detail.
 - Creates object program consisting of code, possibly read-only, initialized data or read-write code, uninitialized data.
 - Relocatable object code is directly executable without further transformation.
 - Object code normally includes a symbol table.
 - Multiple source files.
 - Local labels.
 - Conditional assembly.
 - "Conditional jump" instructions become branches or branches plus jumps depending on distance.
- Library The basic run-time library. These routines are used freely by all software.
 - Buffered character-by-character I/O.
 - Formatted input and output conversion (SCANF and PRINTF) for standard input and output, files, in-memory conversion.
 - Storage allocator.
 - Time conversions.
 - Number conversions.
 - Password encryption.
 - Quicksort.
 - Random number generator.
 - Mathematical function library, including trigonometric functions and inverses, exponential, logarithm, square root, bessel functions.

- **ADB** Interactive debugger.
 - Postmortem dumping.
 - Examination of arbitrary files, with no limit on size.
 - Interactive breakpoint debugging with the debugger as a separate process.
 - Symbolic reference to local and global variables.
 - Stack trace for C programs.
 - Output formats:
 - 1-, 2-, or 4-byte integers in octal, decimal, or hex
 - single and double floating point
 - character and string
 - disassembled machine instructions
 - Patching.
 - Searching for integer, character, or floating patterns.
 - Handles separated instruction and data space.
- **OD** Dump any file. Output options include any combination of octal or decimal by words, octal by bytes, ASCII, opcodes, hexadecimal.
 - Range of dumping is controllable.
- **LD** Link edit. Combine relocatable object files. Insert required routines from specified libraries.
 - Resulting code may be sharable.
 - Resulting code may have separate instruction and data spaces.
- **LORDER** Places object file names in proper order for loading, so that files depending on others come after them.
- **NM** Print the namelist (symbol table) of an object program. Provides control over the style and order of names that are printed.
- **SIZE** Report the core requirements of one or more object files.
- **STRIP** Remove the relocation and symbol table information from an object file to save space.
- **TIME** Run a command and report timing information on it.
- **PROF** Construct a profile of time spent per routine from statistics gathered by time-sampling the execution of a program. Uses floating point.
 - Subroutine call frequency and average times for C programs.
- **MAKE** Controls creation of large programs. Uses a control file specifying source file dependencies to make new version; uses time last changed to deduce minimum amount of work necessary.
 - Knows about CC, YACC, LEX, etc.

1.12. UNIX Programmer's Manual

- **Manual** Machine-readable version of the UNIX Programmer's Manual.
 - System overview.
 - All commands.
 - All system calls.
 - All subroutines in C and assembler libraries.
 - All devices and other special files.
 - Formats of file system and kinds of files known to system software.
 - Boot and maintenance procedures.

- MAN Print specified manual section on your terminal.

1.13. Computer-Aided Instruction

- LEARN A program for interpreting CAI scripts, plus scripts for learning about UNIX by using it.
 - Scripts for basic files and commands, editor, advanced files and commands, EQN, MS macros, C programming language.

2. Languages

2.1. The C Language

- CC Compile and/or link edit programs in the C language. The UNIX operating system, most of the subsystems and C itself are written in C. For a full description of C, read *The C Programming Language*, Brian W. Kernighan and Dennis M. Ritchie, Prentice-Hall, 1978.
 - General purpose language designed for structured programming.
 - Data types include character, integer, float, double, pointers to all types, functions returning above types, arrays of all types, structures and unions of all types.
 - Operations intended to give machine-independent control of full machine facility, including to-memory operations and pointer arithmetic.
 - Macro preprocessor for parameterized code and inclusion of standard files.
 - All procedures recursive, with parameters by value.
 - Machine-independent pointer manipulation.
 - Object code uses full addressing capability of the PDP-11.
 - Runtime library gives access to all system facilities.
 - Definable data types.
 - Block structure
- LINT Verifier for C programs. Reports questionable or nonportable usage such as:
 - Mismatched data declarations and procedure interfaces.
 - Nonportable type conversions.
 - Unused variables, unreachable code, no-effect operations.
 - Mistyped pointers.
 - Obsolete syntax.
 - Full cross-module checking of separately compiled programs.
- CB A beautifier for C programs. Does proper indentation and placement of braces.

2.2. Fortran

- F77 A full compiler for ANSI Standard Fortran 77.
 - Compatible with C and supporting tools at object level.
 - Optional source compatibility with Fortran 66.
 - Free format source.
 - Optional subscript-range checking, detection of uninitialized variables.
 - All widths of arithmetic: 2- and 4-byte integer; 4- and 8-byte real; 8- and 16-byte complex.
- RATFOR Ratfor adds rational control structure à la C to Fortran.
 - Compound statements.

- If-else, do, for, while, repeat-until, break, next statements.
- Symbolic constants.
- File insertion.
- Free format source
- Translation of relationals like $>$, $>=$.
- Produces genuine Fortran to carry away.
- May be used with F77.
- STRUCT Converts ordinary ugly Fortran into structured Fortran (i.e., Ratfor), using statement grouping, if-else, while, for, repeat-until.

2.3. Other Algorithmic Languages

- BAS An interactive interpreter, similar in style to BASIC. Interpret unnumbered statements immediately, numbered statements upon 'run'.
 - Statements include:
 - comment,
 - dump,
 - for...next,
 - goto,
 - if...else...fi,
 - list,
 - print,
 - prompt,
 - return,
 - run,
 - save.
 - All calculations double precision.
 - Recursive function defining and calling.
 - Builtin functions include log, exp, sin, cos, atn, int, sqr, abs, rnd.
 - Escape to ED for complex program editing.
- DC Interactive programmable desk calculator. Has named storage locations as well as conventional stack for holding integers or programs.
 - Unlimited precision decimal arithmetic.
 - Appropriate treatment of decimal fractions.
 - Arbitrary input and output radices, in particular binary, octal, decimal and hexadecimal.
 - Reverse Polish operators:
 - + - * /
 - remainder, power, square root,
 - load, store, duplicate, clear,
 - print, enter program text, execute.
- BC A C-like interactive interface to the desk calculator DC.
 - All the capabilities of DC with a high-level syntax.
 - Arrays and recursive functions.
 - Immediate evaluation of expressions and evaluation of functions upon call.
 - Arbitrary precision elementary functions: exp, sin, cos, atan.
 - Go-to-less programming.

2.4. Macroprocessing

- M4 A general purpose macroprocessor.
 - Stream-oriented, recognizes macros anywhere in text.
 - Syntax fits with functional syntax of most higher-level languages.
 - Can evaluate integer arithmetic expressions.

2.5. Compiler-compilers

- YACC An LR(1)-based compiler writing system. During execution of resulting parsers, arbitrary C functions may be called to do code generation or semantic actions.
 - BNF syntax specifications.
 - Precedence relations.
 - Accepts formally ambiguous grammars with non-BNF resolution rules.
- LEX Generator of lexical analyzers. Arbitrary C functions may be called upon isolation of each lexical token.
 - Full regular expression, plus left and right context dependence.
 - Resulting lexical analysers interface cleanly with YACC parsers.

3. Text Processing

3.1. Document Preparation

- ED Interactive context editor. Random access to all lines of a file.
 - Find lines by number or pattern. Patterns may include: specified characters, don't care characters, choices among characters, repetitions of these constructs, beginning of line, end of line.
 - Add, delete, change, copy, move or join lines.
 - Permute or split contents of a line.
 - Replace one or all instances of a pattern within a line.
 - Combine or split files.
 - Escape to Shell (command language) during editing.
 - Do any of above operations on every pattern-selected line in a given range.
 - Optional encryption for extra security.
- PTX Make a permuted (key word in context) index.
- SPELL Look for spelling errors by comparing each word in a document against a word list.
 - 25,000-word list includes proper names.
 - Handles common prefixes and suffixes.
 - Collects words to help tailor local spelling lists.
- LOOK Search for words in dictionary that begin with specified prefix.
- TYPO Look for spelling errors by a statistical technique; not limited to English.
- CRYPT Encrypt and decrypt files for security.

3.2. Document Formatting

- ROFF A typesetting program for terminals. Easy for nontechnical people to learn, and good for simple documents. Input consists of data lines intermixed with control lines, such as
 - .sp 2 insert two lines of space
 - .ce center the next lineROFF is deemed to be obsolete; it is intended only for casual use.

- Justification of either or both margins.
 - Automatic hyphenation.
 - Generalized running heads and feet, with even-odd page capability, numbering, etc.
 - Definable macros for frequently used control sequences (no substitutable arguments).
 - All 4 margins and page size dynamically adjustable.
 - Hanging indents and one-line indents.
 - Absolute and relative parameter settings.
 - Optional legal-style numbering of output lines.
 - Multiple file capability.
 - Not usable as a filter.
- TROFF
- NROFF Advanced typesetting. TROFF drives a Graphic Systems phototypesetter; NROFF drives ascii terminals of all types. This summary was typeset using TROFF. TROFF and NROFF style is similar to ROFF, but they are capable of much more elaborate feats of formatting, when appropriately programmed. TROFF and NROFF accept the same input language.
- All ROFF capabilities available or definable.
 - Completely definable page format keyed to dynamically planted "interrupts" at specified lines.
 - Maintains several separately definable typesetting environments (e.g., one for body text, one for footnotes, and one for unusually elaborate headings).
 - Arbitrary number of output pools can be combined at will.
 - Macros with substitutable arguments, and macros invocable in mid-line.
 - Computation and printing of numerical quantities.
 - Conditional execution of macros.
 - Tabular layout facility.
 - Positions expressible in inches, centimeters, ems, points, machine units or arithmetic combinations thereof.
 - Access to character-width computation for unusually difficult layout problems.
 - Overstrikes, built-up brackets, horizontal and vertical line drawing.
 - Dynamic relative or absolute positioning and size selection, globally or at the character level.
 - Can exploit the characteristics of the terminal being used, for approximating special characters, reverse motions, proportional spacing, etc.

The Graphic Systems typesetter has a vocabulary of several 102-character fonts (4 simultaneously) in 15 sizes. TROFF provides terminal output for rough sampling of the product.

NROFF will produce multicolumn output on terminals capable of reverse line feed, or through the postprocessor COL.

High programming skill is required to exploit the formatting capabilities of TROFF and NROFF, although unskilled personnel can easily be trained to enter documents according to canned formats such as those provided by MS, below. TROFF and EQN are essentially identical to NROFF and NEQN so it is usually possible to define interchangeable formats to produce approximate proof copy on terminals before actual typesetting. The preprocessors MS, TBL, and REFER are fully compatible with TROFF and NROFF.

- MS A standardized manuscript layout package for use with NROFF/TROFF. This document was formatted with MS.

- Page numbers and draft dates.
 - Automatically numbered subheads.
 - Footnotes.
 - Single or double column.
 - Paragraphing, display and indentation.
 - Numbered equations.
- EQN A mathematical typesetting preprocessor for TROFF. Translates easily readable formulas, either in-line or displayed, into detailed typesetting instructions. Formulas are written in a style like this:
$$\sigma^2 = \frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2$$
which produces:
$$\sigma^2 = \frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2$$
- Automatic calculation of size changes for subscripts, sub-subscripts, etc.
 - Full vocabulary of Greek letters and special symbols, such as 'gamma', 'GAMMA', 'integral'.
 - Automatic calculation of large bracket sizes.
 - Vertical "piling" of formulae for matrices, conditional alternatives, etc.
 - Integrals, sums, etc., with arbitrarily complex limits.
 - Diacriticals: dots, double dots, hats, bars, etc.
 - Easily learned by nonprogrammers and mathematical typists.
- NEQN A version of EQN for NROFF; accepts the same input language. Prepares formulas for display on any terminal that NROFF knows about, for example, those based on Diablo printing mechanism.
 - Same facilities as EQN within graphical capability of terminal.
- TBL A preprocessor for NROFF/TROFF that translates simple descriptions of table layouts and contents into detailed typesetting instructions.
 - Computes column widths.
 - Handles left- and right-justified columns, centered columns and decimal-point alignment.
 - Places column titles.
 - Table entries can be text, which is adjusted to fit.
 - Can box all or parts of table.
- REFER Fills in bibliographic citations in a document from a data base (not supplied).
 - References may be printed in any style, as they occur or collected at the end.
 - May be numbered sequentially, by name of author, etc.
- TC Simulate Graphic Systems typesetter on Tektronix 4014 scope. Useful for checking TROFF page layout before typesetting.
- GREEK Fancy printing on Diablo-mechanism terminals like DASI-300 and DASI-450, and on Tektronix 4014.
 - Gives half-line forward and reverse motions.
 - Approximates Greek letters and other special characters by overstriking.
- COL Canonicalize files with reverse line feeds for one-pass printing.
- DEROFF Remove all TROFF commands from input.
- CHECKEQ Check document for possible errors in EQN usage.

4. Information Handling

- SORT** Sort or merge ASCII files line-by-line. No limit on input size.
 - Sort up or down.
 - Sort lexicographically or on numeric key.
 - Multiple keys located by delimiters or by character position.
 - May sort upper case together with lower into dictionary order.
 - Optionally suppress duplicate data.

- TSORT** Topological sort — converts a partial order into a total order.

- UNIQ** Collapse successive duplicate lines in a file into one line.
 - Publish lines that were originally unique, duplicated, or both.
 - May give redundancy count for each line.

- TR** Do one-to-one character translation according to an arbitrary code.
 - May coalesce selected repeated characters.
 - May delete selected characters.

- DIFF** Report line changes, additions and deletions necessary to bring two files into agreement.
 - May produce an editor script to convert one file into another.
 - A variant compares two new versions against one old one.

- COMM** Identify common lines in two sorted files. Output in up to 3 columns shows lines present in first file only, present in both, and/or present in second only.

- JOIN** Combine two files by joining records that have identical keys.

- GREP** Print all lines in a file that satisfy a pattern as used in the editor ED.
 - May print all lines that fail to match.
 - May print count of hits.
 - May print first hit in each file.

- LOOK** Binary search in sorted file for lines with specified prefix.

- WC** Count the lines, “words” (blank-separated strings) and characters in a file.

- SED** Stream-oriented version of ED. Can perform a sequence of editing operations on each line of an input stream of unbounded length.
 - Lines may be selected by address or range of addresses.
 - Control flow and conditional testing.
 - Multiple output streams.
 - Multi-line capability.

- AWK** Pattern scanning and processing language. Searches input for patterns, and performs actions on each line of input that satisfies the pattern.
 - Patterns include regular expressions, arithmetic and lexicographic conditions, boolean combinations and ranges of these.
 - Data treated as string or numeric as appropriate.
 - Can break input into fields; fields are variables.
 - Variables and arrays (with non-numeric subscripts).
 - Full set of arithmetic operators and control flow.
 - Multiple output streams to files and pipes.
 - Output can be formatted as desired.
 - Multi-line capabilities.

5. Graphics

The programs in this section are predominantly intended for use with Tektronix 4014 storage scopes.

- GRAPH Prepares a graph of a set of input numbers.
 - Input scaled to fit standard plotting area.
 - Abscissae may be supplied automatically.
 - Graph may be labeled.
 - Control over grid style, line style, graph orientation, etc.
- SPLINE Provides a smooth curve through a set of points intended for GRAPH.
- PLOT A set of filters for printing graphs produced by GRAPH and other programs on various terminals. Filters provided for 4014, DASI terminals, Versatec printer/plotter.

6. Novelties, Games, and Things That Didn't Fit Anywhere Else

- BACKGAMMON A player of modest accomplishment.
- CHESS Plays good class D chess.
- CHECKERS Ditto, for checkers.
- BCD Converts ascii to card-image form.
- PPT Converts ascii to paper tape form.
- BJ A blackjack dealer.
- CUBIC An accomplished player of 4×4×4 tic-tac-toe.
- MAZE Constructs random mazes for you to solve.
- MOO A fascinating number-guessing game.
- CAL Print a calendar of specified month and year.
- BANNER Print output in huge letters.
- CHING The *I Ching*. Place your own interpretation on the output.
- FORTUNE Presents a random fortune cookie on each invocation. Limited jar of cookies included.
- UNITS Convert amounts between different scales of measurement. Knows hundreds of units. For example, how many km/sec is a parsec/megayear?
- TTT A tic-tac-toe program that learns. It never makes the same mistake twice.
- ARITHMETIC Speed and accuracy test for number facts.
- FACTOR Factor large integers.
- QUIZ Test your knowledge of Shakespeare, Presidents, capitals, etc.
- WUMP Hunt the wumpus, thrilling search in a dangerous cave.
- REVERSI A two person board game, isomorphic to Othello®.
- HANGMAN Word-guessing game. Uses the dictionary supplied with SPELL.

- FISH** Children's card-guessing game.