USAISEC
US Army Information Systems Engineering Command
Fort Huachuca, AZ 85613-5300

U.S. ARMY INSTITUTE FOR RESEARCH
IN MANAGEMENT INFORMATION,
COMMUNICATIONS, AND COMPUTER SCIENCES
(AIRMICS)

TECHNOLOGY ASSESSMENT
OF
OPERATING SYSTEMS

(ASQBG-I-89-023)

February, 1989

AIRMICS
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Georgia Institute of Technology
Atlanta, GA 30332-0800

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704--188
Exp. Date: Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

1b. RESTRICTIVE MARKINGS
NONE

2a. SECURITY CLASSIFICATION AUTHORITY
N/A

2b. DECLASSIFICATION / DOUWNGRADING SCHEDULE
N/A

3. DISTRIBUTION / AVAILABILITY OF REPORT
N/A

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
ASQBG-I-89-023

5. MONITORING ORGANIZATION REPORT NUMBER(S)
N/A

6a. NAME OF PERFORMING ORGANIZATION
AIRMICS

6b. OFFICE SYMBOL (if applicable)
ASQBG - I

7a. NAME OF MONITORING ORGANIZATION
N/A

6c. ADDRESS (City, State, and ZIP Code)
115 O'Keefe Bldg.,
Georgia Institute of Technology
Atlanta, GA 30332-0800

7b. ADDRESS (City, State, and Zip Code)
N/A

8a. NAME OF FUNDING/SPONSORING ORGANIZATION
AIRMICS

8b. OFFICE SYMBOL (if applicable)
ASQBG - I

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
N/A

8c. ADDRESS (City, State, and ZIP Code)
115 O'Keefe Bldg.,
Georgia Institute of Technology
Atlanta, GA 30332-0800

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
62783A	DY10	00-08	

11. TITLE (Include Security Classification)
Technology Assessment of Operating Systems (UNCLASSIFIED)

12. PERSONAL AUTHOR(S)
1 LT(P) Joseph Nealon

13a. TYPE OF REPORT

13b. TIME COVERED
FROM ________ TO ________

14. DATE OF REPORT (Year, Month, Day)
1989 February 13

15. PAGE COUNT
16

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Operating Systems, problems, trends, history,

19. ABSTRACT (Continue on reverse if necessary and identity by block number)

An assessment of the current, near-term (1995), and long-term (2010) trends in Operating Systems is given. A background of significant historical events and current problem areas is given to put the current, near, and long term trends into perspective.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED / UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL
LT. Joseph Nealon

22b. TELEPHONE (Include Area Code)
(404) 894-3110

22c OFFICE SYMBOL
ASQBG - I

DD FORM 1473, 84 MAR
83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

This research was performed as an in-house project at the Army Institute for Research in Management Information, Communications, and Computer Sciences (AIRMICS), the RDTE organization of the U.S. Army Information Systems Engineering Command (USAISEC). This effort was performed under the AIRMICS Technology Insertion Program to support the U.S. Army Information Systems Command (USAISC) in the development of a report titled "Long Range Planning Guidance - Objective Configuration." An initial meeting was held in early December in Atlanta to coordinate the task. Twenty-six topics were selected for consideration, with AIRMICS agreeing to conduct technology assessments on fifteen of the topics. Planning Research Corporation (PRC) was assigned responsibility for conducting the remaining assessments and consolidating all the assessments for use in the planning document. In a two-week period, AIRMICS completed the assessments and provided the results to ISC-DCSPLANS and ISEC-SID. This research report is not to be construed as an official Army position, unless so designated by other authorized documents. Material included herein is approved for public release, distribution unlimited. Not protected by copyright laws.

THIS REPORT HAS BEEN REVIEWED AND IS APPROVED

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OPERATING SYSTEMS

I. Historical Review.

A simple definition of an operating system would be "a control program for allocating resources among competing tasks." The two key terms are control and resources. Resources would include memory, processor(s), software tools (i.e. library routines and compilers), disk drives and other peripheral devices. Control involves not only efficient use of these resources, but also the ease with which the operating system allows the user to utilize these tools. Operating systems were originally developed to decrease idle processor time and to increase the throughput of programs. Prior to their development, I/O modules had to be created and loaded by the system operator. When the execution of a program was completed, the next set of modules had to be loaded before the hardware could be utilized again.

In the 1950's, these systems were small in size – a few thousand bytes long – and provided only the most basic activities such as job scheduling and peripheral device control. This is in contrast to current operating systems that can run into the tens of millions of bytes and provide much more elaborate services such as virtual memory management (ability to access secondary memory as though it was primary memory) and concurrent processing (more than one task or process executing at the same time). The trend has been from single-user, batch-oriented systems to multiprogramming (several programs executing concurrently), multiprocessing (more than one processor – simultaneous processing), and machine independent operating systems. For the purposes of this paper, simultaneous processing will be defined as more than one program or task executing at the same time (multiprocessing) and concurrent processing as the appearance of more than one program or task executing at the same time. Some current microcomputer operating systems offer more to the user than mainframe operating systems of the 1960's. There has also been a trend to migrate some of the traditional operating system functions to languages and language systems. Some examples include, the management of concurrency control within Ada and the interactive interface of Smalltalk (an object-oriented language developed by Xerox). This transition has several benefits including eased portability and a higher level of abstraction allowing for increased programmer/user control of resource allocation.

Previously, when a computer was purchased the operating system (normally a proprietary one) was a part of the package. This is no longer true. The buyer has a choice between several portable operating systems to include UNIX and Pick. Other current issues concerning operating systems would include the large number of vendors and systems, standards efforts, price variations, unfriendly user interfaces, and problems associated with distributed computing. These issues will be discussed in the following pages.

II. Currently Available.

The next sections provide descriptions of some more commonly used operating systems. This is not an all inclusive listing.

A. Microcomputer Operating Systems.

With the introduction of the Intel 80386 microprocessor (a 32 bit processor as compared to the 8 and 16 bit processors of the past), the scope and capabilities associated with microcomputers has changed dramatically. The 80386 allows for multitasking and a virtual mode making it possible for a micro to function as though it were several micros of the previous generation. However, in order to fully realize the potential of this hardware, the software which runs on it must be specifically designed to take advantage of the services provided.

The four major operating systems for microcomputers on the market today are MS-DOS, Macintosh, OS/2, and UNIX. Each of these have specific *strengths and weaknesses* which will be elaborated in the following discussions.

1. MS-DOS (PC-DOS) - This is a single user, single-task operating system. The first version was released in 1981 and was intended for use on the IBM Personal Computer. Perhaps the greatest strength of this product is the large number of users and applications available (over 35,000 software applications). Another strength is the ease of use and plethora of existing documentation. Because of the large relative size of the existing user base, the costs associated with training can be minimized on an organizational basis.

The most significant weakness of MS-DOS is its inability to provide the multitasking environment required to fully use the processing power of 80386 machines. Because it was designed for a single user, single-task processing environment it can only run one application (process) at a time. MS-DOS applications are also limited to 640K of RAM which is not sufficient for many new applications, especially graphics and Computer Assisted Design/Computer Assisted Manufacturing (CAD/CAM) products.

2. Macintosh - Unlike MS-DOS, the Macintosh operating system produced by Apple is based on the Motorola 68000 processor series. It is probably best known for its graphical/windowing user interface and main form of interaction being via a mouse. This provides one of its strengths by making the system extremely easy to use even for the novice user. Because of this some studies have concluded that training users on the Macintosh is about half the cost of training personnel on MS-DOS systems. Another major strength is a high quality graphics capability. Apple has also committed to network interface standards such as SNA LU6.2 that allows their hardware to be used in a heterogeneous distributed environment.

Perhaps the biggest weakness of this operating system is its lack of built-in MS-DOS compatibility. This is due to the fact that the Macintosh is based on Motorola's 68000 chip series whereas MS-DOS is based on Intel's 8086/80286/80386 chips. It is possible to run MS-DOS applications, but this requires an emulation program and a co-processor board. This prevents the widespread use of the multitude of MS-DOS based applications on this platform.

3. **OS/2** - This operating system was designed specifically to reap the benefits provided by the Intel 80286 processor released in 1982. The Intel chip provides the ability to run in protected mode which in turn allows multitasking (hardware - i.e., I/O controllers - and operating system share the CPU allowing several applications to run at the same time). Because MS-DOS is a *single tasking operating system* incapable of accessing the 80286 protected mode, IBM and Microsoft developed OS/2 which was released in December 1987. In addition, the 80286 provided more addressable memory - 16 megabytes - allowing the development of more elaborate micro-based applications. Another strength of OS/2 is MS-DOS compatibility. With OS/2, one MS-DOS application can run in the foreground while several OS/2 applications are running in the background. The MS-DOS application must run in the foreground due to the physical device control mechanism of the MS-DOS operating system. OS/2 has interprocess communications facilities that allow for the sharing of data and services of several running applications and the Dynamic Data Exchange feature provides dynamic links between executing applications.

The most significant weakness of OS/2 is the lack of available applications (due to its newness). This lack of applications is partly due to an absence of planned extensions. Later versions are to include Local Area Network (LAN) services, and Structured Query Language (SQL) database hooks. Development tools such as Presentation Manager - a graphical user interface - has just recently been released and should speed the development process of third party vendors. As discussed earlier, the current version of OS/2 does not fully use 80386 capabilities such as the virtual mode which enables multiple

MS-DOS applications to run simultaneously. And a final weakness would be the extensive hardware requirements to run OS/2 - 80286/80386 system, 2 megabytes of random access memory, 30 megabyte hard disk, 1.2 megabyte floppy disk drive, and a Enhanced Graphics Adapter (EGA) or Video Graphics Array (VGA) color monitor.

4. UNIX - The UNIX operating system is designed for both a multiuser and multitasking environment. This means that the hardware and operating system work together sharing the central processing unit among both several applications and several users. The greatest strength of UNIX is code portability. Because UNIX was developed in the C programming language, it is an excellent development platform due to the portability features of this language. Another strength is UNIX's unique file system. Other operating systems require explicit file formatting information for file creation. UNIX, on the other hand, views files as a sequence of bytes with no explicit formatting considerations. In addition, unlike MS-DOS and OS/2, UNIX is able to utilize the full addressable memory provided by the 80386 chip. AT&T and Microsoft have 32 bit implementations of UNIX for the 80386 (OS/2 is limited to a 16 bit implementation at this time). In addition, unlike OS/2 several versions of UNIX allow for several MS-DOS applications to run concurrently.

A weakness of UNIX is the limited number of applications available because MS-DOS is still the mainstay for micro based applications, and like OS/2, UNIX is fairly new to users outside of the academic/research community. Another problem is the additional training required for this operating system due to the current user interface that is somewhat cryptic (this problem will be resolved as graphical user interfaces are introduced). The greatest weakness at this time, however, is the lack of a standard and the resulting incompatible versions of UNIX. This problem will be addressed later during a discussion of on-going standards efforts.

B. Mini/Mainframe Operating Systems.

The following is a discussion of some of the more prevalent mini/mainframe level operating systems. This is not an all inclusive listing.

1. DOS/VSE (Disk Operating System/Virtual Storage Extended)- DOS/VSE is a multiprogramming, interactive/batch operating system developed for use on all IBM mainframes. Because its design is based on partitioned memory it is much easier to manage and requires fewer support personnel than other more complex IBM operating systems. In addition, the cost of this operating system is less than other packages (e.g. MVS - Multiple

Virtual Storage). This system currently has the largest number of users for IBM mainframes.

One of the weaknesses of this system is that DOS/VSE is more restricted in growth and expansion capabilities than other systems. Another weakness is the high cost associated with migrating from DOS/VSE to the more powerful operating systems such as MVS. The most significant problem with this system is that IBM has stated that DOS/VSE will not be included in their Systems Application Architecture (SAA) which will be discussed later in this paper.

2. **MVT/VSE** – This operating system is the biggest competitor of DOS/VSE (fully compatible replacement) developed by Software Pursuits. MVT/VSE provides more capabilities and better performance than DOS/VSE. The systems are similar with one difference being a method of dynamic region assignment not possible with DOS/VSE's support of only a fixed number of partitions. This system is more beneficial than DOS/VSE for users that have large multiprogramming/multipartitioned operating requirements.

Though MVT/VSE is compatible with DOS/VSE some conversion tasks are required. For example, MVT/VSE requires a form number scheme which is used by the spooler (Simultaneous Peripheral Operation On Line – high speed device to increase I/O throughput). Also, some programs may need to be recompiled and relinked.

3. **VM** – VM stands for "Virtual Machine" which means it can run several different operating systems at the same time. A large range of processors are supported ranging from the XT/370 to the 3090 series. This feature is extremely beneficial especially concerning software portability. This system is supposedly user-friendly (in relative terms). In 1984; IBM declared VM (along with MVS and TPF) to be one of its "strategic" operating environments at the expense of DOS/VSE. It currently has the greatest growth rate for mainframe operating systems.

Some of the weaknesses of this operating system are its relatively high price and the overhead involved with "virtual" processing.

4. **MVS/370 and MVS/XA (Extended Architecture)** – MVS (Multiple Virtual Storage) is IBM's largest and most complex operating system. It was designed to handle large database applications with communication requirements, multiprogramming, shared disk subsystems, and different processing modes. It is the operating system of choice for large users. MVS/XA is an extension to handle certain constraints present in virtual storage systems.

Some weaknesses include an increased level of support required due to the complexity of the operating system and a relatively high cost.

5. UNIX - Though some of the strengths and weaknesses of UNIX were discussed in the previous section, this section will look at issues related to utilizing UNIX in a mainframe environment. The main strengths of UNIX are code portability and timesharing (multiprogramming) features. Another strength of UNIX is its data communications facilities. Because UNIX is device independent, programmers do not need to relate input/output (I/O) commands to specific I/O devices. This is because I/O devices are specified as files in UNIX which means the programmer need only reference the specific file which will activate the device to perform the operation. A related strength is the ability to easily add additional hardware such as I/O devices. To do so merely involves creating a file for the new device which is much simpler than other operating systems. During the installation of UNIX, system operators do need to generate the I/O primitives for the specific device drivers.

One of the major strengths of UNIX is also one of its major weaknesses, depending upon the operational environment and requirements. This is the issue of UNIX's facility for the easy sharing of files. This can cause severe concerns for operations with security constraints. Versions of a "secure" UNIX are currently available such as Gould Inc. UTX32, Harris Corp. CX/SX, and Sun Microsystems Inc. Sun OS MLS (multi-level secure). The current UNIX user interface is also less than desirable especially for the novice user. This problem should be rectified with upcoming icon (graphical) based interfaces. In addition, UNIX is not as efficient for transaction-based applications as other mainframe operating systems. This is primarily due to UNIX's interrupt handling scheme. The interrupt latency - period between the generation of an interrupt and execution by a handler - is longer in UNIX than with other operating systems that have been optimized for such functions as transaction processing. Future versions will probably be optimized for transaction processing. And finally, traditional UNIX is not the optimal operating system for applications requiring real-time execution due to the manner in which it handles interrupts. Some versions of "real-time" UNIX are being marketed, such as Alliant Computer Systems FX/RT.

C. Application to the IMA.

As has been the trend for several decades, the power of computer hardware has been increasing at an explosive rate. Operating systems that are capable of harnessing and exploiting this power have lagged somewhat behind and are becoming more and more expensive. The number of peripheral devices that current operating systems must support such as optical disks have placed additional requirements on these systems. The result has been a dramatic increase in the amount of computational power at the hands of the end user. This additional power will enable the development of even more complex applications, at lower organizational levels, to support the IMA functions of the Army.

III. 1995 (Near Term).

Currently there are two movements that will impact operating systems by the year 1995 - IBM's System Application Architecture and standards organizations. SAA will be discussed and compared to UNIX in terms of their relative strengths and weaknesses. In addition, current operating system standardization efforts will be covered.

A. IBM's System Application Architecture (SAA).

SAA is IBM's strategy to achieve portability of applications across several hardware architectures. The architectures to be included in this scheme are System/400, Personal System/2, and the 370 series of architectures. The relevant operating systems include MVS, VM, Application System/400, and OS/2 Extended Edition. This is to be achieved by designing and implementing a set of application interface standards for accessing databases and networks across several hardware platforms. Specifically, this will involve the graphical (icon) based user interface of Presentation Manager and the Communication Manager facility. Recently, IBM has stated that they intend to include their version of UNIX - AIX - in their SAA strategy. This is to be accomplished by incorporating Transmission Control Protocol/Internet Protocol (TCP/IP) into its MVS and VM operating systems. The achievement of this goal (SAA) is expected to be in the early 1990 time frame.

B. Comparison (SAA versus UNIX).

The goal of SAA and a feature of UNIX - portability - is a common yet different issue in respect to the two. While SAA promises to provide applications portability across three hardware platforms, UNIX currently provides portability (approximately 90% of code) across a much larger number of hardware platforms. While SAA will be limited to IBM or IBM-like hardware, UNIX is not limited to this restriction. The following chart outlines the significant features and differences between the two (Computer World, Sept 12, 1988, source Digital Consultants, Inc.)

SAA	UNIX
• Applications isolated from operating system	• Operating system independent of hardware
• C replaces assembler as performance tool	• C is the performance language
• Supports older applications	• Must convert to UNIX
• IBM hardware only	• Runs everywhere
• IBM and Microsoft's Presentation Manager	• Open Look, X-Windows, Presentation Manager
• Mature-security, integrity, filing options	• Immature-security, filing, scheduling, utilities
• SAA-standards for application development	• Common Application Environment, X/Open, POSIX, OSI, SQL
• Batch operating system and transaction processing	• Time-sharing operating system not optimized for transaction processing, single-user multitasking

A current problem with UNIX - that of multiple versions - should be resolved by 1995 due to the standardization efforts of groups such as the Open Software Foundation (IBM and others) and UNIX International, Inc. (AT&T/Sun Microsystems and others).

C. Standardization Efforts.

An essential feature to enable portable software is a standard operating system interface. Currently, three interface standards exist - IEEE's Portable Operating System Interface (POSIX), AT&T's System V Interface Definition (SVID), and X/OPEN. Each of these guarantees different levels of portability, greatest to least being POSIX, SVID, and X/OPEN. A key point to keep in mind is that POSIX in itself does not guarantee portability. What it does do is give software developers a "stable target" for applications to run on by specifying an interface between the application and the operating system. Thus, both the operating system and the application must adhere to POSIX standards in order to be portable. The Federal Government has come out in support of POSIX which will have a significant impact on procurement policies. For example, the Air Force has already incorporated POSIX into its Request For Proposals (RFP) for their next generation minicomputer Desktop III.

These standardization efforts will result in more portable software, but it would be naive to believe that the software of the future will be 100% portable.

Assuming that the Open Software Foundation's version of UNIX - AIX - and AT&T's System V become de-facto UNIX standards and both comply with POSIX, applications probably still will not be totally portable across the two. Each group will add functionality to their respective products to give them a "competitive edge" which in turn will hamper achievement of a 100% portability goal. This is still far better than proprietary, single vendor offerings.

D. Additional Trends.

By the mid 1990's, OS/2 will be well on its way of replacing MS-DOS as the de-facto standard for single-user microcomputers. However, due to the extremely large user-base, IBM will be forced to support MS-DOS and AT-class machines. UNIX will probably become the de-facto standard for servers and high-end workstations running applications such as CAD/CAM. UNIX will become a more prevalent operating system for microcomputers, minicomputers, and mainframes, as well as continuing to be the operating system of choice for supercomputers.

In addition, operating systems will have user-friendly graphical interfaces that will provide a level of transparency between underlying operating systems and the user. This will allow even novice users to be much more productive and reduce the costs involved with end-user training.

E. Application to the IMA.

A major problem currently facing the Army that will continue into the near future is that of application portability. The vast number of hardware platforms (and their more often than not proprietary operating systems) have resulted in a less than full utilization of applications and/or expensive re-writes to port code to different environments. The problem should be eased by the year 1995 due to the standards efforts mentioned above. This will result in greater usage of applications across the Army and a savings in manpower and dollars. As user interfaces are improved, the resources required to train personnel should be reduced and their productivity increased. This coupled with a higher level of computer literacy throughout the general population will allow for increased developmental work to be done at the user level freeing up personnel resources for more intricate and involved application development.

IV. 2010 (Long Term).

The following areas will have a significant impact on the operating systems of the early twenty-first century.

A. Distributed Operating Systems.

A distributed operating system is not synonymous with distributed applications. One definition is, "A distributed operating system is one that looks to its users like an ordinary centralized operating system but runs on multiple, independent central processing units (CPUs)." The key concept here is "transparency" (from: "Distributed Operating Systems," Tanenbaum et al, Computing Surveys, Dec 85). These systems will provide for efficient load balancing of tasks across available processors. The user will no longer be required to know the physical location of applications and data. The level of data sharing between geographically distant sites will be increased and additional computing resources will be easily accessible to the user. In order for the realization of truly distributed operating systems to occur, additional research efforts must be undertaken in the areas of distributed computing, file systems, synchronization, and communications.

B. Artificial Intelligence (Expert Systems) Applications to Operating Systems.

Expert Systems will be applied to more and more areas. One such area could be that of operating systems. They could perform monitoring functions and assist in the allocation of resources to tasks, optimize the distribution of data, and enhance communication routing schemes.

C. Massively Parallel Machines.

The supercomputers of today will be the mainframes/minicomputers of tomorrow. To harness the power of these machines, much more advanced operating systems will have to be developed These will include improved algorithms for inter-process communications and control, and efficient task/processor allocation routines.

D. Application to the IMA.

By the year 2010, truly distributed, heterogeneous networks (and their respective distributed operating systems) should be in common use. This will allow for massive and robust computational power.

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