MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0139003 9

ORNL/TM-9901

ornl

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

A Study of UNIX and Its Suitability for the Air Force's WWMCCS Information System

Regis S. Loffman

OAK RIDGE NATIONAL LABORATORY
CENTRAL RESEARCH LIBRARY
CIRCULATION SECTION
4500N ROOM 175
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this report, send in name with report and the library will arrange a loan.

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A03; Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL/TM-9901

Energy Division

A Study of UNIX* and Its Suitability for the Air Force's WWMCCS Information System

Regis S. Loffman

Date Published—April 1986

*UNIX is a registered trademark of Bell Laboratories.

Prepared for the
AFWIS Modernization Program
Gunter AFS
U.S. Air Force
Interagency Agreement DOE No. 40-1493-84

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0139003 9

CONTENTS

ACRONYMS v

ABSTRACT vii

EXECUTIVE SUMMARY ix

1. INTRODUCTION 1

2. BACKGROUND OF WWMCCS AND WIS 3

3. UNIX 5

   3.1 HISTORY AND DEVELOPMENT PHILOSOPHY 5
   3.2 SPECIFIC FEATURES 5
   3.3 HARDWARE ENVIRONMENTS AND VERSIONS 6
   3.4 ADVANTAGES AND DISADVANTAGES 7
   3.5 AT&T's EFFORTS 9
   3.6 UNIX IN THE MARKETPLACE 10

4. CONSIDERATIONS FOR WIS 13

5. REFERENCES 15

6. BIBLIOGRAPHY 17

ACRONYMS

ADP	Automatic Data Processing
AFWIS	Air Force WWMCCS Information System
CAMP	Command ADP Modernization Program
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
ORNL	Oak Ridge National Laboratory
OSI	Open Systems Interconnection
UTS	Universal Timesharing System
WIS	WWMCCS Information System
WWMCCS	Worldwide Military Command and Control System

ABSTRACT

The U.S. Department of Defense is in the process of modernizing its Worldwide Military Command and Control System (WWMCCS) Automatic Data Processing (ADP) system. This modernization will include a new ADP system: WWMCCS Information System (WIS). The need for modernization results from a rapid growth in technology and an increased dependency on ADP support. The Air Force's role in this effort is the modernization of the Air Force WIS (AFWIS). The Air Force requested the assistance of Oak Ridge National Laboratory (ORNL) in investigating UNIX as a possible operating system for its new WIS ADP environment. ORNL reviewed and analyzed (1) WWMCCS documentation for system requirements, (2) technical materials for information about UNIX, and (3) business sources for indications about UNIX's future in a commercial market. This analysis concluded that there are some features required by AFWIS that currently only UNIX can provide; however, its place in the future marketplace is still uncertain.

EXECUTIVE SUMMARY

The rapid growth in information systems technology and the increasing dependence on Automatic Data Processing (ADP) support have resulted in the need for modernization of ADP functions in many organizations. Faced with this need, the U.S. Department of Defense is beginning a major effort to modernize its Worldwide Military Command and Control System (WWMCCS) ADP system and to replace it with WWMCCS Information System (WIS). The Air Force's role in this effort is the modernization of the Air Force WIS (AFWIS). One aspect of ADP modernization of particular concern to the Air Force is the selection of a computer operating system that can both meet current needs and adapt to future needs. Oak Ridge National Laboratory conducted a study to provide the Air Force with information to aid in this decision.

A computer operating system is a computer program that shields the user from the hardware. It performs many functions that are basic to the system (e.g., timing, job scheduling, accounting, interrupt handling, and security) and that should be protected from all but a select group of professionals (systems programmers and administrators). Another important factor in the selection process is the ease with which a user can communicate with an operating system.

A review of Air Force documentation on WIS was conducted to determine the needs of the system, and a few of those needs are (1) that the system handle data in an efficient and responsive manner, (2) that it allow for changes in hardware relatively smoothly, and (3) that it handle classified data.

Another review was made of literature to determine the features, advantages, and disadvantages provided by UNIX. Some of the better-known advantages of UNIX are its ability to move rather easily from one hardware environment to another, its numerous utilities, and the good environment it provides for software development. Some of its disadvantages include its questionable user-friendliness, the proliferation of many UNIX versions and look-alikes, and the perceived lack of documentation.

A third review was conducted to try to determine what place UNIX occupies in the marketplace and what its future will be, a difficult task because of the diverse opinions expressed in the literature reviewed.

After the reviews were completed, the information was analyzed to try to determine the suitability of UNIX for AFWIS. The conclusions reached were that there are some requirements of AFWIS that only UNIX can provide but there are some uncertainties about its future. Air Force decision-makers will need to consider these points when making their selection.

1. INTRODUCTION

The purpose of this document is to discuss and evaluate several aspects of UNIX as an appropriate and suitable operating system for the Air Force's portion of the Worldwide Military Command and Control System (WWMCCS) Information System (WIS) in its modernization effort. Oak Ridge National Laboratory has been engaged by the Air Force, through an Interagency Agreement with the Department of Energy, to conduct an investigation of UNIX to aid in this decision-making process. It is not the goal of this document to make this decision; rather, this document will discuss UNIX in terms of its history, development philosophy, hardware environments, advantages, and disadvantages; and it will then discuss what is happening with UNIX in the real world. This document also comments on how UNIX may fit in the AFWIS environment and will point out some considerations to be addressed that will assist in the decision regarding its suitability for AFWIS.

2. BACKGROUND OF WWMCCS AND WIS

The WWMCCS ADP program began in the early 1970s and runs on Honeywell 6000 computers. Due to the rapid growth in technology and the increasing dependence on ADP support, the system is becoming obsolete and increasingly difficult and uneconomical to maintain and operate.[1] There has been little structure to the ADP organization and, therefore, little centralized direction.

The modernization initiative was begun in July 1982 with the establishment of the Command ADP Modernization Program (CAMP), with one of its results being a study—completed in June 1983—analyzing the H6000 environment. The Air Force WIS program was established in August 1984 to modernize, integrate, and implement Air Force standard command and control systems and command-unique command and control systems at Air Force sites using WIS-developed hardware and system software.

The nature of a command and control system is such that it has to operate under a variety of potentially adverse conditions and guarantee peak performance in time-sensitive, real-world crisis/conflict situations. The system to be developed has a variety of requirements[2] to ensure that it will satisfy the needs of the users and will also be able to function under crisis situations. Some of the requirements are that the system handle a rapid flow of information and data, meet stringent response times, handle classified data, securely transmit classified data between sites, support on-line interactive and batch processing, and have graphics capabilities.

The Air Force is considering UNIX as the operating system for AFWIS because of the current widespread interest in UNIX. If UNIX is considered as the operating system for AFWIS, some user requirements are of special interest. UNIX may be able to satisfy these needs either very well or poorly. The requirements are that the operating system

1. must handle a mix of WWMCCS and unique systems;
2. allow for variously sized interconnected/internetted computers;
3. present a useful and easily understood display of results;
4. be sufficiently adaptable so as to allow an easy transition from the current ADP system to the follow-on system;
5. allow for different hardware from one development stage to the next such that they are compatible through standard protocols and interfaces and are able to support standard languages, file structures, and data base management systems;
6. allow for system-transportable software;
7. have easy-to-use input/output (I/O) devices;

8. have an English-like query language for non-ADP-trained personnel (i.e., it should be user-friendly*); and
9. allow for application systems that cross major functional areas to be compatible with one another through standard protocols and interfaces and be able to access standard files and data base management systems.

*"User-friendly" is a widely used term with many different meanings. For a good discussion on it, consult Jon A. Meads, "Friendly or Frivolous?", *Datamation* **31**(7), 96-100 (April 1, 1985).

3. UNIX

3.1 HISTORY AND DEVELOPMENT PHILOSOPHY

UNIX was created in 1969 by Ken Thompson of Bell Laboratories as a means to run a computer game less expensively. It became operational as an in-house system at Bell Labs in 1971. Originally written in assembler language, it was rewritten in C in 1973 by Dennis Ritchie, also of Bell Labs.

"Portability" refers to moving software from one hardware environment to another. The concept of portability, however, should not be interpreted as allowing this movement without modification of the software. One source[3] states that 30 to 40% of the UNIX operating system is hardware dependent. Software still requires modification when moved to a different hardware environment, and the degree of modification varies with program complexity and hardware. Although the code written in C is approximately one-third larger than the original assembler code, the ability to understand the C code (and hence make modifying and maintaining it easier) contributes to the larger code's portability characteristic. Another portable quality is that C capability can easily be given to other computers by writing C compilers for them. In addition to this significant improvement, enhancements to the C version have made possible both multiprogramming and the ability to share reentrant code.

UNIX was written with the intent to create an operating system that is fairly straightforward and easy to use. One way that UNIX promotes simplicity is through the use of a large number of utilities, each of which performs a small task efficiently, as opposed to using a few utilities, each of which does complicated tasks. There is some question as to the user-friendliness of UNIX and the quality of documentation, apparently contradicting the goals of ease of use and straightforwardness. One user, for example, expressed an opinion that UNIX is hard to learn, easy to use once learned, but definitely not friendly. However, these are subjective qualities that are evaluated differently by users with different understandings and needs.

Numerous enhancements have been added to the original Bell Labs' UNIX by many organizations, but some of the better known enhancements have been made by the University of California at Berkeley. Some of these include performance enhancements, virtual memory capability, and a variety of utilities. These enhancements, combined with the proliferation of UNIX look-alikes, have introduced a standardization problem among the different versions of UNIX.

3.2 SPECIFIC FEATURES

A few of the features of UNIX worthy of note are the shell, the kernel, forks and pipes, and the file system. The shell is not part of the operating system, but it is the means

by which the users and system communicate. It is an application program that acts as the command interpreter between the user and the operating system but has no special privileges. Also an application program, it interprets user commands for the operating system. There are two popular versions of the shell: the Bourne Shell and the C Shell.

The kernel, as its name implies, is the central part of the UNIX operating system. As such, "what is or is not implemented in the kernel represents both a great responsibility and a great power."[4] The kernel handles process control, I/O and file management, and machine-hardware-dependent operations. It is the only portion of the code that cannot be replaced by the user. The kernel hides the physical machine from programs and users, and the degree to which the kernel of two different UNIX versions implement the same functions determines the degree of portability of applications between those versions.

Forking is a system feature by which a process is able to spawn a duplicate process. These two processes are referred to as the "parent" and "child" processes; they run in parallel with priorities that can be manipulated independently of each other. A spawned process can also spawn other processes.

Pipes are a system feature that provides the mechanism for interprocess communication. This feature is often used in conjunction with the fork process to enable parent and child processes to exchange data as though communicating via an I/O channel.

The most unique feature of UNIX is its file system. UNIX has three types of files (determined by their usage): ordinary files, directory files, and special files—which refer to I/O devices. Files have no rules imposed upon them. They are composed of whatever information is placed in them by a user. UNIX imposes no structural restrictions on files; structure, if needed, is handled by the program that uses a file. Directories are also files, and they contain the names of files and the means by which to associate the name of a file with the file itself. Special files appear to be no different from other files on the system. However, special files refer to I/O devices, all of which reside in one directory. The advantages of this are that I/O devices are treated as files (i.e., they are "read from" and "written to") and users do not have to know a different syntax to use I/O devices.

3.3 HARDWARE ENVIRONMENTS AND VERSIONS

There are numerous versions of UNIX (not all of which run on the same computers), and UNIX is available on a variety of hardware systems. Among the various versions are the following:

1. Bell Labs' Version 6 and Version 7,
2. AT&T's System III and System V,
3. Berkeley 4.1 and 4.2 running on VAX, and
4. Berkeley 2.9 running on the PDP-11.

There are also numerous UNIX look-alikes that run on microcomputers and personal computers.

Although IBM has not endorsed UNIX, it does offer its own implementation of UNIX on a variety of its products. PC/IX is available for IBM's Personal Computer XT; PC Xenix (based on System III) is available for the Personal Computer AT; VM/IX is available on the IBM 3083 mainframe computers. At the UNIX Expo held in New York

City in September 1985, it was interesting to note that neither IBM nor DEC were represented. Some people view IBM's UNIX products more as a marketing strategy than as IBM support for UNIX, thereby preventing IBM from being excluded from any specifications because of a lack of a UNIX operating system.

Amdahl offers UNIX in the form of its Universal Timesharing System (UTS), which runs on Amdahl's 5860, 5870, and 470 v7a computers and on IBM 370s. UTS is essentially AT&T's System V, Release 2 with Berkeley UNIX system additions. UTS can run as a free-standing operating system, although most installations choose to run it under IBM's VM operating system.

AT&T has entered the hardware arena; and the AT&T 7300 PC (Safari 4), which runs System V, is the first UNIX-based microcomputer. AT&T also offers a range of minicomputers with the 3B series of computers.

DEC has its own version of UNIX, ULTRIX, available in the following forms: ULTRIX-32 on the larger VAXes, ULTRIX-32m on the MicroVAX, ULTRIX-11 on the PDP and micro PDP-11s, and PRO/Venix (by VenturCom, Inc. for DEC) on DEC's Professional 300 Series.

Hewlett-Packard has the HP-UX operating system, which offers standard timesharing on its HP 9000 minicomputer. Hewlett-Packard's philosophy regarding UNIX research and development is that their products will be compatible with AT&T's UNIX but that Hewlett-Packard will add its own features on top. Hewlett-Packard will probably offer a UNIX-based operating system in early 1986 that will have a real-time shell allowing interrupts, priorities, and other real-time features.

Sperry has redefined its product line, from micros to mainframes, to be UNIX System V compatible. Prime has Primix, its UNIX-based operating system, as the operating system for its product line. The Altos 3068 super microcomputer runs UNIX. UNIX has also been ported to supercomputers by Cray Research, Inc., Control Data Corporation, Denelcor, and Nippon Electric Co., Inc. UNIX is also available in some form on Honeywell, Perkin-Elmer, and Burroughs equipment.

3.4 ADVANTAGES AND DISADVANTAGES

The choice of whether or not to use UNIX depends upon how much the advantages outweigh the disadvantages for a particular system or purpose. Economics is another influence upon this type of decision, but economic issues are not directly addressed in this paper. The advantages of UNIX relate to the portability of applications, which means that very little modification is required to transport UNIX applications from one hardware environment to another (Sect. 3.1 also addresses portability). Application backlogs are reduced when operating system considerations can be relegated to lesser importance. There is also a large number of utilities and applications that accompany many versions of UNIX. Some examples of these are word processing features (editors, text formatting, spelling checks, etc.), electronic filing, electronic mail, and graphics. Because UNIX treats everything (including I/O devices) as files, the syntax is consistent throughout the operating system. As discussed in Sect. 3.3, UNIX runs on a variety of hardware ranging from microcomputers to supercomputers, which allows a user to select the environment most suited to his application and needs.

Perhaps because UNIX was developed by programmers, it is a very good environment for software development. Its modular approach and wide variety of utilities (all of which can be invoked by user programs) assist in the development process. Another advantage of the UNIX operating system is its ability to deal with time-sharing situations.[5] UNIX provides a good work environment for people to share information—particularly on related projects.

UNIX originally became popular within university communities because it was relatively inexpensive. Consequently, there are many university-trained programmers who are familiar with UNIX. This influx of trained users may have a positive effect on the increased use of UNIX.

There are also negative features of UNIX. As mentioned previously, UNIX is not very user-friendly. Commands are very short and cryptic when using the standard C shell. For example, the "ls" command lists the contents of a directory; "cat filename" is used to append files, but its default use is to type out the contents of a file on a terminal ("more" is a more useful, page-oriented "TYPE" command, but some users never discover it).

Some of the rationale (or lack of) behind this type of command mnemonics may be that UNIX was written by programmers for the purpose of software development. It is important to note that even though the power of UNIX is very extensive and the commands to exercise this power are numerous, one does not need to know all about the system to be productive with it. While it is possible to write a personal command interpreter, this is a major undertaking and requires considerable expertise and time. The C shell provides the capability for creating command aliases to make commands more meaningful.

Documentation for UNIX is not very plentiful, and much of what is available is not as helpful as it could be, although this situation is changing as UNIX becomes more popular. Fortunately, some of the UNIX versions and look-alikes provide on-line documentation; however, some of it is not very understandable. The lack of good documentation is a factor to consider, especially when one is trying to convince new users that it is the operating system best suited to their needs. There are numerous user guides, but they often include a caveat that there are many versions of UNIX and some uses may differ depending upon the particular implementation. Adoption of a standard version of UNIX would give an opportunity to develop better documentation.

The majority of literature that deals with UNIX is geared more toward the microcomputer market. There is not as much information available on mainframe UNIX versions. If mainframes are large machines such as IBM, Cray, CDC, etc., they historically were not interactive development machines, which is the environment for which UNIX was developed.

Because of the many good points of UNIX, numerous versions have been developed; and this has produced some disadvantages for UNIX. Section 3.3 discusses the variety of versions and the hardware environments for which UNIX is available. Again, the fact that many versions have been developed or enhanced by different sources has introduced a standardization problem. Although not severe, standardization is a consideration, especially when a user can read about UNIX and then discover that a particular implementation of it does not have the desired capability or that the command syntax is different. This can be particularly frustrating to users when they may have been resistent to automation in general or to UNIX in particular in the first place. Some versions share a large number of

commands in common, but this common set of commands is not uniform among all versions.

UNIX requires a large amount of disk storage for the operating system itself. A range of 3.5 to 12 MB is suggested by one source.[6] There are also few and limited compilers available for UNIX. To ease the storage requirements, utilities that are not needed for a particular system can be removed.

There are also few offerings of independent packaged software available. This limited availability of off-the-shelf software has affected the number of potential UNIX users. They either do not have the resources to do their own programming, or they interpret this lack of software as an indication of the overall regard for UNIX and its future, thus choosing not to enter the UNIX arena.

UNIX was not designed with real-time applications in mind; as a result, only very few systems offer real-time capabilities. Allowing for this capability would require major changes to the operating system itself.[6] Section 3.3 mentioned Hewlett-Packard's plans to offer real-time capabilities early next year.

There are other disadvantages of UNIX also mentioned in the literature and by individuals. Some of these disadvantages include the lack of mainframe versions, the cost and availability of UNIX C programmers, the cost of porting UNIX to current systems versus acquiring hardware that already has UNIX, the time required to learn a new system, the lack of sophisticated graphics capabilities and state-of-the-art networking capabilities (for example, Systems Network Architecture or DECNET), security problems, and the need to be able to communicate with IBM files. The networking problem is expected to change when the International Standards Organization Open Systems Interconnection standards are fully defined and implemented within the UNIX environment (TCP/IP and ARPANET protocols do work under UNIX). Some of the items mentioned above represent startup costs, and for that reason they may not be of as much concern.

3.5 AT&T's EFFORTS

There are many efforts to standardize UNIX within the marketplace. A major related effort on the part of AT&T has been the push to standardize on its System V. AT&T has attempted to establish its position with the publication of its System Interface Definition. This specifies the set of system calls and library routines for any operating system that claims to be based on System V. The Institute of Electrical and Electronics Engineers also has a standards committee for UNIX.

AT&T has an agreement with Unisoft Corp. to develop a set of validation programs to test systems software for true compatibility with System V. AT&T is also working on enhancements such as record-locking features, demand paging in virtual memory, and improving networking capabilities.

At the UNIX Expo in September 1985, Bill Joy of Sun Microsystems, Inc., announced a joint effort between Sun and AT&T to produce a UNIX standard that will support the business user community (best supported by System V) and the engineering/scientific community (best supported by Berkeley's 4.2 BSD). Most of the differences are expected to be easy to resolve, while a few are more complex. The effort is expected to require approximately two years of work.

3.6 UNIX IN THE MARKETPLACE

In an effort to determine current interest in UNIX, three journals that are devoted to UNIX were contacted for estimated circulation figures. *Unique* reported 2,000 subscribers over the past one to two years. Most are domestic, and there are no off-the-shelf sales. *UNIX Review* reported that its estimated circulation for June 1985 was 30,000 issues, 25,000 of which are to controlled circulation. Very few of their sales are through stores, and it is possible that *UNIX Review* will withdraw from this sales vehicle because the journal caters to such a specialized market. *Unix/World* reported circulation figures of 50,000. This is broken down to include 20,000 subscribers, 10,000 nonpaid, and a projected 20,000 in newsstand sales.

Several UNIX users groups were also surveyed for membership figures. Usenix, which is affiliated with AT&T, reported 3,000 members at the end of 1984. At the beginning of each calendar year, memberships are started over. June 1985 membership totaled 1,500. There are two types of membership: individual and institutional. Individual membership pertains to students and individuals. Institutional membership is available to educational institutions and commercial institutions that have an AT&T license.

A more market-oriented organization, /usr/group, provides a basis for exchanging information about UNIX. There are more than 2,600 members nationwide; membership is of two types: associate and general, with general members receiving a few extra benefits.

Large corporations in general have not adopted UNIX on a company-wide basis. Some may have UNIX, but it is more likely to be found on minicomputers within individual departments. Many have not evaluated UNIX for use within their organizations and many have not even considered it. Some of the reasons cited, which were also mentioned in Sect. 3.4, include

- cost of equipment conversion,
- time required to learn a new operating system,
- the number of UNIX versions from which to choose,
- lack of application software,
- lack of UNIX versions for mainframe computers, and
- complicated user interface.[7]

It is difficult to obtain consistent views on the position UNIX has and will have in the marketplace. Most literature surveyed and people interviewed indicated that there is definitely a place for UNIX and that it will be a force to contend with, but no one was outspoken enough to say that it would be the ultimate operating system. Many based this on the uncertainty of IBM's view towards UNIX and the fact that IBM for so long has set the standards and trends with regard to computer communications and data processing.

One means by which UNIX may gain acceptance from established non-UNIX users is to run UNIX as a guest operating system under another operating system, for example under VM. This allows users to become accustomed to UNIX without having to change mainframes immediately.[8] As users become more comfortable with and gain confidence in UNIX, a migration to native UNIX could occur more easily. Another advantage to this approach is that it eases the pressure on the application conversion process. As new applications are developed under a UNIX environment and old applications are converted to

run under UNIX, the older, yet-to-be-converted applications can still be used. This introduces a degree of flexibility to the conversion process.

Predictions about the future of UNIX varied from lukewarm acceptance, through very positive reception, to the point of UNIX being the solution for everybody. The final UNIX role will probably be determined by the degree of standardization that develops and the extent to which third-party vendors will develop application software for UNIX systems.

An indication of the expanded presence of UNIX within the federal government is the recent $946-million contract awarded to AT&T by the National Security Agency to provide, install, and maintain System V-based, 3B Series computers.

4. CONSIDERATION FOR WIS

The ability to fit into many hardware environments is a requirement of WIS, and UNIX is the only operating system that can even remotely fulfill this need. However, WIS requirements include other needs that also must be taken into consideration. One of these is the need for ease of use (some people make the distinction that UNIX is easy to use but not easy to learn), and another is user-friendly capabilities. Section 3.4 discussed the advantages and disadvantages of UNIX, and both of these capabilities were discussed within that context. Many people contend that UNIX has neither of these capabilities. These enhancements can be added to a system through the writing of a UNIX shell to implement a more acceptable and versatile user interface (the shell is also portable).

The Air Force needs to determine what level of experience their staff has with UNIX. If they have no experience, or very little, and the Air Force chooses to implement UNIX within the AFWIS environment, thought will have to be given to how to accomplish the necessary software engineering to prepare their system and then to maintain it. If the Air Force chooses to hire people with UNIX experience, they should be aware that software engineers with UNIX experience generally command prime salaries. Another alternative would be to provide training for their own staff. Training will also cost money and will involve a learning curve. Another alternative would be to contract for support, which can be at varying levels, to develop the shell.

In the documentation supplied by the Air Force, the extent to which AFWIS will require real-time capability was not clearly mentioned. The WWMCCS Objectives and Management Plan described major functions of WIS, one of which is Tactical Warning and Space Defense, that may have real-time implications. The Air Force needs to examine its need for real-time capability and, if it is determined to be necessary, evaluate UNIX in this light.

It is difficult at this point to predict the future of UNIX. It has many features that are well suited to particular needs, but this is true of any operating system or piece of software. As an operating system, UNIX is not very efficient (i.e., certain algorithms and code are not optimized). With today's inexpensive, fast processors, efficiency may not be so important as in the past.

The key question may be "How long can making a decision be put off?". If the decision is to go with UNIX now, there is the risk of being burdened with maintenance of all systems, with questionable help from vendors or software houses. However, AT&T's entry into the computer market will probably be a strong incentive for standardization and third-party development efforts. If this occurs, the decision to use UNIX will be easier to make because no other operating system seems to hold the potential for meeting the requirements of AFWIS, in particular a hardware independent system.

5. REFERENCES

1. Deputy Under Secretary of Defense (Communications, Command, and Intelligence) with the assistance of the Joint Program Manager for the WWMCCS Information System, *Modernization of the WWMCCS Information System (WIS), Executive Summary,* U.S. Department Defense, July 1981.
2. *WWMCCS ADP Concept of Operations and General Requirements for Post-1985,* Joint Chiefs of Staff pub. 19, vol. 2, annex B, February 1982.
3. T. Wilmott, "Unix Perspectives," *Computerworld Focus* **19**(02A), p. 5 (January 16, 1985).
4. K. Thompson, "UNIX Time-Sharing System: UNIX Implementation," *The Bell System Technical Journal* **57**(6, Pt. 2), p. 1931 (July/August 1978).
5. H. McGilton and R. Morgan, *Introducing the Unix System,* McGraw-Hill, New York, 1983.
6. R. S. Jones, "To Market, To Market," *Computerworld Focus* **19**(02A), p. 15 (January 16, 1985).
7. J. Cogen, "Who's Using Unix?", *Computerworld Focus* **19**(02A), p. 19 (January 16, 1985).
8. A. Schroeder, presentation at the "UNIX on Mainframes" conference, UNIX Exposition, New York, September 18, 1985.

6. SELECTED BIBLIOGRAPHY

Banahan, M. and A. Rutter, *The UNIX Book*, Wiley, New York, 1983.

Barlow, D., "See How It Runs," *Computerworld Focus* **19**(02A), p. 21 (January 16, 1985).

Barlow, D. F. and N. S. Zimbel, "Unix—How Important Is It?", *Datamation* **30**(12), p. 90 (August 1, 1984).

Bell Laboratories, *UNIX Programmer's Manual*, vols. 1–2, Holt, Rinehart, and Winston, New York, 1983.

Bernhard, R., "NewsViews: The Unix Outlook—Clouded by CP/M and VM/370," *Systems & Software* **3**(4), (April 1984).

Blachman, N. and P. Ngai, "The ABC's of the Berkley Unix System," *Unix/World* **2**(4), p. 35 (May 1985).

Bork, J. and A. Greenspan, "Supermicro Offers Unix System V Virtual Memory," *Systems & Software* **4**(5), p. 103 (May 1985).

Bourne, S. R., "The UNIX Shell," *Byte* **8**(10), p. 187 (October 1983).

Bourne, S. R., *The UNIX System*, Wiley, New York, 1983.

Bylinsky, G., "The Holes in AT&T's Computer Strategy," *Fortune* **110**(6), p. 68 (September 17, 1984).

Carlyle, R. E., "Amdahl Pushes Unix," *Datamation* **30**(18), p. 46 (November 1, 1984).

Carlyle, R. E., "AT&T's Unix Dilemma," *Datamation* **30**(15), p. 40 (September 15, 1984).

Chester, M., "The Boundaries of Unix," *Systems & Software* **4**(5), p. 50 (May 1985).

Christian, K., *The UNIX Operating System*, 1983.

Cogen, J., "Who's Using Unix?", *Computerworld Focus* **19**(02A), p. 19 (January 16, 1985).

Cohler, J., "No Longer an Outcast," *Digital Review* **2**(4), p. 32 (January 1985).

Deputy Under Secretary of Defense (Communications, Command, and Intelligence) with the assistance of the Joint Program Manager for the WWMCCS Information System, *Modernization of the WWMCCS Information System (WIS), Executive Summary,* U.S. Department Defense, July 1981.

Dubrall, M., "Unix Comes in Many Flavors. It's All a Matter of Taste," *Computerworld Focus* **19**(02A), p. 45 (January 16, 1985).

Feldman, S., "NewsViews: Unix on Minis—Up Front and Accelerating," *Systems & Software* **3**(4), (April 1984).

Fiedler, D., "The UNIX Tutorial, Part 1," *Byte* **8**(8), p. 186 (August 1983).

Fiedler, D., "The UNIX Tutorial, Part 2," *Byte* **8**(9), p. 237 (September 1983).

Fiedler, D., "The UNIX Tutorial, Part 3," *Byte* **8**(10), p. 132 (October 1983).

Forgetta, V. and T. Clark, "A Bridge to SNA," *Computerworld Focus* **19**(02A), p. 33 (January 16, 1985).

Heffler, M., "A Princely Transformation: Making Unix More Friendly," *Computerworld Focus* **19**(02A), p. 25 (January 16, 1985).

Holden, S., "Wonderful World of UNIX: Hacking," *The DEC Professional* **3**(6), p. 66 (November 1984).

Holden, S., "She Sells C Shells," *The DEC Professional* **3**(2), p. 70 (March 1984).

Hunter, B., "UTS: Amdahl's Mainframe Unix System," *Unix/World* **2**(3), p. 76 (April 1985).

Jones, R. S., "To Market, To Market," *Computerworld Focus* **19**(02A), p. 15 (January 16, 1985).

Joyce, J., "A Tour Through the Unix File System," *Byte* **8**(10) p. 170 (October 1983).

Kernighan, B. W. and J. R. Mashey, "The Unix Programming Environment," *IEEE Computer* **14**(4), p. 12 (April 1981).

Krakowsky, P., "Searching for a Unix User Interface," *Attage* **1**(3), p. 36 (May/June 1985).

Krieger, M. and F. Pack, "UNIX as an Application Environment," *Byte* **8**(10), p. 209 (October 1983).

Laderman, D. "The /usr/group Standard: Approved," *Unix/World* **2**(5), p. 43 (June 1985).

Lewis, G. C., "AT&T's Unix Takes a Stand Against Big Blue," *Business Week* (2891), p. 74 (April 22, 1985).

Lomuto, A. N. and N. Lomuto, *A UNIX Primer*, Prentice-Hall, New York, 1983.

Lovett, A. "AT&T Searches for Standard Status with System V," *Computerworld Focus* **19**(02A), p. 37 (January 16, 1985).

McGilton, H. and R. Morgan, *Introducing the Unix System*, McGraw-Hill, New York, 1983.

McIlroy, M. D. et al., *The Bell System Technical Journal,* **56**(6, Pt. 2), p. 1899 (July/August 1978).

McKusick, M. K., W. N. Joy, S. J. Leffler, and R. S. Fabry, "A Fast File System for UNIX," Computer Research Group, Computer Sciences Division, Dept. of Electrical Engineering and Computer Sciences, Univ. of Calif., Berkeley, July 1983.

Morris, D., "How Not to Worry about Unix," *Datamation* **30**(12), p. 83 (August 1, 1984).

Peterson, J. and A. Silberschatz, *Operating System Concepts*, Addison-Wesley, Reading, Mass., 1983.

Rifkin, G. "IBM Takes a Look at Unix—Now What Happens?," *Computerworld Focus* **19**(02A), p. 41 (January 16, 1985).

Ritchie, D. M., "UNIX Time-Sharing System: A Retrospective," *The Bell System Technical Journal* **57**(6, Pt. 2), p. 1947 (July/August 1978).

Ritchie, D. M. and K. Thompson, "The UNIX Time-Sharing System," *Communications of the ACM* **17**(7), p. 365 (July 1974).

Ritchie, D. M. and K. Thompson, "The UNIX Time-Sharing System," *The Bell System Technical Journal* **57**(6, Pt. 2), p. 1905 (July/August 1978).

Roberts, B. "The UNIX Operating System," *Byte* **8**(10), p. 130 (October 1983).

Schnatmeier, V. "The Unix System in Large Organizations," *Unix/World* **2**(3), (April 1985).

Shein, B. and S. Sneddon, "Unix Considered," *The DEC Professional* **2**(3), p. 70 (May 1983).

Silvester, P. P., *The Unix System Guidebook*, Springer-Verlag, New York, 1984.

Sobell, M. G., "The Shell: Standard Input, Output, and Shell Scripts," *Attage* **1**(5), p. 10 (August 1985).

Sobell, M. G., "The Shell: Using Variaables and Command Line Arguments," *Attage* **1**(6), p. 12 (September 1985).

Sobell, M. G., "The Shell: What Is It, How Does It Work?", *Attage* **1**(4), p. 38 (July 1985).

Thomas, R. and J. Yates, *A User Guide to the Unix System*, Osborne/McGraw-Hill, Berkeley, Calif., 1982.

Thompson, K., "UNIX Time-Sharing System: UNIX Implementation," *The Bell System Technical Journal* **57**(6, Pt. 2), p. 1931 (July/August 1978).

Waite, M., D. Martin, and S. Prata, *Unix Primer Plus*, 1983.

Wallace, J. J. and W. W. Barnes, "Designing for Ultrahigh Availability: The Unix RTR Operating System," *IEEE Computer* **17**(8), p. 31 (August 1984),

Wilmott, T. "Unix Perspectives," *Computerworld Focus* **19**(02A), p. 5 (January 16, 1985).

WWMCCS ADP Concept of Operations and General Requirements for Post-1985, Joint Chiefs of Staff pub. 19, vol. 2, annex B, February 1982.

Zintz, W., "Unix Breaks the Realtime Barrier," *Hardcopy* **14**(6), p. 50 (June 1985).

Internal Distribution

1–10. H. G. Arnold
11. P. Y. Bengtson
12. C. R. Boston
13. M. A. Broders
14. R. A. Bryant
15. K. R. Carr
16. J. E. Christian
17. J. L. Christian
18. G. A. Dailey
19. L. D. Duncan
20. M. L. Emrich
21. S. D. Floyd
22. W. Fulkerson
23. R. T. Goeltz
24. M. S. Guy
25. C. W. Hagan
26. C. E. Hammons
27. J. L. Hardee
28. M. R. Hilliard
29. R. B. Honea
30. A. F. Huntley
31. H. L. Hwang
32. D. Y. Kelly
33. A. Klein
34. J. O. Kolb
35. G. E. Liepins
36. A. S. Loebl
37–66. R. S. Loffman
67–116. M. S. Phifer
117. G. T. Privon
118. S. D. Rose
119. R. M. Rush
120. F. L. Sexton
121. C. E. Snyder
122. M. M. Stevens
123. R. A. Stevens
124. M. P. Stulberg
125. L. F. Truett
126. E. A. Vineyard
127. D. P. Vogt
128–147. J. D. White
148. Central Research Library
149. Document Reference Section
150–151. Laboratory Records Department
152. Laboratory Records (RC)
153. ORNL Patent Section

External Distribution

154. Dr. K. C. O'Kane, Department of Computer Science, 8 Ayres Hall, University of Tennessee, Knoxville, TN 37996
155. Dr. C. P. Pfleeger, Department of Computer Science, 8 Ayres Hall, University of Tennessee, Knoxville, TN 37996
156. Dr. D. W. Straight, Department of Computer Science, 8 Ayres Hall, University of Tennessee, Knoxville, TN 37996
157. Office of Assistant Manager for Energy Research and Development, DOE-ORO, Oak Ridge, TN 37831
158–184. Technical Information Center, Department of Energy, P. O. Box 62, Oak Ridge, TN 37831