Hints on Configuring VAX* Systems for UNIX†

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ABSTRACT

This document reflects our experiences and opinions in configuring over thirty VAXes to run UNIX† over the last five years.

Our prime considerations in choosing equipment are:

- Cost
- Performance
- Reliability
- Maintainability and maintenance cost
- Delivery time
- Redundancy of the system
- Conservation of space, power, and cooling resources

We consider components individually and then describe several system packages built from these components, emphasizing independently single-source systems, minimization of cost, and maximal expansion capability.

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† UNIX is a trademark of Bell Laboratories.

* VAX, VMS, MASSBUS, and UNIBUS are trademarks of Digital Equipment Corporation.

DISCLAIMER

This documents reflects our *personal opinions*. We are responsible for software and hardware support of VAX systems, and the recommendations we give reflect what we would do. We are careful to note the equipment that we recommend but are not using; we recommend no second-vendor equipment that is not known to be in use successfully at several UNIX sites. In any case you may get a lemon, no matter what you buy. All we promise is that this is what we believe. Let us know what you find out.

We have little familiarity with VMS. Recommendations made here should not be construed to be applicable to any operating system other than UNIX. We have often adapted UNIX to these devices in a way that may not be possible with other operating systems.

Finally, note that we have not written this document solely to share the knowledge we have acquired with you; we have written it because we do not have the time to talk to everyone who needs this information. Please do not call us to confirm the information here or to ask questions about our opinions. We would like to hear of your experiences, or learn of mistakes in this document or products that we know nothing about, but do not have time to chat about the information that is given here. We do welcome electronic mail sent to our addresses as shown on the first page.

PREFACE TO 1983 REVISION

The VAX/UNIX Community has grown considerably since the last revision of this paper in mid-1981. It is safe to say that 4BSD systems represent a substantial portion of all the VAXes sold. Both the hardware available for building good VAX/UNIX systems and the support services available to those doing the building have increased. A significant portion of the systems now being built are being used in business and private research environments in addition to those in the traditional academic UNIX strongholds. Many of these systems are based on binary licenses rather than the educational source license so familiar at universities.

We hope this document will be of use to a variety of potential VAX/UNIX users. Even the purchaser who chooses to buy a complete system from DEC or a mixed vendor system integrator should be assisted in making a better choice by an increased knowledge of the integration decisions. In the area of hardware, you will find that the sections on disks, network interfaces, and printers have been heavily reworked. In addition to the traditional emphasis on hardware selection, in this revision we try to at least provide pointers to some of the other relevant services available. A list of hardware integrators we are aware of who have developed expertise in the UNIX area is included. In addition, some suppliers of 4BSD software are included.

This revision takes a different policy regarding the inclusion of specific prices for hardware: *No explict prices are included.* We do ocassionally include derived costs such as the cost per Megabyte for a particular size disk system. The are only meant to be approximate and are calculated from current quantity one list prices.

It has been our experience that the inclusion of prices made the release of this paper much more difficult without significantly increasing its value. We were obligated to pass the paper by every hardware vendor for price checking and even so the contents remained accurate for only a brief period. In addition, regional pricing and discounting policys vary widely. We have decided that rather than depend on us for prices, the reader should narrow their range of choices as much as possible and then do some hard bargaining with their suppliers. ‘‘Everybody gets a discount.’’

OVERVIEW

We first discuss components, listing the alternatives we have tried and sometimes a few we have not, and then discuss system packages. We buy a substantial portion of our equipment from vendors other than DEC. The reasons for choosing second vendor equipment are usually some combination of more current technology, lower cost for equivalent equipment or shorter delivery time.

We do not consider devices that have proven unreliable or whose performance we consider inadequate.* In addition, there are many devices that we have no experience with. As a general rule, every new peripheral has required a non-trivial amount of leg work to get up to speed. We suggest using only peripherals that have been previously used successfully on *the type of VAX you are configuring* (780, 750 or 730) or demanding a substantial (50-100%) discount for being a guinea pig. Be especially careful of UNIBUS† interfaces. Almost every manufacturer of a UNIBUS widget now includes the VAX as a machine on which his device will work. Some of these devices have still not been well tested in this situation. These often will not work without substantial modification.

System buyers without ready access to an in−house hardware staff should consider carefully the option of buying as much DEC equipment as possible. If you have the money and time required to do this, there are some strong advantages. Our DEC equipment has, in general, proven somewhat more reliable than the equivalent alternate vendor equipment. Time from equipment delivery to running system is also usually shorter. DEC field service in our area is excellent. Outside service available for non-DEC peripherals is spotty at best.

For smaller installations this option should be carefully considered. It is easier if you can call one party for all your problems, if you can afford it. At Berkeley, we are well past the inventory level where self maintenance begins to pay off even on all DEC systems, so this is not a consideration. One of us (Kridle) manages our local hardware support group.

Unfortunately, the limited selection of configurations currently available sometimes make the all-DEC choice difficult. This is especially true of the smaller configurations as DEC’s bottom end peripherals are less satisfactory for UNIX. We say this not just for monetary reasons; functionally and aesthetically we would prefer to have neither the RK07 disk nor the TS11 tape unit in any system we have to deal with.

We recommend getting field service at least on your CPU for the first year. It has paid off for us in the cost of parts alone. You can drop the contract after the engineering changes have tapered off and most of the infant failures have occurred. DEC requires a certain amount of its peripheral equipment on the machine to qualify for field service. We understand that it is company policy not to provide a maintenance contract for a system without a DEC mass storage peripheral. If you intend to purchase a maintenance contract, be certain that your local field service is willing to support at least the DEC equipment you buy.

BANDWIDTH CONSIDERATIONS

Evaluation of the data transfer capacities between the various parts of VAX systems is a complex task that plays a critical part in system configuration. Unfortunately, there is a tremendous amount of misinformation available on this subject and little useful hard data. We have made many measurements and are always in the process of making more. What we currently know follows.

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* An exception to this rule is made where we have yet to find any satisfactory devices in a particular category. In these instances we have indicated our reservations about the existing choices in the hopes that new products will address the problems we believe are important. The reader should realize that if a vendor’s equipment has been mentioned in a negative light it indicates we at least thought highly enough of it to evaluate it seriously. We are not trying to damage any company’s reputation, merely insure that important information is shared equally.

The 11/780 UNIBUS adapter is the device most frequently shrouded in confusion. DEC documents variously give the bandwidth at between 1.2 MB/sec and 1.5 MB/sec when transferring through a buffered data path. We are not aware of any specifications for the unbuffered data path but have not been able to use it with some devices as slow as 50 KB/sec. One experiment we conducted involved examining the UNIBUS protocol lines with a scope while constantly transferring from a disk drive. We observed that while the drive was transferring at an average rate of about 1.2 MB/sec the UNIBUS was close to one hundred precent busy. This test was conducted on an otherwise idle system. No other devices were active on the UNIBUS and large disk transfers (cylinders) reduced any register set up time to a minimum. We conclude from this that 1.2 MB/sec is the *absolute maximum* transfer rate possible through a 11/780 UNIBUS adapter. Our observations showed that the largest delays while transferring data occurred while the buffered data path was being loaded or unloaded from the SBI. Since the UBA is controlled by a micro sequencer that is also involved in other UBA activities such as processing interrupts, we suspect that on an active UBA this bandwidth may be somewhat reduced.

Measurements of the available throughput to and from the 4.2BSD file system indicate a significant difference between disks running on the native processor bus (CMI or SBI) and those running on the UNIBUS. Average data rates are consistently lower on disks residing on the UNIBUS, even when the controller provides a few sectors of buffering. This leads us to believe that when average reads are 4-8 Kilobytes (the average block size of a 4.2BSD file system), most UNIBUS controllers will fall behind and eventually lose a revolution. This does not, however, seem to occur with the UDA50 UNIBUS controller as it has a much larger amount (16 Kbytes) of buffering†.

There are troublesome devices that cannot buffer enough data to guarantee that the maximum size record can always be transferred (6250bpi tape drives), or do not buffer an adequate amount of data (RK07 disk controller). To handle these devices UNIX provides a software interlock mechanism that prevents excess UBA contention.

The MASSBUS adapters are specified to have a higher potential bandwidth of 2.5 MB/sec. Since they are selector channels that allow only one device to transfer data at a time, the realized bandwidth is limited to the rate of the fastest device. The fastest devices currently available from DEC for 11/750 systems or 11/780 systems with a single memory controller transfer at 1.3 MB/sec. Large 11/780 systems with two memory controllers and interleaved memory may run RP07 disk drives that then transfer data at 2.2 MB/sec.* An interesting bandwidth limit may be established by the memory controller particularly on 11/780s. We suspect that the CPU may be slowed considerably by memory contention when two disk channels are being used simultaneously. This should be alleviated by using interleaved memory controllers.

The appendix to the *VAX Hardware Handbook* titled ‘‘System Throughput Considerations’’ seems to bear out these impressions and should be read carefully by anyone hoping to understand the consequences for VAX applications involving high bandwidth input or output. If we had data intensive applications we would seriously consider the use of RP07 disks (and interleaved memory controllers) because of the resultant higher burst transfer rate; this will be discussed further below.

MEMORY

All VAXes are sold with at least the minimum amount of DEC memory adequate to run diagnostics. Additional memory is the lowest risk alternate vendor choice. We buy the remainder of our 780 memory from Mostek, National Semiconductor or Trendata.* This area is extremely price competitive and there are at least six possible vendors. By all means, ask for competitive quotes. Assure yourself, however, that you are not the first customer for a new vendor.

Add in memory for the VAX 750 is a newer item and prices are not as low. However, this memory is almost identical to the 11/70 MK11 memory and several vendors have managed to build this product by

†A few of the initial UDA50 controllers were delivered with only 4 Kbytes of buffering. Avoid these.

* On machines with only one memory controller the RP07 hardware is arranged to transfer at 1.3 MB/sec.

* A list of second vendors and their phone numbers is given at the end of the document.

modifying their previous 11/70 add-in product. Trendata also has 1 Mbyte 64K RAM modules for both 750s and 730s.

Small quantities (one to two megabytes) are usually available off the shelf. Large quantities (4 megabytes and up) have taken less than 30 days.

For the 11/780 memory, the RAM chips are socketed, and two replacement chips per board are supplied by all vendors we mention; You can pull out the board and replace the chip at your leisure. Since single bit errors are corrected this has never involved any unexpected down time for us. There is at least a one year return to factory agreement on the boards, included in the purchase price. Out of warranty repairs are said to typically cost less than $300. We have returned only one board to the plant in about 30 board years.

When purchased from DEC, memory is much more expensive for any of the machines. Maintenance on a 1 Megabyte DEC memory module is $179 per month with board replacement through field service. The boards are not socketed. Delivery times on memory from DEC have typically been substantially longer than times from second vendors.

If you are going to have more than 4 megabytes of memory on your 780 you will need a CPU expansion cabinet and a second memory controller that includes a second half-megabyte of DEC memory.

There are two models of 11/750 memory controllers and backplanes around. The one currently being manufactured by DEC can be filled with either quarter Megabyte or full Megabyte modules for a maximum capacity of 8 Megabytes‡. The older memory controller and backplane can be populated with only quarter Megabyte modules for a total capacity of 2 Megabytes. To make matters even more complicated, 750s exist which have the newer style backplane and the older controller. These too will only hold 2 Megabytes of memory. The smaller capacity system can be upgraded to the larger one, but this is quite expensive; check with DEC before buying one, or be sure that you will be satisfied with a maximum of 2 Megabytes.

DISKS†

The area of disks and disk controllers is one which has seen a great deal of change since the last revision of this paper in mid 1981. At that time we had no experience with Winchester technology disk drives. Now, after some painful experimentation, we have settled on a few Winchester products which fill our needs reliably. We no longer buy, or recommend, any removable media disk products.

The choice of available controllers is also wider and much improved. High quality controllers are available which interface to the native busses of 750s and 780s as well as the UNIBUS. In addition, DEC has introduced an entire new storage system architecture which places a great deal more function in the controller, incorporates a new controller-drive interconnect, and uses improved error correction algorithms.

First, we will discuss some of the major areas of change in disk/controller technology. We will then explore how these improve, or otherwise affect, our methods of doing business. Finally, we will consider some specific DEC and non-DEC products.

The availability of large capacity, low cost, high reliability Winchester technology disk drives has had an enormous impact on us. The rack mountable, 300 Megabyte or bigger disk which was always ‘‘just around the corner’’ is really here. It is hard to see how we got along without it. We can now put about 2 Gigabytes of storage in the same footprint that previously held 256 Megabytes. In addition, we consume and dissipate about 25% of the energy we did with older, removable media, drives. The prospective buyer should be warned, however, that not all ‘‘winnies’’ live up to expectations with respect to reliability. We are happy with the reliability of the equipment we describe here. If you want to try something else, be sure and have some long heart to heart talks with other users of the product.

Cost per Megabyte of disk storage is down significantly. Cost ranges from $30 to $110 per Megabyte for disks, not counting the price of the controller(s). This value depends on the size of the units purchased and the choice of vendor. Cost per unit storage in terms of both purchase price and cost to operate are a

‡ It is important when mixing memory module sizes in VAX 11/750s to install the memory in consecutive slots beginning with the first and starting with the 1 Mbyte modules.

†Disk sizes shown throughout this document are in bytes of formatted space available.

stronger inverse function of the total drive capacity than ever before. For example, the cost per Megabyte of the 456 Mbyte DEC RA81 is about 35% of that of the 121 Mbyte RA80. The reason for this becomes clear when the drives are examined; many of the components are identical.

The higher recording densities of new disk drives has also been a strong motivator in controller evolution. One technique for increasing the recording density of the drives has been to rely more heavily on sophisticated error correction and block remapping schemes. No large Winchester drive can be depended on to be ‘‘error free.’’ In fact, most the drives we use have uncorrectable media defects. These locations must be remapped using some combination of controller firmware and handler software. In addition, the higher bit rates of new disk drives demand faster serial logic in the controller interface. Many older disk controllers are limited to the burst transfer rate of 3330 style disks of about 1.25 Mbyte/sec.

Two types of controller have evolved for the newer, high bit density disks. The first is simply a version of the traditional SMD or Storage Module Drive interface reengineered for higher data rates. This type of interface characterizes all of the non-DEC controllers which have been produced for VAXes of the last few years. These controllers interface to the native busses of the VAX (SBI or CMI) where possible to allow the higher data rates available to be passed all the way through to memory. Where the controller must operate on a bus incapable of a continuous transfer rate as high as the disk, some amount of internal buffering is provided to maximize the amount of date transferred before the disk ‘‘blows a rev’’.*

Non-DEC controllers most often emulate the DEC RH11, RH750, or RH780 interface. Some support for error correction is provided by the controller although a substantial assist is usually required from the system driver. Remapping of uncorrectable media defects is entirely handled by the driver. All 4.2BSD device drivers support bad block remapping. In addition, error correction and remapping support is, optionally, available in the standalone utilities†. The only part of the system which does not gracefully handle errors or media defects is the first level bootstrap code used on 750s.

DEC has produced a very different type of controller, partially to deal with the challenges of higher density disk drives. This controller, the UDA50, is an example of DEC’s long range plan for mass storage (this ‘‘plan’’ is called the Digital Storage Architecture, or DSA). One of the fundamental goals of DSA is to provide a standard set of disk ‘‘operations’’ across a variety of storage products. With DSA it should be possible to construct standard drivers which know very little about the characteristics or geometry of the actual storage devices they are dealing with. In order to meet this goal, error correction, bad block forwarding, and even the mapping of logical blocks onto the physical disk are handled in the controller. Requests to the controller typically consist of logical block addresses and counts, along with a memory transfer address. Responses then contain either data or a failure message. The controller independently takes all possible measures to recover data before returning failure.

In addition to increasing the functionality of the controller, DSA specifies a new controller to drive interface. The Standard Disk Interface, or SDI, is capable of handling the transfer rates of any drive which DEC may produce in the foreseeable future. This interface is implemented using four electrically isolated radial mini-coax cables to each disk drive embedded in a tough rubber-like umbilical.

On 750 and 780 systems we are, or will be, buying either large (404 Mbyte) Fujitsu disk drives and Emulex SBI or CMI interfaced controllers, or DEC UDA50 controllers with (456 Megabyte) RA81 disk drives. The choice here is not clear as the two packages are both attractive and each has a different set of advantages. Although we do not currently have any UDA50/RA81s at Berkeley, several users of 4BSD do have them, and are very satisfied. In addition, we have visited Colorado Springs, where the drives are manufactured, and run benchmarks on them using an early version of 4.2BSD. The preliminary measurements support our optimism about the UDA50/RA81 combination, though we are not yet ready to publish these results (they will be available at a later time).

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* * By ‘‘blowing a rev’’, we mean a data transfer can not be completed without extraneous disk revolutions. This is mainly a function of the time required by a processor to service an interrupt, the bandwidth of the bus, and the buffering in the controller. With the 4.2BSD file system, disk controllers are now being extended to their limitations, and beyond. This has significantly influenced our concern for the their limitations as bandwidth suffers greatly when such an event takes place.

† Due to limitations in the size of a binary image which may be placed on a boot cassette or floppy, the error correction and bad sector forwarding code is not included in the standalone utilities by default.

It is important not to place too much emphasis on raw performance issues when comparing products as similar in capabilities as the large disk choices presented here. Reliability, freedom from bugs, and ease of maintenance are equally if not more important to us. The value of the product in future configurations is also important. For example, the UDA50/RA81 disk system represents an early implementation of a new architecture. It incorporates many new features heretofore unavailable to us. In addition, it is expandable in the sense that the disk/controller interface is designed to handle future density increases which are not likely to be useable with the traditional SMD interface. On the otherhand, any implementation as new as the UDA50/RA81 is not as likely to be as bug free or as well understood as the traditional RH style interface architecture.

Table 1 indicates some of the tradeoffs as we now understand them.

When searching for less storage for smaller smaller systems, or where two arms are needed for performance and 800+ Megabytes of storage is overkill, another choice is required. Even at $50/Mbyte, a 404 Megabyte drive is not cheap. One of the authors has had good experience on a small 750 system with a 160 Mbyte Winchester disk drive from Tecstore and a National Semiconductor HEX-3000 combination tape and disk controller. We also know of successful use of the Spectra Logic combination controller on a 730 system. Using slightly less expensive disk drives and a combination controller one can obtain cost effective (< $75.00/Mbyte) storage in smaller amounts and provide a tape interface to boot (so to speak.)

TAPES

We use Emulex TC-11/P UNIBUS tape controllers and Kennedy model 9300-3 800/1600 BPI 125 IPS transports. Cipher tape drives and Wesperco controllers are also widely used. When purchasing second vendor equipment, one will also need cables and a rack in which to mount the tape drive. The Kennedy transport comes with a 15 month factory warranty. Our distributor exchanges/repairs the cards in the controllers based on a local diagnostic mode in the transport. After the warranty period, card swaps cost about $75. For transport mechanical failures the transport is returned to the factory in Monrovia, California, or we fix it ourselves.

George Goble at Purdue is using a 6250 tape system with UNIX. It includes a Telex 6253 drive (800/1600/6250 BPI) 125 IPS with a TELEX Formatter and an Aviv 1 board UNIBUS interface. The UNIBUS interface has 4KB of buffering, to help with bus latency problems, and it really appears to be necessary. The whole system cost him about three times what our 1600 bpi systems cost. The Aviv controller emulates a TU10 which is similar to the Emulex NRZ/PE controller. When heavy data transfer is done to the drive at 6250 bpi it uses the entire bandwidth of the UBA. This forces UNIBUS access through the UBA to be arbitrated by the operating system in order that the tape drive and a disk controller may coexist on the same UBA. **N.B.**: The driver for this controller/transport combination is not currently included in the standard 4BSD system but is trivially cloned from the TM11 handler which is a standard part of the distribution. Aviv also has a TM-11 compatible controller, the TFC 822, which supports both Kennedy and Cipher transports. This controller has more internal buffering than the Emulex TM-11 emulator and may be preferable for this reason.

Name	Speed	Densities
Kennedy	125ips	800/1600
Telex	125ips	800/1600/6250

Our original VAX system came in a package with a DEC TE16 on its own MBA. The TE16 is reliable but slow. The DEC TU45 is faster, but fraught with problems as the high maintenance cost reflects. The DEC TU77 is a good transport, but the auto-loading features do not seem to work well, and it is expensive. Finally, there is a relatively new product from DEC, a 1600/6250bpi 125ips tape drive, the TU78. This is the same transport as the TU77. We have two TU78s in use on campus with mixed results.

The UNIBUS tape drive, the TS11, is included in packages for the 11/750 except for the RK07 package system. It does not have a vacuum column, and is thus hard on tapes. It is a problem to load and has been

Criterion	UDA50/RA81	Emulex SC7?0/Fujitsu Eagle
Initial Purchase Cost − 750	UDA50 and 1st RA81 − $57.00/Mbyte w/o additional UNIBUS adaptor; $70.00/Mbyte with UNIBUS adaptor	SC750 and first Eagle − $55.00/Mbyte
Initial Purchase Cost − 780	UDA50 and 1st RA81 − $83.00/Mbyte with UNIBUS adaptor	SC780 and 1st Eagle − $65.00/Mbyte
Cost for Incremental Addition	Additional RA81s − $41.00/Mbyte	Additional Eagles − $32.00/Mbyte
Performance	May be somewhat better in mixed request, multi drive environment due to ordering optimizations possible in controller; software handler at present is suboptimal	Initial tests indicate 5-10% better single file throughput due to better sustained burst rate
Maintenance Costs	Very low − $111/Mo. for 1st drive and controller (compare to $326 for RM05)	Unknown but believed very low
Mean Time Between Failure	Too little experience available yet; RM80 is precursor of RA81 mechanically and has been quite good	Not a lot of experience on these yet either; initial experience looks excellent (smaller Fujis are phenomenal; 30,000 MTBF!)
Mean Time to Repair	Designed for quick field removal of HDA; easy to repair	Not as easy; more complex disassembly
Sources of Maintenance	DEC; maint. contract cheap, real, and available	Not so clear; ask for exchange contract from vendor
Robustness of Drive Interconnect	Incredible − electrical isolation and you could run over cables with a fork lift! Radial connection allows easy removal of a single drive	Same old SMD flat cables; daisy chain
Future Value	Early implementation of new architecture; if it pans out, likely to be compatible with future, high performance, products; DEC resale high anyway	High performance (stretched to limits) implementation of old interface standard; not likely to work again for next increase
Cost to Integrate	Handler is new; some initial bugs likely; probably a bug or two left in controller firmware too	Well known interface; much more likely to be bug free

Table 1. Large Disk System Comparison

found to be unreliable.

Name	Speed	Densities	
TS11	45ips	1600	(Not recommended)
TE16	45ips	800/1600	
TU45	75ips	800/1600	(Not recommended)
TU77	125ips	800/1600	
TU78	125ips	1600/6250	

TERMINAL INTERFACES

With a VAX you get 8 lines of DZ-11 that provide some modem control but are not DMA. We use the Able DH-11 emulator, the SuperMAX DH/DM, or one of the two Emulex DH-11 emulators− the CS-11 or CS-21. We also have tried the Intersil DH-11 emulator and know it to function satisfactorily. All of these provide DMA on output and modem control. The CS-11 is unusual in that it provides expansion of up to four 16 line DHs on a single UNIBUS hex module by placing the RS-232 support and UARTS out on the distribution panels and bussing these panels to the UNIBUS module with one ribbon cable. The CS-11 is an attractive solution where a very large number of lines will be connected to one machine since it reduces the number of cables, and UNIBUS backplane space and power required.

4BSD also provide support for the asynchronous serial portion of the the DEC DMF-32. This is the standard communications interface for the VAX 11/730 and has an additional feature of supporting both DMA and programmed interrupt operation for both input and output. The 4BSD driver currently does not use all this flexibility, treating it pretty much like a DH-11. The DMF-32 driver also works with the Able DMZ-11, a product which emulates the asynchronous serial portions of two DMF-32s.

In the area of non-DMA controllers from DEC, there are the DZ-11 and DZ-32 (a DZ-11 with full modem control).

Both the DZ's and the DH's have input silo's that UNIX can use to reduce interrupt load on input. The DMA output of the DH emulators is especially important for graphics applications where high-volume and continuous output occurs.

PRINTERS

One of the most exciting developments in the area of printers is the availability of desk top laser printers. This paper was printed on an Imagen laser printer we have been using, quite successfully, for several months now. The Imagen offers high resolution (240 dots/inch), uses plain paper, and seems to require minimal hardware maintenance. It is interfaced to one of our VAXes via a 19.2 Kbaud RS-232 line although a parallel interface is also available.

Among the problems with the Imagen are the small number of available fonts and the incompleteness of some of those which are available. In addition, the Cannon LBP-10 printing engine used has only a 200 sheet paper tray. Since the unit employs a wet process Xerography and smells a bit, it is not located in the same room as a person who might be responsible for refilling the tray. This inevitably results in print jobs backing up in a long queue until someone notices paper is needed. The Imagen folks were initially TEX oriented and their *troff* support contains glitches which are purported to go away with future releases of the software. We also hope to eventually interface our printer directly to the Ethernet; as soon as Imagen provides the necessary software to do so.

Another laser printer based on the Canon LBP-10 engine is produced by Symbolics. Symbolics offers both RS-232 and parallel interfaces to the printer. The Symbolics software is known to provide excellent software support for *troff*. We are are now evaluating a Symbolics printer.

QMS in Georgia has apparently solved the mysteries of the Xerox 2700 printer and is distributing an OEM version which might be a good choice. The major potential advantages here have to do with Xerox's size and extensive field support. The unit is dry process (unlike the Imagen and Symbolics) and has 300 dots/inch resolution. With any luck, we will also be evaluating this unit soon.

We have been using some Printronix 300 and 600 line per minute dot-matrix printers. The Printronix printers do point-plotting at 60 points per inch. They are not outstandingly cheap, but are ruggedly built.

The new Data Products B-600-1 is a 600 LPM band printer. We have one and are buying another. Although we had some initial problems getting the first unit into service, it now runs reliably and is our heaviest usage production printer.

PLOTTERS

Electrostatic printer/plotters that are capable of 200 dots/inch are usable both as plotters and as output devices for *troff*. We have an old model Varian that requires considerable care and feeding; newer models are said to be less of a headache. A new Versatec 11'' model sells for about $8,000. The objections to all these guys are that the paper tends to be wet sometimes, stinky, and more expensive than line printer ($20 per 1000 sheets). These are high maintenance items as are all heavily used hardcopy output devices we are familiar with. For *troff,* we now vastly prefer the Imagen laser printer mentioned above.

NETWORK INTERFACES

Networks can be categorized as *local area networks (LANs)* or *long haul networks* according to their geographical limitations. The most widely publicized local area network is the Ethernet. An example of a long haul network is the DARPA Internet which spans many continents and includes devices such as communication satellites for connecting disjoint *sub-networks*.

Among local area networks there are several competing modulation schemes. The Ethernet and several other networks uses *baseband* modulation techniques, while newer technologies, such as *broadband*, are available from other vendors. Some of the major differences between baseband and broadband technologies are maximum station separation, cable bandwidth, and, currently, per station connection cost. At this time, the least expensive, and most readily available local area networking hardware use baseband modulation. However, given the limitations inherent in baseband modulation schemes, companies are placing more work into developing low cost parts for use in broadband networks.

Aside from the question of baseband versus broadband, selection of medium is an issue. Coax cable is commonly used but types of coax vary. Broadband networks normally use the same standard 75 ohm coaxial cable used for CATV, while baseband uses 50 ohm cable. This implies that upgrading a network from baseband to broadband requires expensive installation of a new cable unless one thinks ahead, or your site already has installed cabling for in-house CATV use. Further, the best medium in terms of signal loss and noise immunity is fiber optic cable. However, due to problems such as tapping the cable, few vendors have selected this technology. If you plan to consider broadband at some time in the future, while at the outset using baseband, it is well worth the cost of the extra cable to run parallel 50 and 75 ohm coax.

In looking at network controllers, we will consider only the available local area networking hardware; our experience with long haul networks is limited to the Internet and so is of minimal interest.

There are at least four vendors with existing or announced Ethernet controllers, and with the soon to be available ''Ethernet chips'' more vendors may announce products. It is unlikely, however, that the Ethernet chips will significantly influence the current prices as the price of an Ethernet controller has already been driven down by the market competition. While the influx of new technology may not lower controller prices, it is sure to improve their performance and reliability.

We currently use 10Mb/s UNIBUS Ethernet controllers from both Interlan and 3Com. The two controllers have almost identical throughput characteristics with 4.2BSD, but neither have proven entirely satisfactory. The 3Com controller is the less expensive of the two. Its design is optimal for small PDP-11s and LSI-11s where the processor is resident on the same bus with the controller. The design employs 16 or 32 Kbytes of dual-ported RAM which is directly addressable as UNIBUS (or Q-bus) memory. While this is effective for machines such as the PDP-11 or LSI-11 where no penalty is required when accessing the on-board memory, with a VAX any memory access must be arbitrated by the intervening UNIBUS adaptor. The result of this is that accesses to the on-board memory are heavily constrained by the characteristics of the UNIBUS adaptor.

In accessing memory through a UNIBUS adaptor, all accesses must be performed on even byte boundaries and be no more than two bytes at a time. Consequently, one must either be very careful about the coding of a network interface driver, or the contents of any on-board memory must be copied into main memory before manipulating it. Due to the architecture of the networking subsystem included in 4.2BSD and the lack of control over the code generated by the VAX C compiler, constraining memory fetches was infeasible and the second alternative was taken. This implies that data must be block copied in to and out of the on-board memory a word at a time. The VAX *movc3* instruction is not usable in the UNIBUS address space, making this an expensive operation.

A second problem with the 3Com controller is that it lacks an on-board timer for implementing a backoff algorithm when accessing the Ethernet. This implies the host must perform a timing loop when backing off from a congested Ethernet. When an Ethernet is heavily congested this may prove to be very costly as no other processing may take place while the host timing loop is executing.

A third problem with the 3Com controller is that it does not allow a host to receive its own broadcast packets. This implies that broadcast packets must be captured in software. We consider this a serious deficiency as it prevents hardware testing without an auxiliary echo server.

The second Ethernet controller we have used is made by Interlan. This controller provides DMA access, as well as several desirable features such as on-board retransmissions. Unfortunately, while the DMA interface should be expected to provide higher throughput than the shared memory approach, using the Interlan interface we have been able to attain only comparable transfer rates to those measured with the 3Com interface. In addition, the controller consumes a significant amount of of +5 volt power. While broadcast packets are retrieved by the interface, the Ethernet CRC calculation is not performed.

We know of two other Ethernet controllers, one from ACC and one from DEC. We have two ACC controllers for evaluation, but have yet to gain any experience with them. The ACC controller is based on the UMC-Z80 and provides a DMA host interface. The DEC Ethernet controller was announced at the last DECUS meeting, but as of yet we know of none in customer hands.

To summarize the Ethernet controller situation, it appears the best strategy to follow is to wait for Ethernet chips to become widely available so the vendors can reengineer their existing controllers with minimal cost. If you require Ethernet access from your VAX now, you may wish to follow our approach: select the lowest priced product and treat it as ‘‘disposable’’ in the expectation that something better will eventually be available.

Other than Ethernet, the Proteon proNET 10 Mb/s ring network is also popular. This device is also known as the Version II lni ring network and is in heavy use at LBL and MIT with good results. The Proteon proNET outperforms both the 3Com and Interlan controllers mentioned above in throughput benchmarks run with the 4.2BSD networking support. Further, the ring design eliminates the standard complaints about ring architectures by use of a star-shaped ring configuration. The star-shaped ring allows easy addition and deletion of nodes without splicing drilling or taping. Also, any node can fail without bringing down the ring because it is bypassed at the star-shaped ring’s passive wire center. The major concern with a ring network is that it is incompatible with the de facto standard Ethernet. Cost per station is slightly higher than the Ethernet, but startup costs are lower (unless you use a fiber optic wire center). Proteon has announced they are working on an 80 Mb/s controller which should make the network even more attractive.

SOFTWARE SUPPORT

There has been increasing demand for 4BSD at commercial installations in a form less expensive and more digestible than a source license from Western Electric and an unsupported distribution from Berkeley. A number of companies, licensed by Western Electric to sell and support UNIX in binary form, are now distributing 4BSD. Some of these companies support 4BSD as an enhancement for their hardware offerings others deal only in software. Licenses from these vendors normally cost much less than a UNIX source code license. These companies usually try to make 4BSD more palatable to the non-academic community by providing more first-time user documentation and specialized consulting addressing specific customer applications. More formal software support arrangements than those offered by U. C. Berkeley are also available. 4BSD software sales and support vendors are included in the list at the end of this paper.

SYSTEM PACKAGES

We now present some sample system packages. Each represents a balanced system for timesharing use under UNIX. People often ask us how many users can be supported UNIX in these configurations. In the absence of specific information about applications to be run, this is an unanswerable question. The amount of load presented to the system by different applications varies widely. We mention with each system the count of interactive users typically supported in our university research environment.

We first present systems based on 11/750s and then systems based on 11/780s. With each example we suggest functionally similar systems configured in at least two different ways: first with as much equipment as possible from DEC and second with the best equipment known to us. We will not consider the VAX 11/730 as we believe it is not a viable option for most timesharing environments. Our experience with the 730 indicates it has approximately the raw processing power of a PDP-11/34 size CPU. Thus, even though it is a reasonable choice for people looking for an entry level VAX, we consider it mostly a single user machine.

Various measurements of the speed of the 11/750 and 11/780 indicate that the 11/750 executes at roughly 60 percent of the speed of an 11/780. By comparison, an 11/70 runs at roughly 75 percent of the speed of an 11/780 using the same benchmarks, which involve no floating point, no 32 bit arithmetic on the 11/70, and no system calls. For UNIX time sharing usage we believe that the 11/750 has better performance than an 11/70. This is due mainly to additional tuning and performance enhancements to the VAX kernel, and to the larger address space of the VAX architecture.

The first system we consider is a small 11/750. This is followed by an expansion of the 11/750 into a larger system. We are fond of the VAX 11/750 as it provides the most computational power per unit cost of the three VAX implementations.

The second base system is a small 11/780. We show how it can be built from a DEC RUA81/TU78 package system, and how to build it from mixed vendor equipment. We then expand it in two increments.

The small systems we suggest start with a single disk and tape controller and some memory. For time-sharing applications we configure our VAX systems allowing 256K bytes of memory for the kernel and roughly an additional 100k bytes of memory per active user.* Memory is cheap, especially for the 11/780, so we don't skimp on it.

With more than a few users, it is critical that more than one disk arm be present in the system. Thus all but the smallest systems include more than one disk. As the active user count rises, having more than one disk controller is also a good idea. The large system packages include two disk controllers. For really large and i/o intensive systems we recommend high bit density disk drives like the Fujitsu Eagle or the RP07 drive from DEC as they provide a higher transfer rate than the 1.25 Mbytes typical of the remaining drives. Using this transfer rate effectively requires running with interleaved memory.

It is desirable on all UNIX systems to have at least 100MB of disk space so that all the source for the system and all the standard programs may be kept on line with some room for locally developed programs. The amount of space required by user programs varies per installation; we manage to run many of our instructional/research machines using about 300-600 megabytes of space actively, although slightly more than this would be desirable.

Our large research machine runs with 1 Gigabyte of disk storage, with 2 disks on a UNIBUS and 2 disks on MASSBUS adapters. The weakest point in this system is that it has only a 45ips TE16 tape drive for backups. For even the smallest systems, 45ips will soon seem slow. We therefore recommend starting with a 125ips 1600bpi tape drive. As full 2400 foot tape reels hold only 30MB at 1600bpi, large systems should

* These numbers work reasonably well in an environment typical of University work (course work, paper preparation, debugging programs, developing applications for microcomputers, etc.) More demanding applications could require substantially more memory per user.

consider including at least one tape drive capable of writing 6250bpi tapes.

VAX 11/750 PACKAGES

We want to put together a small 11/750 system capable of supporting about 8 time-sharing UNIX users, and a larger 11/750 system for roughly 16-24 users. We need a minimum of 100 megabytes of space for the small system and a reasonable tape drive, preferably a 125ips unit so that tape operations can be done in a reasonable amount of time; if the system is to include only non-removable disks, we consider the faster tape system to be important. For the larger system, we wish to add disk space to give the system a minimum of 250 megabytes of space, and have more than one disk arm.

Small system

Small 750 System		
	DEC System	Mixed Vendor System
CPU	11/750	11/750 from Broker or Integrator with .50 Mbyte DEC Memory but 8 Mbyte capacity.
Memory	1 Mbyte DEC	1 Mbyte National/Trendata/Mostek
Disk System	UDA50 Unibus Controller RA80 121 Mbyte Drive	Emulex SC750 RH750 Emulator Fujitsu 134 Mbyte Drive
Tape System	TGE16 45 ips Tape Sys.	Emulex or Wesperco Controller Cipher or Kennedy 125 ips tape

The small DEC system is based on the SV-BXGMB-CA package, and includes an RL02 in addition to the RA80. We basically ignore the RL02 which is of little use to us and use the package because it is the cheapest way to get started. We add a TGE16 tape system as the best choice among a myriad of evils. It is really too slow, but it is reliable and not too expensive. DEC has been promising some better low cost tape units soon.

The mixed vendor system is as inexpensive as possible while retaining upward expandability. If the builder were sure that this system was not going to be expanded much then a substantial amount more could be shaved from the cost by making several substitutions. A National Semiconductor or Spectra Logics UNIBUS combination disk and tape controller could be substituted for the separate CMI disk controller and UNIBUS tape controller shown. A slower, perhaps 45 ips, tape unit with built in formatter could be substituted for the 125 ips tape drive. An older CPU with 2 Megabyte maximum memory capacity could be used. These are available for substantially less than the CPUs equipped with the newer memory controller and backplane. Even with these modifi cations, another disk and another Megabyte of memory could easily be added to produce substantial performance improvement. One advantage of the mixed vendor system as shown is that the Emulex SC750 controller keeps the disk drives off the UNIBUS. If an Ethernet controllers is added to the system, they will not be contending for the bus.

Medium system.

To expand this basic system to support more users, we would add additional lines, disk storage and memory. To the small all-DEC system we would add another RA80, another Megabyte of memory and a DZ-11E. To the mixed vendor system we would add another Fujitsu 134 Mbyte disk, an Able or Emulex DH-11 emulator and another Mbyte of memory:

Augmenting the Small 750 to a "Medium" System		
	DEC System	Mixed Vendor System
Additional Disk	RA80 121 Mbyte Drive	Fujitsu 134 Mbyte Drive
More Memory	1 Mbyte DEC	1 Mbyte National/Trendata/Mostek
More Serial Lines	DZ-11E	Able/Emulex "DH"

There are, of course, further expansion possibilities for the 11/750. These vary depending on the application but could include a floating point accelerator, more memory up to 8 Mbytes, and an additional UNIBUS adaptor on the DEC system if other high speed devices like network interfaces are to be on the UNIBUS along with the UDA50.

VAX 11/780 PACKAGES

For a system with more growth possibilities than an 11/750, faster processing, and higher i/o bandwidth, we recommend starting with a small 11/780. Our goal here is to start with a system capable of supporting 8-16 timesharing users and expanding the system to be capable of supporting roughly 24 users. We also consider a large expansion of this system, to a system that might support 32 to 40 terminal users to the exhaustion of available CPU cycles.*

Small system

For our small system we use 400 Megabytes of disk storage and a 125ips 6250bpi tape drive that will be capable of handling file backups if the system is eventually expanded. In our first expansion of this small system, we wish to add to the available space to a minimum of 800 Megabytes of disk storage, acquire at least two disk arms, and add additional terminal lines. In a large expansion of this system we include more terminals, an additional disk controller to get at least two separate disk channels, and an additional 800 Megabytes of storage for a total of 1600 Megabytes.

To build a small system from all DEC equipment, we would start with the RUA81/TU78 based system, the SV-AXECA-CA. This system includes 8 terminal lines, 4 Megabytes of memory, a 456 Megabyte disk drive and a 125ips 6250bpi tape. The system is equipped with two UNIBUS adaptors so that the UDA50 does not contend with other UNIBUS devices. To this we would add a floating point accelerator.

On the mixed vendor system we would substitute a Fujitsu Eagle 404 Mbyte disk drive on an Emulex SC780 SBI interfaced controller and an Aviv/Telex 6250 tape subsystem.

Small 780 System

	DEC System	Mixed Vendor System
CPU	11/780	11/780 from Broker or Integrator with .25 Mbyte DEC Memory and UNIBUS Adaptor Included
Memory	4 Mbyte DEC	4 Mbyte National/Trendata/Mostek
Disk System	UDA50 Unibus Controller RA81 456 Mbyte Drive on own UBA	Emulex SC780 RH780 Emulator Fujitsu 404 Mbyte Drive
Tape System	TEU78 125ips 6250 ips Tape Subsystem	Aviv Controller Telex Drive/Formatter
Serial Lines	DZ-11A	Able/Emulex ‘‘DH’’
Other	DEC Floating Pt. Acc.	DEC Floating Pt. Acc.

Medium system

To expand this basic system to support more users and get additional disk space, we would add additional lines and disk storage.

* Using systems similar to the largest shown here, in an environment consisting of small student programming some sites have reported running up to 70 interactive users; CPU cycles are the critical resource with this many users.

Augmenting the Small 780 to a “Medium” System		
	DEC System	Mixed Vendor System
Additional Disk	RA81 456 Mbyte Drive	Fujitsu 404 Mbyte Drive
More Serial Lines	DZ-11E	Able/Emulex “DH”

Large system

To form a system with the emphasis on handling of data-intensive applications, and to emphasize total growth of the system, we would add a second disk channel and interleave memory to increase i/o throughput and reduce average CPU memory access as much as possible. In both the DEC and mixed vendor systems a CPU extension cabinet would be required in addition to another DEC memory controller. We would fill out the second memory system to 4 Megabytes.

For more disk throughput, we would add an REP07-AA 504MB disk drive on a MASSBUS controller to the basic DEC system. This disk provides a very high burst data throughput and could share the MASSBUS Adaptor of the Tape Unit with only minor performance loss while the tape unit was being used.

To accomplish the same ends with the mixed vendor system, we would simply add a second Emulex SC780 disk controller channel and at least one more Fujitsu Eagle 404 Mbyte disk drive.

Augmenting “Medium” 780 to “Really Big” System		
	DEC System	Mixed Vendor System
Additional Disk and Channel	RP07 (516 Mbyte) on MASSBUS with tape sys.	Fujitsu Eagle (404 Mbyte) on another SC780 controller
Second Memory Controller and Cabinet	DEC	DEC
Additional Memory	DEC	Trendata/National Mostek
More Serial Lines	DZ-11E	Able/Emulex “DH”

SUGGESTIONS ON BUYING HARDWARE

The are a variety of ways in which you can acquire the systems we have suggested here, whether they be all DEC or mixed vendor. Your choice of acquisition methods depends on a number of factors including:

- How much can you afford to pay?
- How long can you wait?
- How much risk and responsibility are you willing to assume for integrating your own hardware components?
- What kind of maintenance is available to you?
- How much help you need in integrating 4BSD?

Here is a simplified breakdown of the possibilities:

1. **Buy as much as possible from your DEC marketing organization.**

   Although this solution, in our experience, takes the longest and costs the most, it has its advantages. DEC is likely to ship you a well tested, integrated system, close to the time initially promised. In most cases they will support you well through any initial start-up problems with the hardware. The system bought this way will automatically be accepted for a DEC maintenance contract. Of course, the can’t help you much with 4BSD (yet). Also, they are not likely to be very flexible about adjusting their configuration to your needs.

2. **Buy an all-DEC system from a an OEM specializing in 4BSD**

   These OEMs are a relatively new phenomenon. They usually get a much better discount from DEC on hardware and can pass part of this through to you in terms of UNIX expertise as well as reduced cost. Sometimes they will be able to deliver hardware quickly when DEC is telling you months. Since they sell largely DEC systems, you can still take advantage of DEC Field Service and most systems sold this way are guaranteed acceptable for a DEC maintenance contract.

3. **Buy a mixed vendor system from a systems integrator**

   DEC has had a long love/hate relationship with people who specialize in building systems which use DEC’s CPUs and other manufacturers peripherals. We think these integrators serve many useful functions. First, and foremost, they often build a cheaper and better system, frequently on short notice. Second, they keep DEC honest. Sometimes we feel they should charge for their quotations, since these are often used advantageously to encourage DEC to come down to a more reasonable price on a system.

   Don’t assume mixed vendor systems are not maintainable. There is a whole spectrum of maintenance possibilities for these systems, particularly in major metropolitan areas. If you are considering this route, be sure and spend some time on the phone with the customers of your prospective vendor. Insist on the names of *long term* customers, and talk a lot about maintenance experience. The folks we mention on the last page of this paper are known to have experience with 4BSD.

4. **Integrate the mixed vendor system yourself**

   If you are qualified for this adventure, then you probably know who you are. We can’t begin to tell you all the pitfalls. Start small. Buy a mostly integrated system and add something you can afford to have not work for a while, such as more memory (almost too easy), or a better tape drive, or more terminal interfaces. If you really want to do the whole thing, finding the CPU is one of the harder parts. Get yourself a copy of *Computer Hot Line*. You can probably get a complimentary copy by calling them at (800) 247-2244. This is the social register of computer brokers and a substantial portion is dedicated to folks selling new and used DEC. (Hot Line, Inc. also distributes the Farm Machinery Hot Line and several other classified flea market variety publications. They can not be expected to control the content of adds. Use at your own risk!)

We would like to make two more observations about buying equipment. It has been our experience that the service you will receive from your source is directly proportional to the risk in using that source. Further, the service often is inversely proportional to the sources size. Loosely translated, little guys work harder.

Many who have dealt with DEC sales report disappointing experiences. Lack of product knowledge and inability to bend to customer needs are typical complaints. This is not to say that there are not excellent DEC sales people. There are. And you must remember, when you finally close that deal with your DEC salesperson, **it will be delivered,** eventually.

On the other hand, the systems integrator who builds one or two systems a month typically succeeds or fails based of the experiences of his small customer base. We have known many of these folks to make superhuman efforts to pull together a customer system, often succeeding without half the resources available to DEC sales people. They are also much quicker to pick up trends like an interest in 4BSD and start to mold their services to fit. Once again, there is always the exception, the ‘‘Unix Systems Integrator’’ who couldn’t tell an inode from a tree toad. If you go this route, you have a good selection to choose from. **Spend time talking to previous customers.**

CONCLUSIONS

We have presented sample VAX systems over a wide performance range using both all-DEC and the best available second vendor equipment, emphasizing, independently, minimal cost and maximal expandability. Use this information wisely; price shouldn’t always be the bottom line.

Consider the all-DEC system if you can afford it. If not, the second-vendor equipment in the packages here is all thought to work well on VAX hardware. You can reliably build and operate such a system. When you have struggled through your particular set of difficulties and are up and on the uucp network, be sure and write us about your experiences. Good luck!

ACKNOWLEDGEMENTS

This document represents a lot of work. It would have been easier, except for everyone who sent us helpful hints and suggestions and, in general, kept us honest. In particular, we would like to acknowledge all those vendors who were patient with us, especially those whose products were ultimately not included. George Goble at Purdue made several helpful comments which greatly improved the content of the document, and his experiences with Fujitsu Eagles has made a significant impression on us. The DEC DSA engineering team in Colorado Springs, including Paul Massiglia, Bill Grace and Chuck Hess were particularly generous with their time and energies. Peter Weinberger of Bell Laboratories shared his experiences with the UDA50/RA81 with us. Kirk McKusick spent time traveling to Colorado Springs to aid in evaluating the DEC RA81 disk drive. David Mosher has worked diligently as the purchasing agent for CSRG and also contributed to our understanding of the subtler points of disk manufacturing and operation. Jim Reeds gave the paper a careful proof reading and found many oversights.

VENDOR REFERENCES

Manufacturer	Product	Phone	Vendor contact
3Com	Ethernet Cont.	(415) 961-9602	3Com (Mike Hallaburka)
Able	Async. Mux	(714) 979-7030	Able Computer (Norm Kiefer)
Aviv	Tape controllers	(619) 247-6844	Aviv (Ed Hagenbuch)
Data Products	Printers	(415) 948-8961	MQI Associates (Avery Blake)
Emulex	Controllers	(415) 820-2933	Eakins Associates (Bob Sigal)
Fujitsu	Disks	(415) 969-5109	Eakins Associates (Bob Sigal)
Imagen	Laser Printers	(415) 960-0714	Imagen (Bob Wallace)
Interlan	Ethernet Cont.	(714) 752-4002	Interlan (Gary Steadman)
Intersil	Async. Mux	(408) 743-4300	Intersil (Alan Truscott)
Kennedy	Tape Transports	(408) 245-9291	Electronic Marketing Specialists
Mt Xinu	4BSD Binary Sales	(415) 644-0146	MtXinu (Bob Kridle)
National	Memory	(800) 538-8514	National (Don Johnson)
National	Disk/Tape Cont.	(800) 538-8514	National (Don Rudolph)
NMS	Disk/Tape Sys	(415) 443-1669	NMS(Bob Crippen)
Printronix	Printers	(408) 245-4392	Group III Elect. (Scott Drzewiecki)
Proteon	Network Cont.	(617) 894-1980	Proteon (Al Marshall)
Spectralogics	Disk/Tape Sys.	(415) 443-1669	Nat. Mem. Sys. (Bob Crippen)
Symbolics	Laser Printer	(415) 494-8081	Symbolics (David Shlager)
Tecstore	Disks	(408) 732-2143	Tecstore (Mel Feintuch)
Trendata	Memory	(714) 540-3605	Trendata (Miles Efron)
Varian	Plotters	(408) 733-2900	Varian (Ted Downs)
Versatec	Plotters	(415) 828-6610	Versatec (Bruce Fihe)

SYSTEM INTEGRATION/SUPPORT

Name	Phone	Contact	Notes
VLSI	(415) 490-3555	Joe Voelker	Mixed Vendor Systems and Support
IDS	(408) 738-3368	Dick Cavanaugh	Specialize in All DEC Systems
Eakins Assoc.	(415) 969-4533	Bob Sigal	Mixed Vendor Systems and Support
IPS	(713) 776-0071		Mixed Vendor Systems
Iverson Inc.	(415) 459-5665	Jon Iverson	Mixed Vendor Integration
UNIQ	(415) 362-0470		All DEC Systems