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Information Survey for Microcomputer Systems Integration

Kerry A. Hake

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
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INFORMATION SURVEY FOR
MICROCOMPUTER
SYSTEMS INTEGRATION

Kerry A. Hake

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LIST OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

ANSI	American National Standards Institute
API	Application Programmers Interface
ASCII	American Standard Code for Information Interchange
AT	Advanced Technology IBM Personal Computer
BIOS	Basic Input Output System
BITBLK	Bit Block
CARS	Consolidated Acquisition Reporting System
CD-ROM	Compact Disk-Read Only Memory
CISC	Complex Instruction Set Computing
CPU	Central Processor Unit
DAES	Defense Acquisition Executive Summary
DAT	Digital Audio Tape
DEC	Digital Equipment Corporation
DGIS	Direct Graphics Interface Standard
DMA	Direct Memory Access
DNA	Digital Network Architecture
DOS	Disk Operating System
EBCDIC	Extended Binary Coded Decimal Interchange Code
EISA	Extended Industry Standard Architecture
ESDI	Enhanced Small Device Interface
FTP	File Transfer Protocol
GB	Gigabytes
GUI	Graphical User Interface
I/O	Input/Output
IBM	International Business Machines
IEEE	Institute of Electrical and Electronics Engineers
ISA	Industry Standard Architecture
LAN	Local Area Network
LU	Logical Unit
MB	Megabytes or millions of bytes
MCA	Micro Channel Architecture
MFM	Modified Frequency Modulation
MHZ	Megahertz
MIPS	Millions of Instructions Per Second
MPS	Megabytes Per Second
ms	milliseconds or thousandths of a second
MSS	Mass Storage System
NCP	Network Control Processor
NTSC	National Television Standards Committee
OS	Operating System
PC	Personal Computer
PC-AT	Personal Computer - Advanced Technology
PEO	Program Executive Officer
PM-AIM	Project Manager-Acquisition Information Management
PMIS	Program Manager's Information System

PM	Project Manager
PMSS	Program Manager's System Software
PS/2	Personal System/2
RAM	Random Access Memory
RCC	Remote Cluster Controller
RGB	Red Green Blue
RISC	Reduced Instruction Set Computing
RLL	Run Length Limited
SCO	Santa Cruz Operations
SCSI	Small Computer Systems Interface
SNA	System Network Architecture
TIGA	Texas Instrument Graphics Architecture
VGA	Video Graphics Array
VLSI	Very Large Scale Integraton
VM	Variable Mode
WORM	Write Many Read Many
WORM	Write Once Read Many
WYSIWYG	What You See Is What You Get

FOREWORD

Technology information presented herein represents the commercial state-of-the-art for microcomputing from the time period January 1990 through March 1990. This time period reflects when the Project Manager-Acquisition Information Management (PM-AIM) was formulating plans for the PMIS workstation.

1. INTRODUCTION

One goal of the PM-AIM is to provide U.S. Army Project Managers (PMs) and Project Executive Officers (PEOs) with a fundamental microcomputing resource to help perform acquisition information management and its concomitant reporting requirements. Providing key PMs and PEOs with a microcomputer-based workstation configured with appropriate application software represents one means of accomplishing this goal. This workstation would furnish a broad range of capabilities needed in the PM and PEO office settings as well as software tools for specific project management and acquisition information. Although still in the conceptual phase, the practical result of this exercise in systems integration will likely be a system called the Project Manager's Information System (PMIS) or the AIM workstation. It would include such software as, Project Manager's System Software (PMSS), Defense Acquisition Executive Summary (DAES), and Consolidated Acquisition Reporting System (CARS) and would conform to open systems architecture as accepted by the Department of Defense.

2. STATEMENT OF THE PROBLEM

ORNL has assisted PM-AIM in the development of technology ideas for the PMIS workstation concept. This paper represents the compilation of information gained during this process. This information is presented as a body of knowledge (or knowledge domain) defining the complex technology of microcomputing. The concept of systems integration or tying together all hardware and software components reflects the nature of PM-AIM's task in attempting to field a PMIS or AIM workstation.

3. THE MICROCOMPUTER SYSTEM

The mass of technical information essential to microcomputing systems integration simplifies into seven categories. These categories are: (1) the processor platform, (2) the operating system, (3) display technology, (4) mass storage, (5) connectivity, (6) application software, and (7) the human-computer interface. Although functionally distinctive, individual items in these categories continue to blend with advances in Very Large Scale Integrated (VLSI) technology. One well known example of this is the incorporation of the IBM (International Business Machines) Video Graphics Array (VGA) chip set on the IBM Personal System/2 (PS/2) system planar (called the motherboard by most other vendors). This eliminates the need for an additional bus card video adapter. The blurring of elemental distinction is also seen in the categorization of systems as either a personal computer (PC) or a workstation¹ (Nicholls, 1989). When it comes to computing with microcomputers, this paper relegates such categorization to the realm of arbitrary distinction and uses the term workstation in a very broad sense. Advanced computing with microcomputers transcends this distinction, as evidenced by the increased performance of systems traditionally viewed as belonging to the PC class. A multiprocessor microcomputer produces performance in the same order of magnitude as today's supercomputers.

It is understood that *a priori* considerations may influence any systems integration exercise. For example, project requirements could mandate a compiler which only targets a specific processor. Or, even more common, organizational policies may only allow purchases of specific components like the display technology. Considering the building block metaphor, the process of integration must then, by necessity, use the display technology block as the piece to which the others must conform. This does not constitute a new layering of the dependent building blocks; it simply assumes a different fixed starting point from which related blocks must be properly combined.

3.1. THE PROCESSOR PLATFORM

The processor platform generally refers to the central processor unit(s) (CPU) and its immediate hardware environment. This usually includes supporting chips or chip sets, such as the basic input output system (BIOS), network control processor (NCP), direct memory access (DMA), or floating point arithmetic chip, widely referred to as the co-processor. It also includes the input/output (I/O) system dominated by the bus. The bus permits peripheral hardware to interact with the CPU via plug-in slots or pin/cable connectors. Plug-in

¹ Three definitions for Workstation are identified by Alan Freedman in *The Computer Glossary*: "(1) A workstation is a high-performance, single user microcomputer or minicomputer that has been specialized for graphics, computer-aided design (CAD), computer-aided engineering (CAE) or scientific applications. Today, high-end personal computers, such as 80386-based machines and the Macintosh II, are also competing in the market traditionally served by workstation vendors, such as Digital, HP and Sun. (2) In a local area network, workstation refers to a personal computer that serves a single user in contrast with a file server or network server, which serves all the users in the network. (3) Workstation is sometimes used to refer to any terminal or personal computer."

connectors for memory can appear on the processor platform motherboard or reside on connector cards plugged into the bus slots.

Compatibility and performance dominate the criteria for the CPU. Compatibility considerations limit other choices (for instance, application software). If a requirement exists to run a suite of software that is CPU-specific, some application software will not work. Performance considerations, such as how fast a CPU can run an application, may not be so limiting. It may be possible to select the same CPU running at a faster rate to increase performance (for example, 33 MHZ instead of 16 MHZ).

The microcomputing market currently offers two major categories of CPUs, the reduced instruction set computing (RISC) and the complex instruction set computing (CISC) chips. Processor platforms with a combination of the two become a "symmetrical processor." Examples of RISC CPU chips would be the Motorola 88000 series; the SUN Microsystem SPARC series; the IBM ROMP and Powerstation 6000 series (Smith, 1990); the MIPS series from MIPS, Inc., used in Digital Equipment Corporation (DEC) workstations; and the Intel 80800 series, where the currently marketed chip is dubbed the i860. Examples of CISC CPU chips would be the Motorola 68000 series; the Intel 80800 series; the NEC V series, which emulates the Intel 80800 series; DEC CVAX and FPU chips; IBM and other manufacturer mainframe chips and chip sets; and so on.

A great debate has arisen over the advantages of RISC or CISC (Tucker, 1989, Nutt, 1989 and March, 1989). Try to remember that processor performance ratings, particularly MIPS (millions of instructions per second), do not furnish totally reliable measures of comparison. A RISC chip will execute more instructions per second than a CISC chip. It gets difficult to compare when a CISC running at a faster clock speed, measured in MHZ, matches or eclipses the performance of a RISC chip. The computer manufacturers currently use a measure of performance called the SPEC (Systems Performance Evaluation Cooperative) benchmark suite. Ultimately, the performance of a particular application over a specified time yields a more pertinent comparison. Even then, processor external factors should be considered, including the effects of operating system overhead, compiler optimization, and competition from other users.

Standards for the processor platform bus split into a dichotomy. On one side of the market lies an industry standard, having passed planning and approval committees. This includes organizations like the Institute of Electrical and Electronics Engineers/American National Standards Institute (IEEE/ANSI). On the other side lies the *de facto* standard, considered a standard because of market volume and vendor support. It is usually, fostered and supported by individual corporations and sometimes a consortium of like-minded businesses. Industry standard buses include such monikers as S100, Multibus I and II, VMEbus, NuBus, and Futurebus (White, 1989). De facto standard buses include the ISA (Industry Standard Architecture) developed by IBM for the Personal Computer Advanced Technology (PC-AT or AT), EISA (Extended ISA) developed by IBM competitors in the PC market as an improvement and extension of the ISA, and Micro Channel Architecture (MCA) from IBM as the ISA on their line of PS/2 microcomputers.

Critical aspects of the bus involve the size of the data path, the rate of data transfer, and the clock speed. A data path, given in bits, usually comes in 8, 16, or 32 bits. The widely used

VME bus may also be implemented for 24-bit use. The Futurebus specifies a 64-bit data path but allows for compatible 64-, 128-, and 256-bit alternative data paths (Pri-Tel and Rehhauser, 1989). Some 32-bit buses, the NuBus and Futurebus for instance, do not allow smaller subsets, like a 16-bit connection. The rate of data transfer, generally referred to as the bandwidth, varies in the range of megabytes (millions of bytes) Per Second (MPS). Some example bandwidths include 6 MPS for ISA, 20 MPS for MCA, 33 MPS for EISA, and 80 MPS for SUN Microsystems' SBus (Baran, 1990). Also, note that a clock speed governs a bus as well as a CPU. Similar bus architectures as implemented by different manufacturers will differ in performance depending on this variable.

3.2. OPERATING SYSTEM

The operating system (OS) should complement the processor platform capabilities, work with any potential target application software, and allow the type of human-computer interactions that fit your requirements. In other words, if you have selected a platform based on a 32-bit architecture, then the OS should make full use of it. The application software should also be compatible for that OS and compiled for that CPU chip-specific 32-bit platform. Recent microcomputer operating systems offer an application programmers interface (API) allowing program access to imbedded features, such as direct manipulation on screen objects with a pointing device and control of specific bus adapter cards.

Microcomputer operating systems will reach a state of comparability in 1991, making a choice more difficult. In order to remain competitive, microcomputing market leaders will release OS enhancements geared toward equalizing the market. This should include Apple Macintosh System 7.0 with built-in virtual memory management (Thompson, 1989); IBM OS/2 2.0 with Presentation Manager for 32-bit processors (Smith, 1989); various UNIX offerings with Graphical User Interfaces (GUI; discussed later in the human-computer interface section) based on at least three different specifications (Cortese, 1989 and Hampshire, 1989); and enhancements for NEXT, Inc.'s NeXTStep user controlled object oriented programming (Farber, 1989).

Choosing an OS becomes difficult for workstation systems integration where the choices revolve around the type of multitasking, support for parallel processors, and faithful duplication of the IBM PC Disk Operating System (DOS).

Comparing multitasking quickly becomes difficult to understand. It concentrates on such arcane but essential concepts as cooperative, fully preemptive, or time-slice preemptive processing (Crabb, 1989).

Few OS offerings exist for parallel and multiprocessor support, although, product announcements are expected from a number of vendors throughout the coming months (Press Release, November 1989). Santa Cruz Operations (SCO) markets a UNIX V for a handful of vendor-specific, multiprocessor platforms. This could conceivably provide IBM with a good market outside the PS/2 and Power Station platforms for its AIX version of UNIX V.

Most importantly, microcomputer OS vendors realize the importance of catering to the large installed base of DOS application software and strive to maintain DOS functionality. Even

IBM and Microsoft hope for better market acceptance of OS/2's DOS compatibility box with the future release of OS/2 2.0 for the 80836 processor. Critics have dubbed it the "incompatibility box". Reviews and comparisons of various OS offerings constantly appear in the popular literature (Southerton, 1989a, Crabb, 1989).

3.3. DISPLAY TECHNOLOGY

The GUI of most operating systems and advanced applications make high resolution color display technology a necessity. As will be seen later, advances in the human-computer interaction will mandate this. Display technology includes the monitor and its attached signal generator--an adapter card or chip set--on the processor platform. This discussion also categorizes as display technology what is usually referred to as output--that is, printouts, hardcopy, recorded images, or plots. It qualifies as display technology, albeit traditionally a static one. Workstation computing should begin to think of the static display or hardcopy output as an extension of the transient visual output (Seymour, 1989). The common jargon used for comparable monitor display and hardcopy output is WYSIWYG (or what you see is what you get). Proper planning for integrating this technology includes consideration of the types of inputs and outputs, the desired resolution, the number of simultaneous colors, and the display speed needed.

The advent of multimedia applications gives rise to various types of inputs and outputs. These include NTSC (National Television Standards Committee), the standard television signal for VCRs and television monitors; RGB (Red Green Blue) for separate and synchronized color signals, available in multiple scan rates; S-video for Super VHS standard signals; and others (PC Week, 1989a, Milburn, 1989).

The number of color dots, called pixels or pels, in the rows and columns of a matrix specify monitor and film recorder resolution. A typical monitor resolution of 1024 rows by 1024 columns has more than 1 million pixels. High-resolution imaging recording devices exceed 16 million pixels with pixel arrays starting at 4096 x 4096 (Jackson, 1989a and Fersko-Weiss, 1989a). Bear in mind, however, that screen size and pixel size vary; therefore, the term "resolution" does not have an empirically comparable spatial meaning.

Resolution for color paper output devices, however, does have a more comparable meaning. Given in dots per inch, output of laser printers/plotters and thermal transfer systems produce a better perspective of the granularity or visual coarseness of an image. This distinction will become moot in the near term as techniques of transferring color dye to media reach the microscopic level. This developing technology employs micro-encapsulated thermal transfer dyes rendering photographic, halftone quality images (Fritzer, 1989, Lehman, 1989).

The number of simultaneous colors displayed directly controls the visual effect. An object with continuous color shading appears banded, not smooth, even when 256 simultaneous colors are used. For printers and plotters, this relates to the number of pens or color jet combinations. Most analog color monitors can reproduce millions of colors; therefore, the importance of color production goes to the signal generator or graphics subsystem driving the monitor (Alexander, 1989). These graphics adapter cards or chip sets require their own memory. They support a specific number of pixels in the x dimension (or rows), the y

dimension (or columns), as well as the z dimension (or colors) per pixel at a single x/y location.

Finally, carefully weigh the ability of a graphics subsystem to produce an image at a desired speed. For full motion animation of 30 frames per second, a graphics subsystem and processor platform must compute and output over 30MB per second. Very few of the vendors in the popular microcomputer market today can claim this capability (Smalley and Corts, 1989)! The activities of a graphics subsystem fit into four basic categories: drawing text, drawing lines, filling or flooding areas with color or pattern, and BitBlt manipulations--bit block transfers where rectangular blocks of bits are transferred from memory to the display) (Henning, 1989 and Ruddell, 1989). Certain graphics adapters are better suited for specific tasks, even though each adapter performs tasks in all four categories. Specific OSs and applications programs that depend largely on bitmapped icons benefit from a graphics processor capable of fast bit block transfers. Current high speed graphics cards use either chips with proprietary support or chips with open support such as the Texas Instrument 34000 chip family. They run the Texas Instrument Graphics Architecture (TIGA) and Direct Graphics Interface Standard (DGIS) developed by Graphics Software Systems Incorporated (Bernard, 1989).

3.4. MASS STORAGE

Mass storage refers to microcomputer subsystems that retain and retrieve information in large quantities for long-term storage and data exchange with other computing systems. This should not be confused with microcomputer memory, which has the primary function of supplying the operating system and application software with temporary high-speed storage. This type of storage usually loses its contents when the power goes off, whereas mass storage systems do not usually require continuous power to retain data. Numerous options face the systems integrator when considering mass storage. Critical factors include access speed, the anticipated volume of data, and compatibility requirements for size and shape or form factor. Integrally related to each of these factors is the type of media used to store information and the controlling hardware.

Today, the realm of media goes beyond the familiar storage of information on magnetic-coated surfaces such as the familiar floppy and fixed or hard disks. Current commercial offerings include laser technology, a combination laser and magnetic technology, and silicon or chip technology. Laser technology includes CD-ROM (compact disk-read only memory) (Manes, 1990 and Bonner, 1990) and WORM (write once read many) optical disks (PC Week, 1989 and Digital Review, 1989). The crossover technology between magnetic surface and optical offers WMRM (Write Many Read Many) or erasable optical (Gardner, 1989 and Deagon, 1990). Mass storage using chip technology consists of: Random Access Memory (RAM) chip storage backed up with battery power, sometimes called "disk emulators" (Jenkins, 1989); power retention alloys; and specialized chips where imbedded bubbles keep track of information while the power is off (Donlin, 1989).

Additionally, other magnetic media are undergoing innovation for use in microcomputing. Tape systems now include extended length quarter-inch tape systems, the 4mm Digital Audio Tape (DAT), and 8mm videotape (Zarley, 1989). The updated floppy drive allows reads and

writes at not only 720KB and 1.44MB, but also up to 50MB based on floptical technology variable mode (VM) storage (Oski, 1989 and Sullivan, 1989).

Every mass storage device requires an I/O controlling device, either as part of the processor platform, as part of the device itself (like the IBM PS/2 integrated controller and hard files subsystem) or, as a connecting piece of circuit board. These controllers must be compatible with both the processing platform bus and the operating system. Common controller types include Run Length Limited (RLL), Modified Frequency Modulation (MFM), Enhanced Small Device Interface (ESDI), and Small Computer Systems Interface (SCSI) (Fersko-Weiss, 1989b). These controllers are not interchangeable. However, interchangeable SCSI controllers may be on the horizon because of movements toward standardization. (Brownstein, 1989).

Of the three critical factors mentioned above, speed stands out as the most difficult to understand. Manufacturers tout various measures of performance. Two basic measures normally cited are the transfer rate, given in megabytes per second, and the access speed, given in milliseconds (ms or thousandths a second) (Costlow, 1989). Two oversimplified examples illustrate these measures. First, a graphical application may benefit most from a high transfer rate so large numbers of pixels could be retrieved and displayed quickly. Second, a large database application, by contrast, would benefit most from low disk access times so a random portion of the database might be found very quickly. It is interesting to note that the media with the fastest transfer rate and access time, RAM-based, beats the nearest competition, the magnetic-coated surface media, by a factor of 100.

Within the offerings of magnetic media, the controller plays a dominant role in speed. ESDI controllers—especially those with on-board memory, called "cache"—are among the fastest. SCSI controller technology however, keeps improving and new offerings may soon greatly outperform ESDI technology.

Laser technology mass storage media has the slowest response time. Recent announcements indicate, however, that this technology does not lag far behind and indeed will soon successfully compete with magnetic media performance (Jackson, 1989b). SCSI controllers are the general rule for CD-ROM, WORM, WORM, and other laser technologies.

The amount or volume of data storage varies by media. RAM media has the smallest storage capacity ranging under 100MB. This practical limit exists because memory costs per megabyte remain higher than other media technologies. The theoretical limit lies more in the realm of GB (gigabytes, or billions of bytes), with the ability of the central processing unit to address the memory. Next in scale comes magnetic media, which range from less than 1MB (for example, floppy disks) to a little over 3GB fixed disks (Finn, 1989). The largest volume per media size belongs to juke-box mass storage systems (MSS), that contain multiple laser platters or cartridge tapes storing information in the realm of terabytes, or trillions of bytes (Breidenbach, 1989).

Each media type comes in various form factors. RAM disks can be an integral part of the processor platform or an add-on bus connection subsystem. Some common magnetic media form factors include 2", 3.5", 5.25", 8" diskettes, 5.25" and 8" cartridges, various sized removable disk packs, various sized cassette tapes, standard 9-track computer magnetic tape

reels for external tape subsystems, and hard disks that may be external to or contained within the microcomputer processor platform (referred to as internal). Optical media are not so diverse and come in platter form, also commonly referred to as "disks." They range in size from 3" and 5.25" to 14". Like the hard disk subsystems, laser technology has both external and subsystems internal to the processor platform.

An important point to remember when planning for mass storage use is that operating systems, and even some applications, store information on media according to their own specifications, or format. They are not necessarily interchangeable with other microcomputer systems. An additional caution applies to controllers which may not necessarily work with all operating systems.

3.5. CONNECTIVITY

Connectivity among computers describes the process and extent a computer platform, PC, minicomputer, or mainframe exchanges information. Individuals with workstations desiring to share information around the world or even across the room must learn the hows and whys of electronic information transfer. This complex interaction environment may be understood both as physical and logical realms which fit into various levels of connectivity.

3.5.1. Physical Realm

The physical aspect of connectivity refers to the manner in which one computer system attaches to another. One straightforward form of physical connectivity is a microcomputer linked to another microcomputer via a cable. Each micro would require an I/O channel, usually an RS-232, serial port or parallel port. The physical connection alone will not permit exchange of information; this is where logical connectivity begins. The transfer of information along the physical connection requires a co-operating operating system and possibly some specialized application software (Gloster, 1989, Gordon, 1989, and McClatchy, 1989).

By contrast, a highly connective microcomputer may have a locally attached printer or scanner. It may also have an attached modem or local area network (LAN) adapter with concomitant software for communicating with another computer. This connectivity could be made in a variety of ways: by a modem over telephone lines, a cable connection to a terminal control device attached to another computer, or a cable connection to other microcomputers in a LAN. The LAN itself may link through a gateway to other LANs or a wide area network (WAN) with numerous LANs and host computing systems. Offering multiple paths to numerous computers quickly becomes a complex matter.

3.5.2. Logical Realm

The ability of the attached computers to understand each other contributes to the degree of connectivity. This may be termed the computer's logical connectivity. Toward this end, the implementation of the LU6.2 (logical unit) specification allows microcomputers to communicate with each other (as well as with mainframes, and minicomputers) as equal partners in what is called peer-to-peer mode (Horwitt, 1989).

3.5.3. Levels of Connectivity

This connectivity can be generalized into four levels. These levels are: (1) terminal emulation, (2) file transfer, (3) application interaction,² and (4) distributed function³ going from simple to complex. The last two levels may be thought of as sophisticated networking techniques. The change from the terminal emulation to file transfer level is many times easier than going from the file transfer to application interaction level or from the application interaction to distributed function level (Hake, 1990).

Two very common terminal types are DEC VT100 and IBM's 3270 series devices. DEC VT100s, like many terminals, use ACSII (American Standard Code for Information Interchange) encoding, whereas IBM 3270 terminals are based on the EBCDIC (Extended Binary Coded Decimal Interchange Code) in conjunction with a 3270 series mainframe remote cluster controller (RCC). Workstations often require additional circuitry to emulate an IBM 3270 device; either a chip set on the processor platform or a bus adapter card.

Well known file transfer protocols are Kermit, X-Modem, Y-Modem, Z-Modem, and FTP (File Transfer Protocol). These are capable of handling binary files as well as ASCII files. Binary files are sometimes called "system files," such as image, executable, and machine code files. ASCII files may be called "clear text," "flat," or "alphanumeric files." Most importantly, these protocols have error-correction schemes built in to identify and attempt to fix transmission problems. Error-correcting modems enhance or take the place of these software-implemented protocols (Jackson, 1989c).

Many networking strategies exist for application interaction and distributed function levels of connectivity. Major players in the network market include IBM's System Network Architecture (SNA) with SNA net, DEC's Digital Network Architecture (DNA) with Ethernet, TCP/IP (Transmission Control Protocol/Internet Protocol), and the ISO (International Standard's Organization) with the OSI (Open Systems Interconnection) standard. Some strong sentiment exists to declare the OSI standard the winner by the end of this decade (Cashin, 1989).

LAN strategies vary from vendor to vendor but share some basic topologies. Common architectures include the bus, star, ring, token ring, and arbitrary tree (Brenner, 1989). They may be connected with twisted pair wire (similar to modular telephone wire), coaxial cable, multiwire computer cable, fiber optic links, or even microwave, laser, and satellite transmissions. Each LAN has performance and capacity limitations. One standard

² In a closed or proprietary environment, application interaction may occur when a particular DBMS vendor has written code to run on several different machines and possesses the ability to transfer a connection with a host or other microcomputer, log onto that computer, selectively query the "remote" database, perform computation, select a subset of the results, convert the results for the destination computer's specific data standard requirements, and return the results.

³ Distributed function connectivity embodies the concepts of application interaction; in addition, the processing power may migrate between the differing processing platform CPUs computers unknown to the user.

requirement includes a network server, a high performance microcomputer with copious quantities of mass storage.

The WAN allows geographically dispersed machines and LANS to communicate. The concept of electronic mail (E-mail) on a WAN as opposed to a LAN is analogous to facsimile (FAX) transmissions. Messages and graphics files quickly transfer over great distances. Protocols used here include X.25, OSI, TCP/IP, UUCP, Kermit, and Xmodem (Kolstad, 1989).

The trend toward open systems standards facilitates connectivity progress towards the application interaction level. The Consultative Committee on International Telephony & Telegraphy (CCITT) produced the X.400 and X.500 standards for linking E-mail systems and directory services, respectively (Sweet, 1990). Furthermore, the U.S. Government, National Institute of Standards and Technology (NIST), promulgates a Federal Information Processing Standard (FIPS) to serve as a reference model for communication among heterogeneous computer systems. FIPS 146, a.k.a. GOSIP (Government Open Systems Interconnection Profile), was released in 1989 and is required for all federal agency communications purchases (Masud, 1989).

3.6. APPLICATION SOFTWARE

The vast offerings of application software and programming languages (loosely associated with this category) pose a formidable challenge to the systems integrator. The challenge here relates to painstakingly matching their abilities with the CPU, the operating system, and any other known interaction elements such as the GUI. Effectively using hardware and supporting software, means complementing their capabilities with the appropriate application software. A proper match would be a package or compiler that was specifically designed for the target CPU (for example, a 32-bit compiler for a 32-bit chip). Another would be a database management system specifically written for an operating system that takes advantage of the attributes of a 32-bit CPU.

3.7. THE HUMAN-COMPUTER INTERFACE

It is hard to compartmentalize the human-computer interface (HCI) because it is interwoven with the operating system and application software, as well as the hardware. Three major foci appear in the human-computer interface literature today: the GUI, hypermedia, and multimedia.

The current de facto standard for a GUI (sometimes pronounced "goeey") includes windows, icons, and a mouse or other pointing device. It is sometimes referred to as "WIMPS" (short for Windows, Icons, Mouse, and PointerS) (Coffee, 1989). Windowing gives a computer display the ability to split into separate boxes or information windows. Information may generally be transferred between or shared among these windows. The GUI uses symbols or icons to represent potential computing activities. Human interaction with these icons occurs by directly manipulating them via a pointing device such as a mouse, touch screen, or track ball (Perry and Voelcker, 1989).

IBM has attempted to influence industry direction for a GUI with their Systems Application Architecture (SAA) (Ray, 1989). This set of specifications intends to improve consistency, portability, and connectivity of applications across the IBM line of computers. Their tripartite approach includes: (1) the Common User Access (CUA), for a consistent "look and feel"; (2) the Common Programming Interface (CPI), for programming language and applications integration; and (3) the Common Communications Support (CCS), for distributed and cooperative processing among different processing platforms. The CUA reflects the knowledge gained from such systems as the Xerox Star, Apple MacIntosh, and Microsoft Windows.

Many GUI standards vie for dominance. MIT developed the X Window System in 1984 for the UNIX GUI frontier. IBM, DEC, Santa Cruz Operations (SCO), and Hewlett-Packard, among others, have formed the Open Software Foundation (OSF) to develop OSF/Motif. NeXT Inc. has produced NeXTStep. Sun Microsystems has teamed up with AT&T to work on Open Look (Taft, 1990, Southerton, 1989b, and Greenberg, 1989). DEC has also entered GUI development with its Application Integration Architecture (AIA) (Grygo, 1989). IBM uses the OS/2 Presentation Manager as the GUI promoting SAA. In the DOS world, Quarterdeck Office Systems battles Microsoft by marketing *DESQview* to compete with *Windows 3.0*. The evolving GUI standards have no clear winner in sight (Morris and Brooks, 1989 and Brown, 1989).

The popular prefix "hyper" relates to a type of GUI application where human-computer interaction can be easily orchestrated and manipulated in a user-organized fashion. Apple Computers came to the market with Hypercard and the Hypertalk language as a successful implementation of Object-Oriented Programming Systems (OOPS)⁴ and pioneered the market for this technology (Coffee and Dang, 1990). Operating systems for other microcomputer platforms are adding this capability as their GUIs mature (Stone, 1989 and Dallas, 1989).

Multimedia presents a new challenge to the systems integrator. The dream of multimedia involves the ability of a computer to capture, display, and store full-motion video and real-time audio, including digital voice recording, synthetic voice reproduction, and actual voice recognition (Guglielmo, 1989). The commercialization of multimedia, in its infancy, currently offers Compact Disk-Interactive (CD-I), Compact Disk-Video (CD-V), and Digital Video Interactive (DVI) (Lippincott, 1990, Cook, 1990, and Robinson, 1990). This exciting area of technology has even developed its own data structure dubbed the BLOB (for Binary Large Object) (Shetler, 1990).

⁴ Alan Freedman, in *The Computer Glossary*, defines object-oriented programming as "a technology for creating programs that are more responsive to future changes. Object-oriented programs are made up of self-sufficient modules that contain all of the information needed to manipulate a given data structure. The modules are created in class hierarchies, and the methods or code in one class can be passed down the hierarchy or inherited. New and powerful objects can be created quickly by inheriting their characteristics from existing classes. For example, the object MACINTOSH could be one instance of the class PERSONAL COMPUTER, which could inherit properties from the class COMPUTER SYSTEM. Adding a new computer requires entering only what makes it different from other computers, while all the general characteristics of personal computers can be inherited."

4. CONCLUSIONS

The knowledge base of systems integrations for microcomputer-based workstations covers a broad spectrum of information. A straight-forward means of understanding systems integration is to simplify the data collection process by grouping information into functional categories. These categories are: (1) the processor platform, (2) the operating system, (3) display technology, (4) mass storage, (5) connectivity, (6) application software, and (7) the human-computer interface.

The process of assessing current technology for specific systems integration potential involves a considerable amount of time which may be drastically reduced through the on-line database retrieval systems and CD-ROM-based literature searches.

A paradigm for computer systems integration may be developed from the functional categories identified in this research.

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