SESSION II INVITED ADDRESS

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Buying and maintaining microcomputer systems

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The purchase and maintenance of new and used mini- and microcomputers require knowledge of the comparative advantages and disadvantages of available systems, sources of discounted and used computers, and a set of strategies and techniques for maintaining the operation of the computers throughout their useful life. This paper addresses each of these areas and suggests sources of additional information.

Decreasing costs and the increasing reliability of microcomputers have led many psychologists to purchase or consider the purchase of one or more microcomputer systems to replace or supplement existing instructional, laboratory, and/or word processing equipment. The selection of a system at the lowest possible price and the maintenance of the system are major concerns that require the development of skills that may be unfamiliar to academic or research-oriented scientists.

A thorough discussion of the factors affecting the selection of a particular system to fulfill a specific requirement is beyond the scope of the present paper, however, the major computer magazines, such as *Byte*, *Kilobaud*, *Interface Age*, *Creative Computing*, *Compute*, and others, frequently publish tables of technical specifications that facilitate a feature-by-feature comparison between systems, as well as advertisements by virtually every vendor of new and used equipment.

The availability of applications software that will run on the system is a major concern. Unless the purchaser is willing to invest hundreds or thousands of hours of in-house software development time, the availability of adequate software will probably be a major deciding factor.

The maintenance history of a given system is also an important consideration. Unfortunately, virtually no information on the breakdown records or service histories of various systems is available, and what little information exists is mostly anecdotal. Manufacturers and the magazines in which they advertise are understandably reluctant to publish breakdown statistics for customers or potential customers to read.

Conferences such as the National Conference on the Use of On-Line Computers in Psychology bring potential

purchasers into contact with seasoned users, and the hallways resound with heated arguments about the relative merits of Apples, Radio Shacks, PETs, and DEC's. Sessions in which users discuss mistakes and problems with hardware and software serve to forewarn potential purchasers about typical problems and help them to make final system purchasing decisions.

Once a decision is reached, the purchase of a computer system requires a new set of skills. First, the departmental or grant budget must be consulted to determine whether a new computer can be purchased or whether a used system must be located. Second, a surreptitious analysis of college and purchasing department regulations must be made to determine whether special restrictions apply to the purchase of computer equipment. Many purchasing departments seem to have alarm bells that ring whenever the word "computer" appears on a purchase order and such terms as "state-approved computer system," "registered state vendor," "competitive bidding," or simply "order rejected" appear on memos. Techniques for circumventing the bureaucratic controls that ensure that no innovative or modern computer equipment can be purchased typically involve the judicious use of semantics.

Purchase orders must be written in such a way as to eliminate the use of such words as "computer," "data analysis," "disk drive," "programmable," and so on. In some schools, it is adequate to call a TRS-80 microcomputer a "logic system for experimental control" or a "student operant behavior station." Other schools with really clever purchasing departments or limited budgetary categories require that a system be purchased as "miscellaneous secretarial supplies," "typewriter repairs," or "laboratory chow and bedding." Most of the smaller

computer dealers are willing to invoice for such items as long as it has been arranged in advance. Smaller independent computer dealers advertise in the popular computer magazines mentioned previously, and many are also listed in the section below dealing with sources of used equipment. Because advertisements are expensive, the size of the ad usually indicates the size of the dealership.

USED COMPUTERS: PROS AND CONS

Shrinking budgets and the increasing reliability of small computer systems make used computers a viable alternative to new systems. But the pros and cons of used equipment and maintenance techniques and strategies must be carefully weighed before making a final decision.

The advantages of buying a used computer include lower price, a "burned-in system," and, usually, the availability of an entire system, including software, for a much lower price than the components would total if purchased individually. The disadvantages include an unknown operating and maintenance history and possible difficulty in obtaining a factory maintenance contract.

Used computer systems and peripherals can be purchased from many sources at savings of 25% to 99% off list prices. It is often possible to telephone 5 or 10 dealers and find prices ranging from 25% to 50% off original price. The variation in prices may reflect the purchase prices paid by the dealers, the greediness of the dealer, or hidden options, such as late-revision circuit boards or later model numbers or serial numbers. To shop intelligently for a computer, it is important to know as much as possible about the system and its manufacturing history. For example, the DEC PDP-11/34 is available in two versions: 11/34 and 11/34A. The price of the 11/34 is about \$4,000 less than the 11/34A, but the 11/34 cannot support the hardware floating-point package. Older Radio Shack TRS-80 computers have mechanical keyboard contacts that occasionally produce multiple letters. Later models use sealed contacts and newer, improved read-only memory programs, and the latest units include a lowercase character generator.

The first step in purchasing a used computer is to learn as much as possible about revisions, models, options, serial numbers, and price trends. This information can usually be obtained directly from used equipment dealers. These dealers will generally try to sell the most expensive computer in stock, and in the process, they will explain how the various models differ. You can then weigh the advantages of later revisions against lower prices and make an informed decision.

If at all possible, some form of guarantee should be extracted from the dealer. Some of the larger dealers, such as Newman Computer Exchange and American Used Computer Company, have fairly good guarantees. Purchasing a computer from a smaller company or an

individual is more risky, but you can still demand a written guarantee and request all of the available service invoices; sometimes you can even obtain the types and frequencies of service calls.

Most manufacturers of mini- and microcomputers offer service contracts that can apply to used systems, even after ownership has changed and the initial warranty period has expired. They usually require an on-site inspection, and sometimes they require that they bring the system up to current specifications by performing the latest circuit revisions or "engineering change orders" (ECOs). For a large system, this is usually the most practical way to obtain reliable service. For the smaller, more reliable systems, paying for maintenance on a per-call basis, keeping a spare system on hand, and learning some of the maintenance tricks presented later in this paper are usually much less costly. A spare microcomputer typically costs less than the annual cost of a maintenance contract on 10 microcomputers and much less than a service contract on a minicomputer.

Second-source maintenance, in which an independent company does the service, is usually significantly less expensive than factory service. One problem is that second-source companies are usually less familiar with the specific problems of a particular computer and may take much longer to fix it. This increase in repair time may make the cost of repairs exceed the price of factory service. Most academic institutions have an electronic shop that can perform routine maintenance at a considerable savings. If there are other similar computers in-house, you can often arrange to swap major components or circuit boards, which should simplify the isolation of the problem. These options can make up for the absence of an original purchaser warranty or even a service contract, and they should help make a used computer a viable option.

USED COMPUTERS: SOURCES

Sources of used computers vary widely from huge corporations to tiny basement or attic entrepreneurs. The two giant companies, Newman and American Used, usually have a very large stock of minicomputers but do not, at this time, deal heavily in microcomputers. They are very reliable sources of equipment and can be counted on to provide a working system and to fully honor their guarantees.

The *Computer Hot Line* is a thick newsletter-format publication that lists thousands of dealers, systems, and purchaser's needs. You can run a free "want-to-buy" ad in this publication and locate almost any kind of system within a few weeks. This is the place to look for names of dealers and to familiarize yourself with the marketplace. A free sample issue is usually available by calling their WATS phone number. The *Processor* is a similar but smaller publication.

Another publication that serves the used computer

market is the *Computer Shopper*, which contains thousands of classified ads for microcomputers, minicomputers, systems, peripherals, software, and services.

The largest source of used computer equipment in one geographical area is the Trenton Computer Festival (Trenton, N. J.). It combines an excellent microcomputer exposition with a huge 5-acre flea market in which incredible (as-is) bargains can be found. Prices as low as 1% of original cost are common. For example, I bought three fully functional 8-KB PDP-8/e computers with programmers' panels and serial interfaces for \$50 each in 1981. Unfortunately, the festival meets only once a year in April. Its nearest rival, the annual New Jersey Microcomputer Show, held at the Holiday Inn at Newark airport, is much smaller, although it had over 200 dealers in its flea market area in 1981. Amateur radio operators, or "HAMS," have been holding "ham-fests," which include electronic equipment flea markets, for many years. Now, most HAMS have become avid computer hackers, and their flea markets consist of at least 25% computer equipment. These flea markets are held throughout the United States during the warmer months and can be located by reading any of the amateur radio magazines, such as *CQ*, *73*, *QST*, and *Ham Radio*.

Computer bulletin boards and local club or users' group newsletters often turn up elusive pieces of equipment. The advertisements on timesharing systems bulletin boards are usually full of bargain-priced computers and peripherals. Micronet, a timesharing network run by Compuserv, charges \$5 to a Visa or MasterCard account for each connect hour and has dozens of local telephone numbers. It provides anyone with an ASCII terminal and modem access to hundreds of constantly changing classified ads and the opportunity to post free want-to-buy or help-wanted ads.

Dealers such as Fair Radio, Herbach and Rademan, Poly Paks, and Rondure, and hundreds of others that advertise in the computer magazines, have large and varied stocks of peripherals and components at extremely low prices. These dealers all publish catalogs that are available free and that should be useful in establishing the current market value and availability of equipment.

In most cases, used equipment is priced high by dealers in expectation of a naive or foreign customer who has not shopped around for the lowest prices. You can almost always play one dealer against another and bargain the prices down by 10% to 50%. Always offer less than the asking price, and you stand a good chance of having your offer accepted. If you are willing and able to personally push a pay order through the accounts payable department and guarantee rapid payment, you can often bargain the price down further with smaller dealers who usually have to wait 1-6 months for payment from schools.

With these comments and suggestions, you should be able to approach the purchase of a used computer with confidence and save a large percentage of the original price.

IMPROVING SYSTEM RELIABILITY

Before discussing maintenance and repair strategies, a few general techniques for improving system reliability and preventing breakdowns may be helpful. Since many system failures are the result of broken, dirty, or physically overstressed interconnecting cables, careful planning of the layout of a computer system and its peripherals is important. To prevent stresses on cables or connectors, the system components should be permanently located in such a way that they will not have to be moved. When necessary, cables should be clamped or at least taped to system cabinets to relieve any stress on the connectors.

Regardless of how many ac line filters are used to eliminate high-voltage transient spikes from the ac power lines feeding the computer, some types of power-line surges can still get through, with possibly catastrophic results. Lightning strikes produce extremely high voltages and currents and can totally destroy entire computer installations. One of my friends had every integrated circuit explosively blown off all circuit boards of his entire TRS-80 system when lightning hit power lines 1 block from his house. Not a single component of his system was turned on at the time, and the lightning must have jumped across all of the power switches. I had 15 ICs blown out on my PDP-8/e when lightning hit the power lines 3 miles from my house. It should be an absolute rule to keep all line cords of a computer system in an ac power distribution strip and to unplug the cable to the strip whenever storms occur or the system is left unattended.

A related problem that drastically affects system reliability is static electricity build-up as personnel walk on carpets on dry days. Tens of thousands of volts may be discharged through a computer system in this way. This will produce, at best, loss of data bits and, at worst, major system failures. Elaborate and expensive electrically conductive grounding mats are available to place on the floor around a system, and some servicemen wear a grounded metal wrist bracelet when working on a system. Neither method can fully protect against a highly charged person walking in and touching the system. One protective technique known only to a few computerists is much less expensive and cumbersome. Joy kitchen detergent sprayed on a carpet will eliminate static build-up for weeks.

Another frequent cause of system unreliability is electrostatic and electromagnetic interference. Most microcomputers are built in plastic boxes through which this interference can pass freely. An example of such interference is the slow wavering of lines of text on one microcomputer's video monitor when it is operating too close to another monitor. Other examples include lost data and programs when high-voltage spikes from wires feeding motors or large solenoids pass through the plastic computer case and are inductively or capacitively coupled into the circuitry. The simplest cure for

such problems is to use grounded aluminum foil shielding while being careful not to block ventilation holes. A neater and more satisfactory "fix" comes from spraying the inside of the plastic case with very low-impedance conductive paint and electrically connecting the paint layer to chassis ground. XECOTE is the trade name of a paint that provides 60 dB of attenuation and an impedance of 1 ohm/in. It is available from Metex Corporation at either 970 New Durham Road, Edison, New Jersey 08817, or 20437 S. Western Avenue, Torrance, California 90501.

Mistreatment of magnetic mass media, such as cassette tapes and diskettes, is a major source of system failures. They must be carefully protected from dirt, stray magnetic fields, and physical abuse. A diskette placed on a plastic-cased video monitor will frequently lose some data, and a pencil dropped from a height of only 1 in. can produce a dimple that will destroy the disk and make data unreadable. The solution is to arrange and organize the computer system so that diskettes never need to be put down. They should go directly from their dust jackets to the disk drive and back.

SIMPLE REPAIR AND MAINTENANCE TECHNIQUES

Carefully following the preceding suggestions should produce a major improvement in system reliability, but, sooner or later, maintenance will probably be required. Computer users seldom have the interest or expertise to perform even routine preventive maintenance on their systems. When problems arise, users are often faced with downtime while they wait for service personnel to arrive, diagnose, and repair the hardware. Microcomputers, with their low cost and high reliability, make it possible to simply exchange components and peripherals until the faulty component is isolated. However, a working knowledge of some of the special tricks used by computer field service personnel helps to reduce downtime and increase the time between service calls.

Service technicians often seem unwilling to explain diagnostic and repair techniques to computer users. The good ones develop a set of tricks that work frequently enough to impress clients and superiors. But technicians jealously guard these secrets. Several of these tricks are widely applicable and can be used by even the most unsophisticated end user. Technicians who repair or fail to repair the same type of system day after day develop a catalog of symptoms and cures. These specific tricks are seldom available to end users unless they carefully cultivate a relationship with the service technician. With proper application of reinforcement during the relationship, a technician will sometimes provide a diagnosis or advice over the telephone. (Learning of the effects of the microscopic cracks in Apple circuit boards due to flexing and of the problem with cracks in the plated-through holes that supply 12 V to the memory chips is an example.)

Virtually every model of computer has specific hardware weaknesses that lead to predictable types of breakdowns. A concerted effort to ask as many owners, dealers, and service personnel as possible about the "typical" or "common" problems associated with your system will provide a list of probable causes to help diagnose and repair your system.

GENERAL DIAGNOSTIC AND REPAIR TECHNIQUES

If the cause of a system failure is not immediately recognizable, a set of general diagnostic and repair strategies and techniques can be employed to localize the problem. The first step is to determine exactly when the breakdown occurred, what happened, and whether there was any obvious cause that could help narrow the search for damaged components. If, for instance, the breakdown occurred when someone tripped over a cable, replaced a circuit board, or hooked up an interface, look for damaged cable connectors, improperly seated boards, or incorrect voltages applied to the interface.

If no specific cause can be determined, a set of general diagnostic techniques must be used to localize the problem. Probably the most frequently overlooked diagnostic technique involves a careful visual inspection of the entire computer system. Broken, cracked, pinched, or burned cables, connectors, and components can frequently be spotted visually before any electronic troubleshooting is required. If a careful visual inspection fails to reveal the source of the problem, tapping circuit boards and connectors with a heavy insulated tool will often reveal intermittent solder connections and wiring.

The most frequent source of failure in electronic systems is interconnecting cables and connectors. As the amount of current drawn across the contacts of connectors decreases from the several amps required by relay circuits to the milliamps of TTL circuits to the microamps of CMOS circuitry, the microwelding of connector contacts also decreases. (Microwelding is the physical bonding of two contacts produced by current flow.) With decreased or nonexistent microwelding, many older style connectors, especially those designed for higher current applications, cannot provide reliable, low-impedance connections between components. Gold plating helps to reduce this problem, but tiny amounts of residue from grease or cigarette smoke in the air often make even gold contacts unreliable after variable periods of time. Many manufacturers have dispensed with gold plating as an economy measure.

One top field service technician for DEC has reported that he can cure over 50% of his service calls using only a pencil eraser. The moderately soft red rubber eraser is rubbed over all accessible pins of card-edge and other types of connectors so as to remove residue and slightly burnish the contact fingers. The eraser is soft enough to avoid removing the thin gold plating but firm enough

to remove residue. Most top technicians distrust the so-called contact cleaners and prefer the eraser technique and an ordinary nylon toothbrush to remove eraser shavings.

The Radio Shack TRS-80 microcomputer is connected with its expansion interface and disk drives by ribbon cables and card-edge connectors that are not gold plated. Many cases of mysterious memory losses, rebooting, and nobooting of the disk have been eliminated by the eraser treatment. Often, removing and reinstalling the connector a number of times will fail to solve the problem, but a thorough eraser treatment will provide a long-lasting cure. One enterprising company, recognizing this universal problem, offers a kit of solder-on gold contact-finger replacements. Even the infamous key-bounce problems of the old-style gold contacts in TRS-80 keyboards and intermittents in Apple plug-in cards can be fixed by the eraser technique. The pins of socketed integrated circuits also suffer from these problems, and the eraser burnishing of the pins of memory chips sometimes will bring memory on-line again.

Connectors frequently fail internally due to mechanical fatigue or stress placed on their cables. They should be removed or attached only by their casings, and the cable should never be pulled or twisted as an aid in removing the connector. Connector failures may be characterized by intermittent or sudden catastrophic malfunctions but can usually be replicated by wiggling the connector or cable. After disconnecting the cable from the computer, a careful ohmmeter checkout of every pin, coupled with simultaneous flexing of the cable and connector, will usually pinpoint the location of the problem. Insulation displacement connectors that are crimped over ribbon cables frequently open up slightly and allow the connections to separate. Sometimes a simple fix can be obtained by squeezing the connector in the flat jaws of a vise to force the cable back down onto the contacts, but too much force can cut through the cable wires.

Other general diagnostic techniques include a careful search for possible solder balls that, after a period of time, may short out the narrow spaces between tightly packed printed circuit board traces. A stiff toothbrush rubbed vigorously over the soldered side of a printed circuit board will often remove solder balls and return a circuit board to working condition. Solder balls and hairline-cracked traces on circuit boards can often be diagnosed by watching for intermittent operation while carefully flexing the circuit board.

Another useful trick for dealing with stubborn intermittent circuit and memory problems is to boost the +5-V regulated voltage power supply to +5.15 V. This is particularly useful with CMOS circuits, in which the additional voltage results in negligible additional heat dissipation but often significantly improves the operation of the circuit. One major mainframe manu-

facturer recommends this as a routine procedure for all of their computers. The same company's chief field service technician reports considerably improved reliability. There is often a slight resistance in the wiring from the power supply to the circuit or memory board. So it is important to measure all voltages at the chips on the circuit board rather than at the power supply. Power supplies sometimes have to be set slightly high to compensate for voltage drops in the cabling to the circuit boards.

High temperatures frequently produce intermittent operation in logic circuits. Temperature problems usually develop at some fairly consistent time after the equipment has been turned on and can be precipitated by reducing cooling airflow across circuit boards. A hair drier will allow selective heating of individual chips to aid in determining which chip is heat sensitive. Cooling sprays can be used to cool suspected chips and restore operation, but few technicians use cooling sprays because of the moisture that immediately condenses as they are used. This moisture can conduct voltages and provide alternate current paths that may obscure circuit problems and make diagnosis more difficult. In critical situations, I cool a suspected integrated circuit chip by resting an ice cube wrapped in a plastic bag on its insulated plastic or ceramic case.

SUMMARY

I hope that these remarks will be helpful in improving the reliability and longevity of computer systems. One book that summarizes some of these techniques and provides many more ways of diagnosing and repairing electronic circuits is the *Electronic Technician's Handbook of Time-Savers and Shortcuts* (Grolle, 1974). Of course, many other techniques have been developed. I hope that this paper will encourage others to share their favorite and valued maintenance techniques with other computer users both at future conferences and in the pages of *Behavior Research Methods & Instrumentation*. And finally, always remember: "If it works—don't fix it!"

REFERENCE

GROLLE, C. G. *Electronic technician's handbook of time-savers and shortcuts*. West Nyack, N.Y.: Parker, 1974.

APPENDIX

SOURCES OF USED COMPUTER EQUIPMENT

American Used Computer Group

Box 68, Kenmore Station, Boston, Massachusetts 02215. (617) 437-1100. One of the largest sources of used minicomputers and peripherals.

Newman Computer Exchange

1250 North Main Street, Ann Arbor, Michigan 48107. (313) 994-3200. Very large stock of minicomputers, peripherals, odd units, and a few used microcomputers from time to time.

Computer Hot Line

Box 1373, Fort Dodge, Iowa 50501. (800) 247-2247. The most complete listing of dealers, used minicomputers, peripherals, large mainframe computers, and a few microcomputers.

The Processor

Box 518, Webster City, Iowa 50595. Similar to the Computer Hot Line.

The Computer Shopper

Box F, Titusville, Florida 32780. (800) 327-9920. Thousands of classified ads listing used microcomputers and minicomputers, peripherals, software, test equipment, and so on. It is probably the most comprehensive listing of small systems. \$10/year.

Trenton Computer Festival

Contact the Amateur Computer Group of New Jersey, UCTI, 1776 Raritan Road, Scotch Plains, New Jersey 07076. This is the largest outdoor computer flea market, with 5 acres of computer enthusiasts selling everything from micros to macros, lasers, terminals, software, ICs, and so on. Usually held in April at Trenton State College.

New Jersey Microcomputer Show

Kengore Corporation, 3001 Route 27, Franklin Park, New Jersey 08823. (201) 297-2526. Smaller version of the Trenton show.

Computer Bulletin Board Systems (CBBS)

Many timesharing systems, computer clubs, and individuals support bulletin boards that can be accessed with a terminal

and modem. Members advertise to buy or sell used equipment and software. One of the largest is the Micronet system, run by Compuserve, 5000 Arlington Centre Boulevard, Columbus, Ohio 43220. (614) 457-8600.

Users' Groups

Most larger towns and cities have computer users' groups. These are listed in the popular computer magazines. Members often advertise used computers and equipment in monthly newsletters or at meetings.

Fair Radio Sales

Box 1105, Lima, Ohio 45802. (419) 227-6573. Mostly military electronic radio and computer surplus.

Herbach and Rademan

401 East Erie Avenue, Philadelphia, Pennsylvania 19134. (215) 426-1708. An odd mixture of electronic components, optical equipment, computer peripherals, motors, and so on. Prices are a bit high.

Poly Paks

Box 942, South Lynnfield, Massachusetts 01940. (617) 245-3828. Thousands of computer components, ICs, and so on.

Rondure Company

2522 Butler Street, Dallas, Texas 75235. (214) 630-4621. Miscellaneous lots of surplus computer peripherals. Condition varies from good to poor but is honestly described.