UNIX/32V — Summary

March 9, 1979

A. What's new: highlights of the UNIX†/32V System

32-bit world. UNIX/32V handles 32-bit addresses and 32-bit data. Devices are addressable to 2^{31} bytes, files to 2^{30} bytes.

Portability. Code of the operating system and most utilities has been extensively revised to minimize its dependence on particular hardware. UNIX/32V is highly compatible with UNIX version 7.

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.

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.

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† UNIX is a Trademark of Bell Laboratories.

B. Hardware

The UNIX/32V operating system runs on a DEC VAX-11/780* with at least the following equipment:

memory: 256K bytes or more.

disk: RP06, RM03, or equivalent.

tape: any 9-track MASSBUS-compatible tape drive.

The following equipment is strongly recommended:

communications controller such as DZ11 or DL11.

full duplex 96-character ASCII terminals.

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/32V, and to keep all source on line. More memory will be needed to handle a large number of users, big data bases, diversified complements of devices, or large programs. The resident code occupies 40-55K bytes depending on configuration; system data also occupies 30-55K bytes.

C. Software

Most of the programs available as UNIX/32V 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, and a compiler for the programming language C—enough software to write and run new applications and to maintain or modify UNIX/32V 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.
- ○ ‘‘Group’’ access permissions for cooperative projects, with overlapping memberships.
- ○ Alarm-clock timeouts.
- ○ 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:
- ○ Asynchronous interfaces: DZ11, DL11. Support for most common ASCII terminals.
- ○ Automatic calling unit interface: DN11.

*VAX is a Trademark of Digital Equipment Corporation.

○ Printer/plotter: Versatek.
○ Magnetic tape: TE16.
○ Pack type disk: RP06, RM03; minimum-latency seek scheduling.
○ Physical memory of VAX-11, or mapped memory in resident system.
○ Null device.
○ Recipies are supplied to aid the construction of drivers for:
  Asynchronous interface: DH11.
  Synchronous interface: DU11.
  DECtape: TC11.
  Fixed head disk: RS11, RS03 and RS04.
  Cartridge-type disk: RK05.
  Phototypesetter: Graphic Systems System/1 through DR11C.

☐ BOOT Procedures to get UNIX/32V started.

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/32V’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 Peremptorily 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.

☐ MESG 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/32V.

☐ 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.
○Creates object program consisting of
code, normally read-only and sharable,
initialized data or read-write code,

uninitialized data.
- ○Relocatable object code is directly executable without further transformation.
- ○Object code normally includes a symbol table.
- ○‘‘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.

□ OD — Dump any file. Output options include any combination of octal or decimal or hex 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 is sharable by default.

□ 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 memory 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.
- ○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/32V Programmer’s Manual

□ Manual — Machine-readable version of the UNIX/32V 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/32V 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/32V 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 VAX-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

☐ 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.

☐ CRYPT — Encrypt and decrypt files for security.

3.2. Document Formatting

☐ 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 are capable of elaborate feats of formatting, when appropriately programmed. TROFF and NROFF accept the same input language.
- 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 sup 2 ˜=˜ 1 over N sum from i=1 to N (x sub i − x bar) sup 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.

☐ 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.

☐ BCD Converts ascii to card-image form.

☐ CAL Print a calendar of specified month and year.

☐ 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?

☐ ARITHMETIC
Speed and accuracy test for number facts.

☐ QUIZ Test your knowledge of Shakespeare, Presidents, capitals, etc.

☐ WUMP Hunt the wumpus, thrilling search in a dangerous cave.

☐ HANGMAN Word-guessing game. Uses a dictionary supplied with SPELL.

☐ FISH Children's card-guessing game.