IDA PAPER P-2040

# MINIMUM REQUIREMENTS FOR THE CUS WORKSTATION

James Baldo, Jr.

April 1987



*Prepared for*
Command, Control and Communications Systems
Joint Requirements Integration Manager Office
Joint Chiefs of Staff



INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311





IDA Log No. HQ 87-32675

## DEFINITIONS

IDA publishes the following documents to report the results of its work.

### Reports

Reports are the most authoritative and most carefully considered products IDA publishes. They normally embody results of major projects which (a) have a direct bearing on decisions affecting major programs, or (b) address issues of significant concern to the Executive Branch, the Congress and/or the public, or (c) address issues that have significant economic implications. IDA Reports are reviewed by outside panels of experts to ensure their high quality and relevance to the problems studied, and they are released by the President of IDA.

### Papers

Papers normally address relatively restricted technical or policy issues. They communicate the results of special analyses, interim reports or phases of a task, ad hoc or quick reaction work. Papers are reviewed to ensure that they meet standards similar to those expected of refereed papers in professional journals.

### Memorandum Reports

IDA Memorandum Reports are used for the convenience of the sponsors or the analysts to record substantive work done in quick reaction studies and major interactive technical support activities; to make available preliminary and tentative results of analyses or of working group and panel activities; to forward information that is essentially unanalyzed and unevaluated; or to make a record of conferences, meetings, or briefings, or of data developed in the course of an investigation. Review of Memorandum Reports is suited to their content and intended use.

The results of IDA work are also conveyed by briefings and informal memoranda to sponsors and others designated by the sponsors, when appropriate.

The work reported in this document was conducted under contract MDA 903 84 C 0031 for the Department of Defense. The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that agency.

This paper has been reviewed by IDA to assure that it meets high standards of thoroughness, objectivity, and sound analytical methodology and that the conclusions stem from the methodology.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

## REPORT DOCUMENTATION PAGE

AD-A179 058

| | |
|---|---|
| 1a REPORT SECURITY CLASSIFICATION<br>Unclassified | 1b RESTRICTIVE MARKINGS |
| 2a SECURITY CLASSIFICATION AUTHORITY | 3 DISTRIBUTION/AVAILABILITY OF REPORT<br>Public release/unlimited distribution. |
| 2b DECLASSIFICATION/DOWNGRADING SCHEDULE | |
| 4 PERFORMING ORGANIZATION REPORT NUMBER(S)<br>IDA Paper P-2040 | 5 MONITORING ORGANIZATION REPORT NUMBER(S) |
| 6a NAME OF PERFORMING ORGANIZATION<br>Institute for Defense Analyses<br>6b OFFICE SYMBOL<br>IDA | 7a NAME OF MONITORING ORGANIZATION<br>OUSDA, DIMO |
| 6c ADDRESS (City, State, and Zip Code)<br>1801 N. Beauregard St.<br>Alexandria, VA 22311 | 7b ADDRESS (City, State, and Zip Code)<br>1801 N. Beauregard St.<br>Alexandria, VA 22311 |
| 8a NAME OF FUNDING/SPONSORING ORGANIZATION<br>C3 Systems, JRIM Office, JCS<br>8b OFFICE SYMBOL (If applicable)<br>C3S/JRIM/JCS | 9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER<br>MDA 903 84 C 0031 |
| 8c ADDRESS (City, State, and Zip Code)<br>Room 1D766, The Pentagon<br>Washington, D.C. 20301 | 10 SOURCE OF FUNDING NUMBERS<br>PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. T-I5-444 / WORK UNIT ACCESSION NO. |
| 11 TITLE (Include Security Classification)<br>Minimum Requirements for the CUS Workstation (U) | |
| 12 PERSONAL AUTHOR(S)<br>James Baldo, Jr. | |
| 13a TYPE OF REPORT<br>Final<br>13b TIME COVERED<br>FROM _____ TO _____ | 14 DATE OF REPORT (Year, Month, Day)<br>1987 April 20<br>15 PAGE COUNT<br>62 |
| 16 SUPPLEMENTARY NOTATION | |
| 17 COSATI CODES<br>FIELD / GROUP / SUB-GROUP | 18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)<br>WWMCCS Information System (WIS); workstations; local area network (LAN); Common User Subsystem (CUS); interoperability; compatibility; Systems Network Architecture (SNA); networks; protocols. |

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

The purpose of this IDA Paper is to provide the JCS/J6W, JRIM office with a set of minimum requirements for workstations as defined by the WIS Common User Subsystem Contract A-specification in case other vendors are sought in the future. A mapping between these requirements and the WIS 3270 PC/XT workstation identified some potential problems that may affect the selection critieria of an alternative workstation. The document contains overviews of WIS and the WIS workstation, an analysis of the minimal workstation requirements, issues concerning interoperability and compatibility, and an analysis of how various system components impact workstation requirements.

| | |
|---|---|
| 20 DISTRIBUTION/AVAILABILITY OF ABSTRACT<br>☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS | 21 ABSTRACT SECURITY CLASSIFICATION<br>Unclassified |
| 22a NAME OF RESPONSIBLE INDIVIDUAL<br>James Baldo | 22b TELEPHONE (Include area code)<br>(703) 824-5516<br>22c OFFICE SYMBOL<br>IDA/CSED |

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

IDA PAPER P-2040

# MINIMUM REQUIREMENTS FOR THE CUS WORKSTATION

James Baldo, Jr.

April 1987



INSTITUTE FOR DEFENSE ANALYSES

Contract MDA 903 84 C 0031
Task T-I5-444

## Table of Contents

## List of Figures

## Preface

The purpose of IDA Paper P-2040, Minimum Requirements CUS Workstation, is to communicate the results of a review of the current WIS workstation requirements, establishing selection criteria for an alternative WIS workstation, and accessing the impact of developing standards and technology on interoperability of Command and Control of Information Systems. Several problems were encountered during the analysis segment of this paper. The list below is a description of each problem:

a. Design and implementation documents on the WIS workstation were unavailable for review since they were still in draft form.

b. IDA was unable to arrange an interview with the WIS Common User Subsystem contractor, IBM, for the first three months of a four month study.

c. IBM informed IDA during an interview that they were recommending that the WIS workstation be upgraded to a modified IBM PC/AT machine. The bulk of the analysis was based on documentation that specified a modified IBM PC/XT machine.

The importance of this document is based on fulfilling the objective of Task Order T-I5-444, Command and Control Information System Interoperability. which is to support the Joint Chiefs of Staff Command, Control, and Communication Systems Joint Requirements Integration Management Office with guidance on interoperability. Paper P-2040 will be used by the sponsor as an accessment aid for evaluating alternative WIS workstations. As a Paper. P-2040 is directed towards personnel using, designing, or procuring command. control, and communication information systems.

This Paper was reviewed by Dr. Joseph Linn. Dr. Robert Winner. and Ms. Katydean Price.

## EXECUTIVE SUMMARY

The sponsor, Joint Chiefs of Staff, Command, Control and Communications Systems, Joint Requirements Integration Manager (officially refered to as JCS/J6W,JRIM) Office, requested IDA to assist them in developing selection criterion for Workstations on the WIS LAN. This document was developed under IDA task T-I5-444, "Command and Control Information System (C2IS) Interoperability."

In the analysis of the minimum requirements for the WIS workstation the following observations have been made:

a. The 3270 PC Control Program is central to the architecture and operation of the WIS workstation. The functionality of this program must be successfully ported and supported by the alternative workstation.

b. The LAN communication through the X.25 hardware (IBM RIC board) and TCP/SAP software interface may possibly be implemented on the alternative workstation by vendor supplied hardware and software. However, a review of the commercial products available and testing or modification will have to be performed.

c. The maximum architected memory size, 640K Bytes, of the XT-based system is a severe constraint on the applicaiton programs.

d. Use of a 80286 (PC/AT) would enhance workstation performance and types of commercial off the shelf software available for the system. The architecture of the WIS workstation should include upgrading considerations to the 80X86 family of microprocessors.

e. Alternative workstations must be able to meet the TEMPEST specifications. Consideration of workstations that already have a TEMPEST model is an obvious advantage.

**Minimum Requirements CUS Workstation**

This report outlines the minimum requirements that are absolutely necessary for a WIS Workstation. The requirements are partitioned into the following areas:

a. Keyboard

b. Processor

c. Workstation

d. Software capabilities

e. Memory

f. Display

g. Interfaces

# 1. INTRODUCTION

## 1.1 Purpose

The purpose of this document is to provide the JCS/J6W,JRIM office with a set of "minimum requirements" for workstations as defined by the WIS Common User Subsystem Contract A-Specification [WIS 84] in case other vendors are sought in the future. A mapping between these requirements and the WIS 3270 PC/XT workstation identified some potential problems that may effect the selection criteria of an alternative workstation. The following is a list of these criteria:

a. 3270 PC Control Program

b. Memory Constraint of 1M bytes

c. IBM Realtime Interface Card (RIC)

d. Intel 8088 processor

e. TEMPEST specification

## 1.2 Scope

Sections 2 and 3 describe overviews of WIS and the WIS workstation respectively. Section 4 contains an analysis of the minimal WIS workstation requirements from the A-specification to be used for as the selection criteria for an alternative workstation. Issues concerning interoperability and compatibility are discussed in Section 5. Section 6 contains an analysis of how various system components impact workstation requirements. The report is summarized in Section 7.

### 1.3 References

[FIPS 71] FIPS-PUB-1-1, code for Information Interchange (ASCII) 24 December 1980.

[GOS 86] Government Open Systems Interconnection Procurement Specification, 18 December 1986.

[INFO 86] WWMCCS Information System Common User Contract, System Critical Design Review Meeting, 26 August 1986.

[MOD 82] Modernization of the WWMCCS Information System, July 1982.

[MITR 86] MITRE Quick-Look Evaluation. Z-248 Re-Host Issues, 14 October 1986.

[RFC 87a] Request for Comments: 1001, March 1987.

[RFC 87b] Request for Comments: 1002, March 1987.

[WIS 84] WIS Common User Subsystem Contract, A-Specification 30 January 1984.

## 2. BACKGROUND

The World Wide Military Command and Control System (WWMCCS) has been under going modernization since the late 1970's, evolving from the WWMCCS ADP system to the WWMCCS Information System (WIS). The system was initially designed and implemented based on mid-1960's technology. Problems that exist in WWMCCS ADP today result from of older technology being applied to current problems [MOD 82]. The status and description of the approach taken for modernization up until early 1982 is contained in [MOD 82].

WIS modernization restructures the WWMCCS ADP system into groups of LANs that can be interconnected by the DDN as shown in Figure 1. The distributed capabilities of WIS are accessible to workstations through the Common User Subsystem (CUS) Interface. The CUS uses a standard set of interfaces to provide these services.

The CUS interface provides the following capabilities:

a. Communications window to the WIS LAN for a CUS host[1] or workstation[2].

b. AUTODIN Message Processing.

c. CUS workstation access to H6000/Level 6 processors and the CUS host to execute WWMCCS application programs.

d. The CUS shall provide the following user support capabilities :

1. Electronic mail
2. Text processing
3. Forms support
4. Menu and help files
5. Basic Graphics

[1]CUS Host - Provides support for automated message handling.

[2]CUS Workstation - Provides user access to CUS Host, H6000/Level 6 processors, and personal computer capabilities

Minimum Requirements CUS Workstation

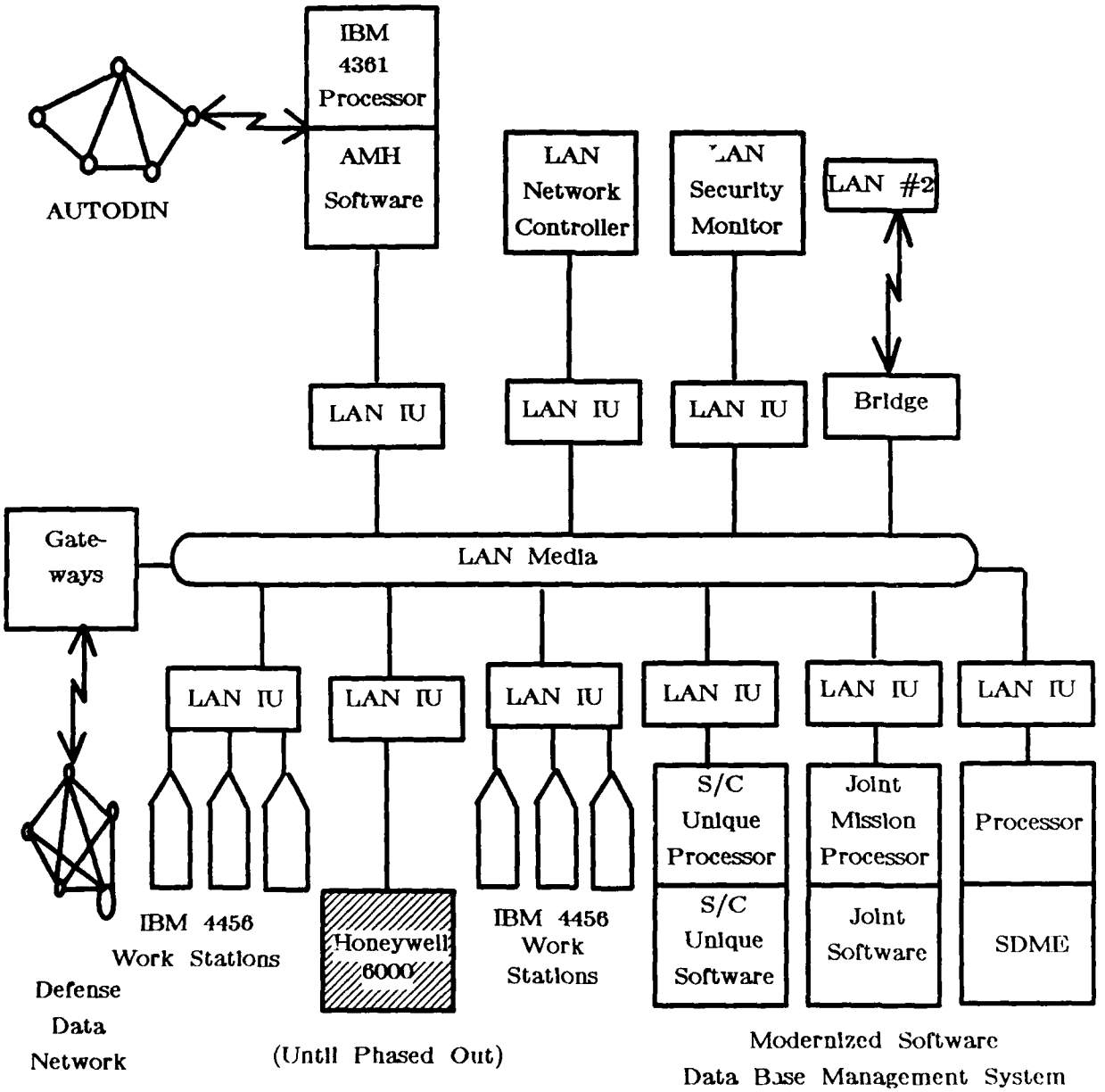



Figure 1. Typical WIS Site Architecture

e. A standalone mode for execution of commodity software.

A common standard interface increases portability and interoperability of existing products. The degree of these two system characteristics has a major impact on cost and extensibility.

The CUS gives the commander greater flexibility in configuring his headquarters. This flexibility is provided by lowering development costs for mission-specific equipment customized for the command post and by allowing the increased of commercial off the shelf hardware and software. In fact, a primary goal of WIS is to facilitate the use of COTS hardware and software. Advantages of the COTS approach are: (1) utilizing contemporary technology; (2) eliminating the development costs that are incurred with customized products; and (3) increasing the selection of products from which to choose. The CUS facilitates the evolution of new technology into the command headquarters by providing a standard framework for the integration of components.

## 3. MINIMAL WIS WORKSTATION REQUIREMENTS

From a hardware and software implementation perspective, a number of factors need to be considered to assure that the workstation can support the functionality of the CUS. Determining how much physical memory, graphics support, type of keyboard, and programming language used for implementation of application programs are just a few factors that should be considered in selection criteria of the workstation.

If an alternative workstation is to be considered, it must at least support the minimal CUS functionality as described in the A-specification [WIS 84]. This report will examine the minimal WIS workstation requirements for the WIS CUS Subsystem. The requirements will be listed and mapped to a generic WIS workstation. This generic model can be used as a baseline for assessing the capabilities of alternative workstations.

The WIS workstation is composed of hardware and software components and subcomponents. These components must meet the physical requirements (e.g., electrical power, TEMPEST, memory size, etc.) as described in the A-Specification. The specification also includes performance requirements (e.g., program start-up time, messages per minute, etc.) that are not necessarily implied by meeting the physical requirements.

From an ideal perspective, the alternative workstation should be able to use software and hardware from the WIS workstation without modification. Appendix A shows the minimum WIS Workstation Requirements and problems that may result in mapping the functionality to the alternative workstation. Appendix A also details requirements in the following areas: keyboard, processor, workstation software capabilities, memory, display, and interfaces.

# 4. OVERVIEW OF WIS WORKSTATION

## 4.1 Introduction

The WIS workstation shall provide the capabilities as described in Appendix A of this report. The workstation shall have access to CUS functions through defined interfaces. CUS workstations will communicate through the LAN using a CUS host front-end interface (HFI) and front-end protocols. For communication between H6000/Level 6 processors, two methods are available. A connection can be established using the LAN front-end protocols (i.e., Telnet) or a direct physical connection can be made through a port on the workstation.

## 4.2 The WIS Workstation IBM 3270 PC/XT

The WIS workstation being developed by IBM is essentially a modified IBM 3270 PC/XT. The following description is based on documents that IDA obtain through the WIS System Program Office (SPO), WIS Joint Program Management Office (JPMO), and IBM Federal Systems [MITR 86, WIS 84, INFO 86].

Figure 2 shows the basic components of an IBM 3270-PC. This machine enables a user to have sessions with IBM host computers such as 43XX and 308X and also provides a PC/XT capability. Overall, the system can support seven concurrent activities: one local PC-DOS 2.0 session, four remote mainframe sessions, and two local electronic notepads. It should be noted, however, that the workstation does not support true multitasking such as switching among several processes heavy weight simultaneously resident in memory.

The 3270-PC has a different keyboard layout from the normal PC: the return and shift key have been enlarged and the cursor keys have been removed from the numeric keypad to form a new key group. A total of twenty function keys have been placed in two rows at the top of the keyboard. Keys have been annotated, blue legends are used to designate PC specific functions, and black legends for 3270 functions.

To support the mainframe communications, a 3270 communication adapter card is used to handle the remote sessions. The keyboard interface has a

Minimum Requirements CUS Workstation

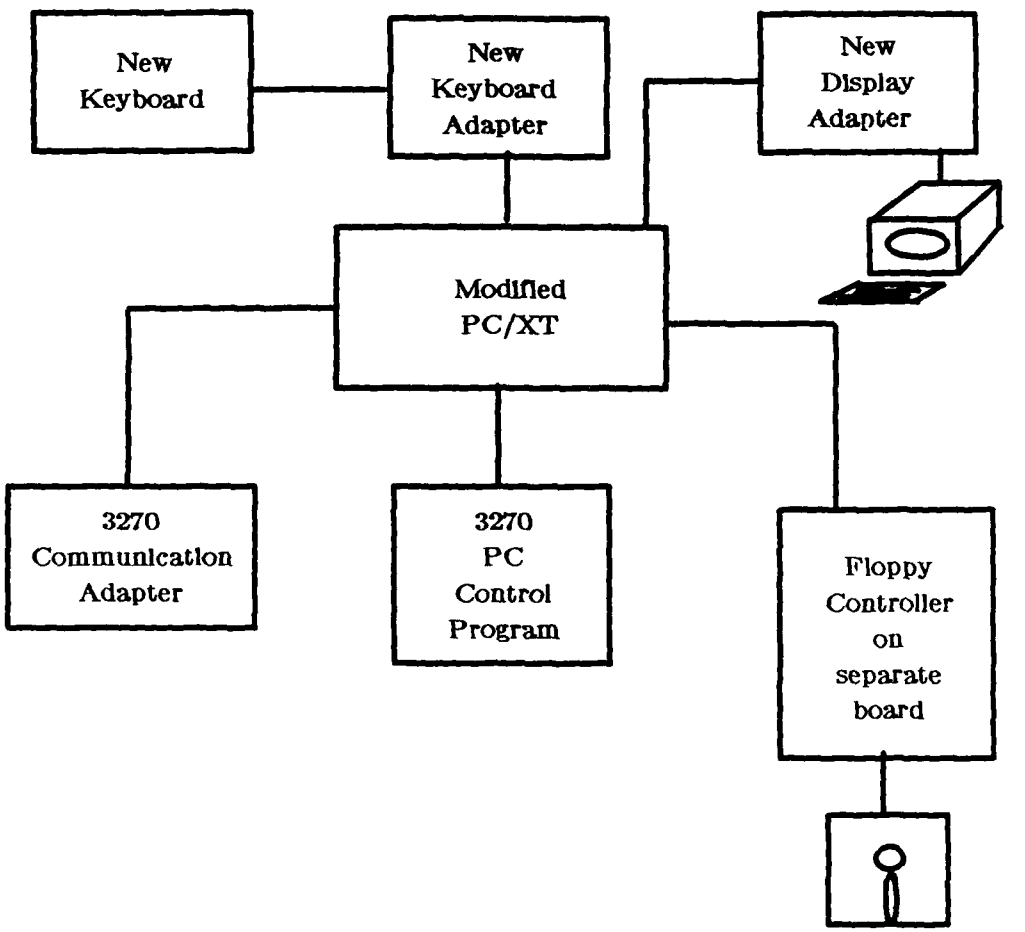



Figure 2. IBM 3270 PC/XT Configuration

special "card", while normal (non-WIS) PCs have this interface on the PC motherboard.

The 3270-PC Control Program runs in conjunction with the PC-DOS 2.0 operating system. This program manages sessions with the IBM hosts and DOS as well as managing windows accessed by applications software via a set of functions that IBM calls advanced screen management.

Appendix B contains a detailed description of the differences between the WIS 3270 PC/XT and the COTS IBM 3270 PC/XT.

## 5. INTEROPERABILITY AND COMPATIBILITY ISSUES

### 5.1 Overview

The functional requirements of the WIS workstation are representative of a set of capabilities that the workstation will provide to the user. Accurately evaluating the entire system for selection of a compatible alternative workstation is a difficult task. Figure 3 illustrates an ideal mapping of WIS functions to an alternative workstation. Although theoretically possible, a number of incompatibilities and interoperability problems prevent this approach from being straightforward. To develop criteria for the evaluation of alternative workstations, the following must be considered:

a. Determine differences between basic WIS 3270 PC/XT hardware and alternative workstations.

b. Evaluation of WIS workstation functionality supported by application specific software on the alternative workstation meets WIS requirements.

c. Evaluate the Man-Machine Interface (MMI) to determine if it can be supported identically on the alternative workstation.

d. Overall hardware component and reliability standards should match or exceed that of the WIS workstation.

e. Test the WIS workstation software, application-specific and COTS, for performance degradation (or enhancements) and execution problems.

Figure 4 gives an overview of some specific areas that may be problems with respect to portability.

### 5.2 Hardware Issues

One of the greatest advantages that the PC brings to the market place is its vendor supply base. This base supplies machines, software, and peripheral equipment. In the commercial arena a large number of peripherals (e.g., cards) products have been successfully designed to be

Minimum Requirements CUS Workstation

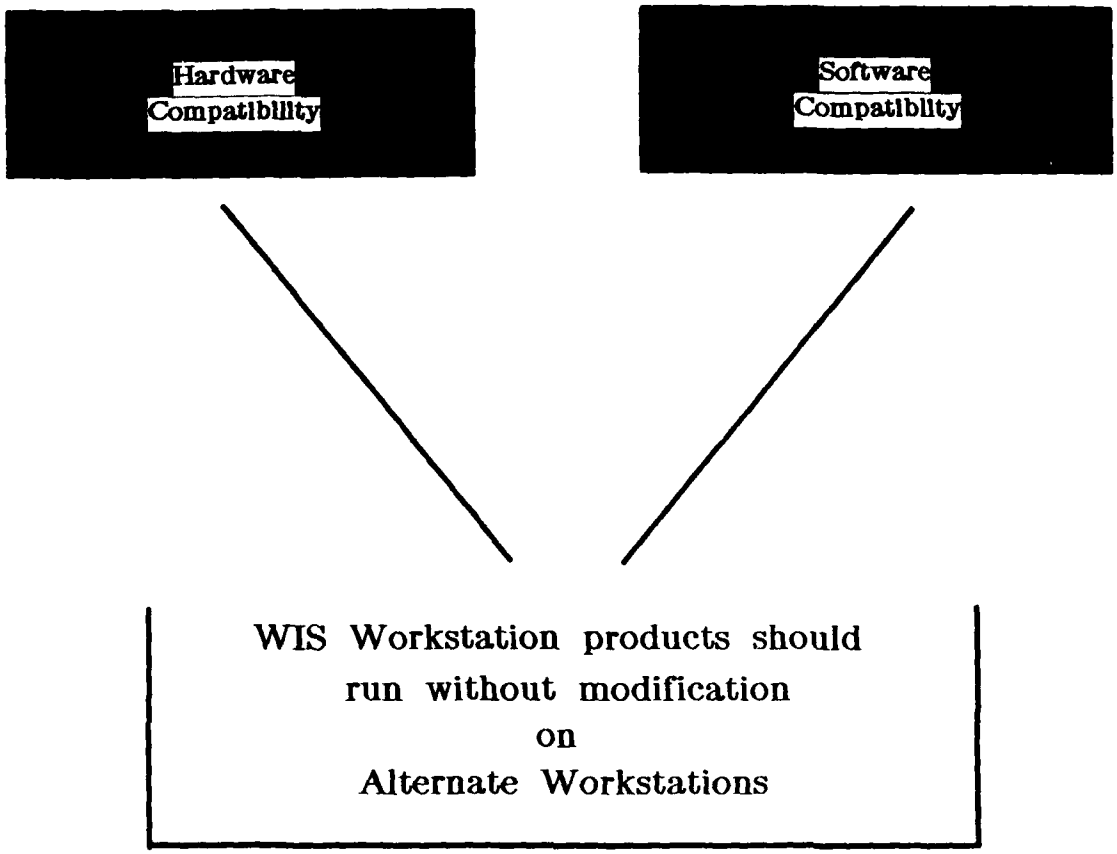



Figure 3. Aspects of Compatible WIS Alternate Workstations

Minimum Requirements CUS Workstation

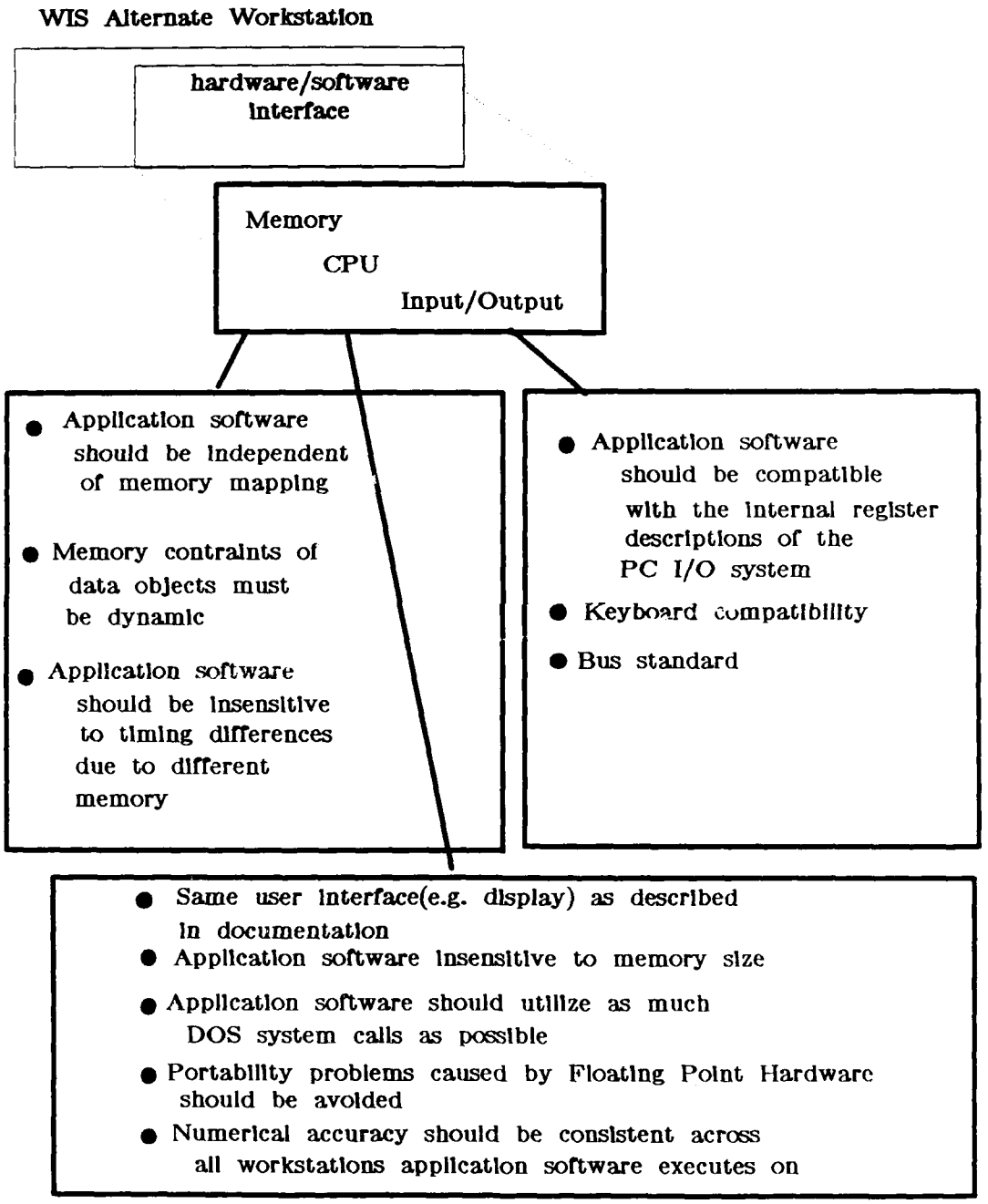



Figure 4. Workstation Portability Aspects

compatible across a large number of machines. Several differences amongst PC compatible machines that can cause compatibility problems in the ROM BIOS, PC bus, and memory.

The ROM BIOS and PC Bus will be further discussed in 6.1.2 and 6.1.3 respectively. Program and peripheral board problems related to memory can occur when specification across different memory chips vary enough to cause timing problems.

The issues listed below are possible hardware incompatibilities that are specific to the selection of the WIS alternative workstation:

a. IBM Real-Time Interface Card - Provides a risk in the selection of an alternative workstation. It is not clear [MITR 86] that this board would be available for the alternative workstation. The current WIS LAN is being built using these boards. As seen from past protocol development in the ARPANET, different implementations of the same protocols (hardware and software) is not necessarily a straightforward design and build effort. Incompatibility problems due to different interpretations of protocol specification can cause extensive time and cost problems.

b. Keyboard - The WIS keyboard is a IBM Keyboard III modified to the ANSI X4.14 standard. The alternative keyboard must either be modified if the standard keyboard does not meet X4.14.

### 5.3 Software Issues

The WIS 3270 PC/XT is essentially driven by the 3270 PC control program. It is the keystone to the overall software architecture (Figure 5). Without the 3270 control program the workstation functionality would be equivalent to a PC/XT. The control program provides the following essential services:

a. Manages concurrent sessions with IBM mainframe (four). DOS (one). and electronic notepad (two) .

b. Provides display support for windows.

c. Supports data copying between mainframe session windows.

Minimum Requirements CUS Workstation

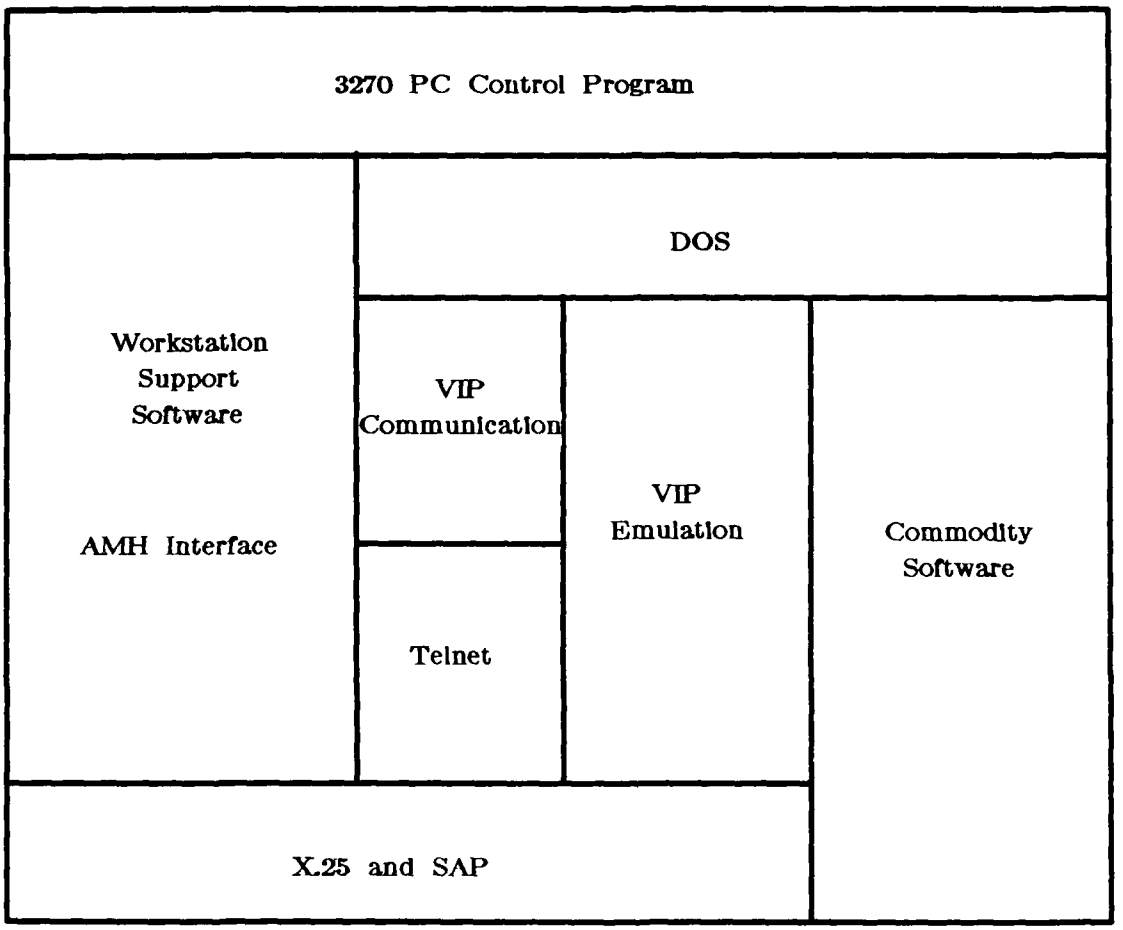



Figure 5. Software Architecture of WIS Workstation

d. Provides SNA protocol support for communication with IBM mainframe(s).

e. 3270 Terminal Emulation for access to Automated Message Handling (supports AUTODIN message processing) facilities on IBM mainframes.

f. Provides file transfer capabilities between IBM mainframe and workstation.

g. Manages all communication through the X.25/ULP Interface Software (TCP/SAP).

The MITRE report [MITR 86] has indicated that IBM considers a complete port of the control program to be impossible due to its specific design tailored to the hardware architecture of the IBM 3270 PC/XT. This leaves only one alternative, to map the functionality of the control program to an equivalent implementation on the alternative workstation.

Rehosting the 3270 control program on another workstation is considered by the MITRE report to be a large risk with respect to time, cost, and accuracy of the port. The reason for this is due to the close coupling of WIS software and the control program.

There is another area of uncertainty concerning the SNA communication protocol of the present WIS system. The Federal Government is presently changing its policy on communication protocols that would mandate the use or conversion to ISO protocols (see 6.1.7). If this policy is carried out successfully, the time frame for this transition is mid-1990s.

Since the protocol issue has some degree of uncertainty, it is important that the architecture of the control program not be based on any one communication protocol. It is recommended that the communication aspects of the control program be protocol independent. Therefore, protocol substitution can be used as policy or technical considerations dictate.

# 6. ISSUES RELATED TO CHANGING TECHNOLOGY

## 6.1 Overview

Since the WIS workstation is being designed, prototyped, tested, and fielded during a time frame in which rapid changes in technology are occurring, several components of the workstation have been analyzed for impacts by these changes.

### 6.1.1 Processor

The Intel 8088 is the processor of the WIS 3270 PC/XT. Since the majority of PC compatibles will use the 8088, this should not be an issue of concern in the selection criteria of the alternative workstation.

While this report was being generated, IBM Federal Systems recommended that WIS adopt the 3270 PC/AT as their workstation. The rationale that was given for this decision is that the 3270 PC/AT would:

a. Reduce file transfer time by 40%.

b. Increase memory.

c. Enhance growth and transition to block B.

d. Enhance hardware graphics capability.

e. Be compatible with broader range of IBM PC compatibilites.

f. Be fully compatible with early product software.

Also, a few vendors have recently started sales of PCs using the 80386 processor. At present, these machines provide only faster execution of some applications PC software. A new operating system will be needed to exploit the capabilities of the 80386.

Since the workstation requires a multi-tasking environment, the selection of a processor designed for multi-tasking is an obvious choice. Due to the upward

compatibility of the 8088 to 80286, portability of software should be high. The effects of operating systems are discussed in 6.1.4.

### 6.1.2 BIOS

In the IBM PC family, software interacts with all I/O through the Basic Input Ouput System (BIOS). A standard I/O interface supports program portability. Althought the principle of having a BIOS encourages good software engineering, variations existing in current BIOSs across members of the IBM PC family that detract from the benefits. This is due to the different features of each machine. A variation in BIOS services could impact an application program developed on one machine then attempted to be ported to another.

The problem of the BIOS is even further complicated for IBM PC compatibles since each vendor must supply their own version of the BIOS. Although the functionality of the service is preserved, there is no guarantee that the implementation of the service is the same on all machines. (It would be possible to require all machine to use the same BIOS, which could be obtained/licensed separately from a vendor.)

Presently, an IEEE working group, P1134, is working on a standard for the BIOS for PCs using the 80286 and 80386. A standard to implement a BIOS will remove the variations that exist presently. It appears that P1134 will submit a draft of the standard in February 1988 to the Microprocessor Standards Committee for review and comments.

### 6.1.3 Bus

The present IBM PC and XT buses have 62 separate lines including 8-bits for data. The AT includes an additional 36 lines which increases the data lines to 16. The AT bus is physically arranged so that all the PC signals are partitioned in a separate connector identical to that on the PC/XT buses. A second connector contains the additional AT bus signals. This provides compatibility with PC/XT cards.

A number of problems have been found when designing peripherals for the PC and AT data bus. For example, rise time on signals can cause incompatibility across a spectrum of compatible machines. The problems for the most part

can be attributed to differences in the components used for the bus.

An IEEE working group, P996, has been developing a standard for the 8-bit PC and 16-bit PC AT buses. These standards should help designers in developing boards that will interoperate amongst IBM products and compatibles.

The schedule for the 8 and 16 bit standards to become final is Fall 1987. This should not impact the WIS workstation, since the IBM bus is constructed of high quality components. IBM will also assure that the alternative workstation will meet the same high quality of their own bus.

The IEEE P996 group is also working on a standard for the a 32 - bit extension PC AT (for 32-bit machines) standard. The specification for the extension will not be specific to any one processor architecture. The following existing bus standards have been reviewed by the committee as candidates for the extension bus: IEEE P1196 Nubus, IEEE P1096 VSB, and IEEE 896 Future Bus.

Each of the above candidate 32-bit bus architectures is not specific to any one processor architecture. Also, all support a multiprocessor environment. It is fairly safe to predict that the adoption of a bus architecture of this type will have reasonable lifetime.

Apple Corporation has implemented a bus architecture (Apple Nubus) for their Macintosh II, which is very similar to the IEEE Nubus. The adoptation of the Nubus standard creates the possibility of designing peripheral cards that would be compatible for both the Macintosh and PC machines.

A major concern for WIS workstations and alternatives is identifying the impact a bus standard would have in the procurement of future workstations. Since technology is rapidly changing the capabilities, performance, cost, and functionality of workstations, it is probable that WIS would want to integrate this new technology into the LAN with existing workstations.

The P996 standards group is committed to providing support for bridging -bit and 16-bit bus peripherals to work on the 32-bit extension. This would extend the lifetime WIS specific or special cards as new workstations are integrated into the LAN.

### 6.1.4 Operating Systems

The impact of Unix or Unix-like operating systems on the WIS workstation is difficult to access. Unix is continuing to gain popularity and widespread acceptance. Presently, several versions of Unix are already available for PCs (Microsoft Xenix, MINIX, etc).

With a new generation of 80386-based machines beginning to appear, it is possible that the Unix population may increase many fold. An obvious advantage that Unix has today is its large established base of software applications and users. In addition the 80386 machine have the capability of running multiple operating systems concurrently.

Microsoft should be delivering MS-DOS 5.0 (also known as 286-DOS) within the next 12 months, which will provide multi-tasking support. MS-DOS 5.0 will provide full memory addressability to 16M bytes. This will significantly increase the types of programs that can be executed on PC/AT machines. However, it is not clear what the migration path from 2.x/3.x to 5.0 is for existing applications.

### 6.1.5 Memory

The A-Specification requires that the workstation have a minimum of 128K of memory. With the capability to expand to 512K. Since the IBM WIS Workstation was intended to handle memory up to 640K without the need of invoking special services, it is likely that the majority of alternative workstations will have the same architecture. The risk of compatability in this area is low.

The concern in the area of memory is based on the time that the A-Specification was written. Currently, it common to find workstation memory sizes of 1M byte as standard. This dramatically alters the types and implementation of application software packages. Since 8088 processor of the XT supports an address space of only 1M byte (and all but 640K is used up for I/O, BIOS, etc.), future software applications are severely limited.

Although expanded memory can provide anywhere from 64K to 8M bytes of memory, it is limited to data only. Programs must still reside in the regular

640K memory. Application software must also incorporate calls to an Expanded Memory Manager (EMM) when using the expanded memory.

A transition to an AT machine increases the memory size to 2M. This limitation may be resolved when a new version of MS-DOS becomes available that takes advantage of the 80286's full capabilities.

### 6.1.6 Software Compatability

Portable and reuseable PC software is a highly desirable characteristic that WIS would like to attain in their procurement of workstation software. This should reduce software costs for both the alternative workstation and evolution to upgraded workstations.

Several guidelines that designers and purchasers of PC software should be aware of are:

a. Generic DOS Programs - A generic DOS program uses only DOS functions accessible through interrupts 20-3F(hex). Any program that uses interrrupts outside this range are not generic. For application software to be completely portable, all I/O must be performed through the DOS.

b. Ada - WIS has already required that as much of the current software be designed and implemented in Ada as possible. Although Ada is just beginning to be used in embedded system implementations and its benefits are not necessarily realized at present, its use should be encouraged.

c. Hardware Configuration - Programs should be designed to be insensitive to hardware configuration.

d. Memory - Programs should be able to determine memory size of present machine and then execute taking maximum advantage of the resource.

e. CPU Clock - Attempts should be made to make the program as insensitive as possible to CPU clock rate.

### 6.1.7 NetBIOS

Recently, two Request for Comments (RFC) [RFC 87a, 87b] have come up for review from the Network Information Center concerning the NetBIOS. The NetBIOS essentially provides a vendor-independent software interface for IBM PCs and compatibles for computer networking. An underlying protocol will support the network capabilities. RFC 1001 and RFC 1002 defines a standard protocol to support NetBIOS services using TCP and User Datagram Protocol (UDP).

The rationale for this standard protocol is that if NetBIOS is to be used in the Internet, then all network support services must be able to interoperate. Existing implementation of NetBIOS nets today cannot necessarily interoperate due to their use of different protocols. All NetBIOSs based on TCP/IP or UDP/IP protocols will be able to communicate.

NetBIOS interfaces can also be adapted for larger computers. This will enable larger computers to act as servers and therefore distributing resources. It is important to note that these RFCs encourage interoperability through standardization.

If vendors build to the RFCs, access to TCP/UDP/IP (of which there are many) networks will be relatively straightforward through the NetBIOS. Since there is a large number of PCs and many machines that support TCP/UDP/IP protocols, the incentive to support such a service is economically attractive.

What impact may the NetBIOS have in the future on WIS? There are several issues to consider. The current WIS LAN does use the TCP/IP protocols to transmit information between hosts. A HFI outboards the TCP/IP protocols from the hosts. Communication between the HFI and host is through a X.25 connection. Application processes in the hosts use primitives describe in Appendix A to transfer data and control information over the LAN.

It is evident that an increasing number of software applications are using the network services provided by the systems that they are executed on. The evidence is strong that these types of application will become more

prevalent in the future. Providing a universal interface to network services encourages the development of such software.

Providing that NetBIOS applications on TCP/UDP/IP networks becomes widespread, WIS may have to reconsider this interface to take advantage of the available COTS software. However, the Federal Government through the Government Open Systems Interconnection Procurement (GOSIP) Specification [GOS 86] is committed to procure only ISO communication protocols starting sometime in 1990 and convert all TCP/IP systems over to ISO by 1995.

The success of the implementation of the ISO protocols based on cost and performance will be closely watched within the next few years. If the ISO protocols are successful, then TCP/IP networks will be available only in the commercial arena. NetBIOS services based on RFCs 1001 and 1002 many not have enough of a demand to make it economically feasible for a product line.

Two points of interest with respect to protocols. A number of commercial vendors are beginning to produce a suite of ISO protocols. By far, TCP/IP is still widely used in defense and commercial applications; in fact, many European LANs are TCP/IP based.

Networking is still a relatively new field. The demands that are placed on networks that were designed several years ago with excess resources to handle demands unimaginable are quickly becoming overwhelmed with traffic. A perfect example is the current daytime response time on the ARPANET. With demands of multimedia to start using network services, network architecture may need to be completely restructured.

## 7.0 SUMMARY

In the analysis of the minimum requirements for the WIS workstation the following observations have been made :

a. The 3270 PC Control Program is central to the architecture and operation of the WIS workstation. The functionality of this program must be successfully ported and supported by the alternative workstation.

b. The LAN communication through the X.25 hardware (IBM RIC board) and TCP/SAP software interface may possibly be implemented on the alternative workstation by vendor supplied hardware and software. However, a review of the commercial products available and testing or modification will have to be performed.

c. The memory constraint of 640K bytes appears to be a severe limitation for the memory demands of application programs

d. Use of a 80286 (PC/AT) would enhance workstation performance and types of COTS software available for the system. The architecture of the WIS workstation should include upgrading considerations to the 80x86 family of microprocessors.

e. Alternative workstations must be able to meet the TEMTEST specifications. Consideration of workstations that already have a TEMPEST model is an obvious advantage.

## Appendix A. WIS Workstation Minimum Requirements

This appendix is a detailed outline the requirements that are absolutely necessary for a WIS Workstation. They were extracted from the WIS Common User Subsystem Contract A-Specification [WIS 84]. The requirements will be partitioned into the following areas: keyboard, processor, workstation software capabilities, memory, display, and interfaces.

### A.1 Keyboard

The keyboard should meet the following requirements :

a. Support full 128 ASCII character set (FIPS Pub. 1-1).

b. Conform to ANSI X4.14-1971.

c. Have a numeric keypad.

d. Conform to the standard typewriter keys as described in ANSI X4.14-1971.

e. Have cursor keys.

f. Have programmable function keys.

### A.2 Processor

The workstation processor must be capable of supporting a commercially available and separately available operating system. Also, the processor must be able to support the list of software capabilities described in A.3.

### A.3. Workstation Software Capabilities

WIS software must supports on-line sessions with the CUS processor. It will be necessary to implement software that provides the following functionality detailed in A.3.1 - A.3.4.

### A.3.1 Ease-of-Use Software

#### A.3.1.1 Menus

Menus are used to guide and present novice and experienced WIS workstation users to a function selection. The implementation of menus should adhere to the following guidelines:

a. Function selection and options should be presented in the same sequence that a user would logically select or execute the function.

b. Menus should present a limited number of selections in order not to overwhelm the user.

c. Nested menus should be constrained to a reasonable level.

d. Identical options that appearing on multiple menus, should be located in the same position with each appearance.

e. Experienced users should be able to bypass all or parts of menus.

f. Text within the menu should be brief and self-explanatory.

g. Menus should indicate options selected by user.

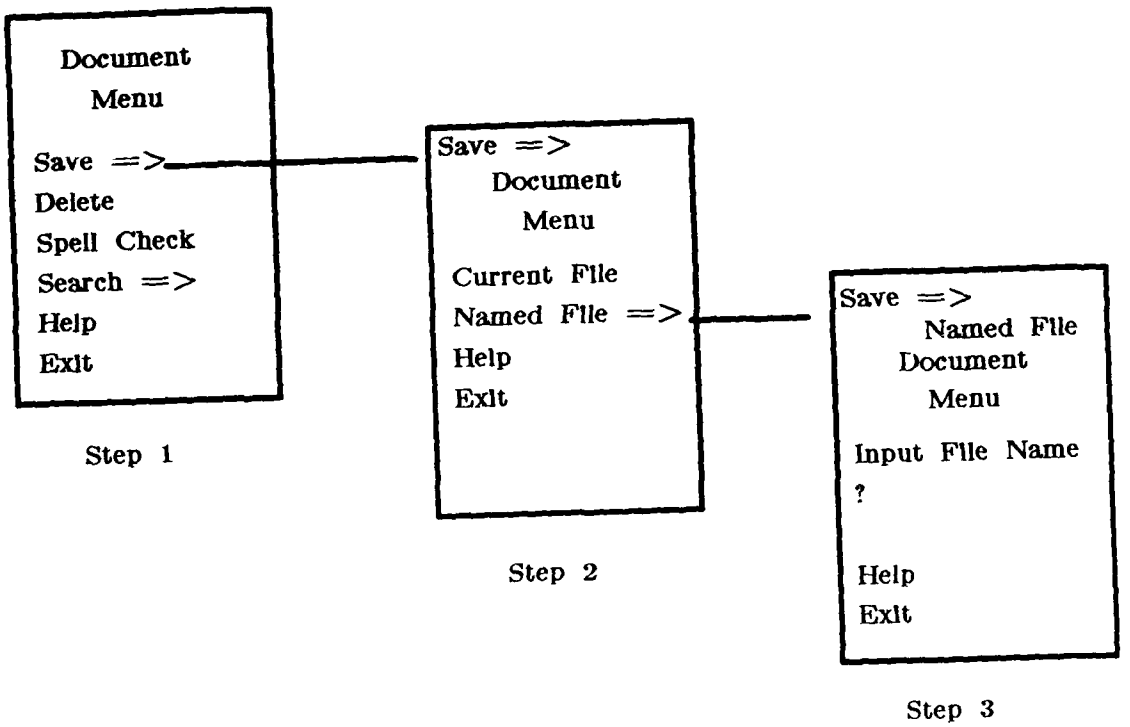
Figure 7 shows an example of a menu based on the above criteria.

#### A.3.1.2 Forms

The forms capability should allow the user to create, save, delete, and modify forms. Protected and unprotected field capabilities shall be supported. Display keys shall provide cursor movement through the form.

#### A.3.1.3 Help

Every function shall provide help and error feedback features to assist users. Terse and concise description of function features and selection




Novice User Scenario - Steps 1, 2, and 3.

Experienced User Scenario - Step 1
Type in file name and execute.

Figure 7. Menu Example

shall be available upon request. Error feedback should attempt to assist user when possible with a diagnostic message.

#### A.3.1.4 Abort

A mechanism shall be available to abort from any function.

### A.3.2 Word Processing

This feature shall be used to compose AUTODIN messages and other user text applications.

#### A.3.2.1 Character Set

ASCII characters 32-126 (DEL not printable) decimal will be able to be generated, processed, and display.

#### A.3.2.2 Display Configuration

Two windows shall be provided to view two sets of data on the same screen. Window attributes, such as size and location shall be configurable. Setup for window attributes should be menu driven.

#### A.3.2.3 Paging

User shall be able to move through text on a page-by-page basis. At least two lines of the previous page must be visible on the new display. The paging operation will be through a function key.

#### A.3.2.4 Scrolling

Bidirectional horizontal and vertical viewing of text will be provided. See Figure 8 for a comparison between paging and scrolling.

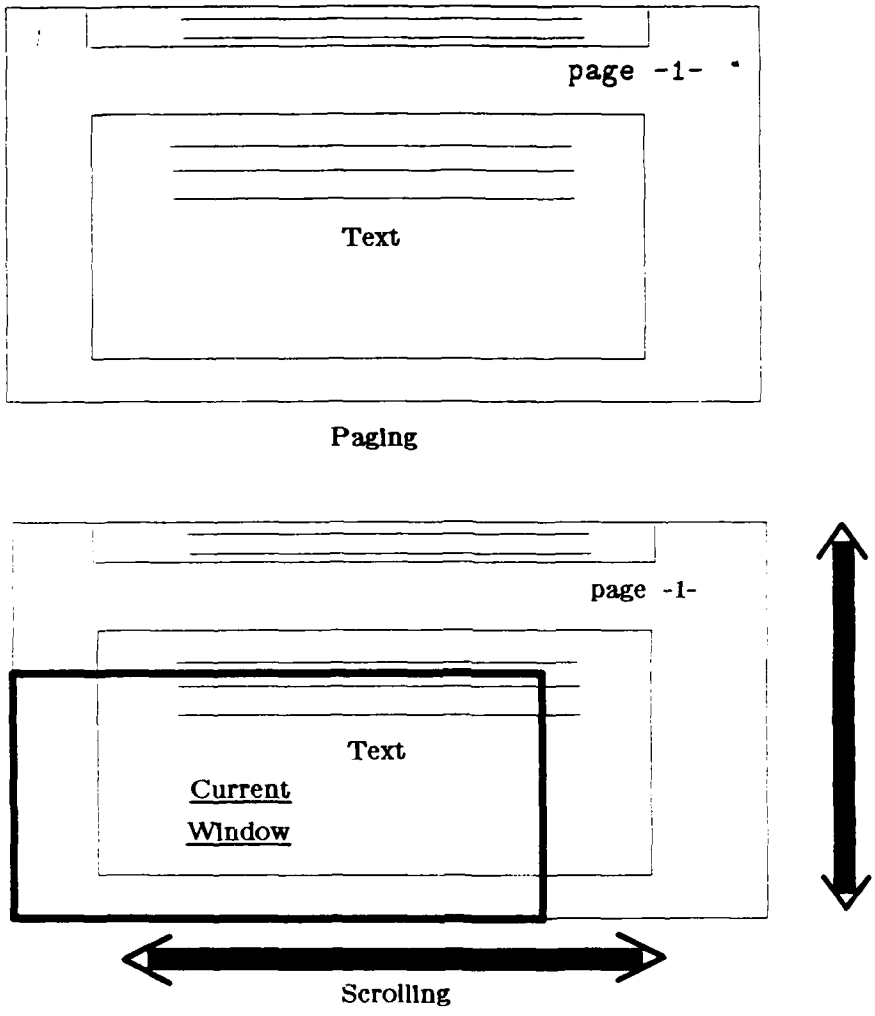



Figure 8. Paging and Scrolling Examples

### A.3.3 Text Processing

In the WIS workstation environment, text is either structured or unstructured. Structured text is defined through forms. In the text processing mode the user shall be able to create and save forms. The following user capabilities shall be provided in A.3.3.1 - A.3.3.3

#### A.3.3.1 Composition

Capabilities shall be provided to compose forms, messages from forms, and other data.

#### A.3.3.2 Review

Paging and scrolling of text shall be enabled at any time during composition or review. A return to previous page or scroll position shall be possible.

#### A.3.3.3 Formatting

The following format functions will be provided:

a. Right/Left margins settings

b. Header/Footer settings

c. Automatic centering of marked text

d. Tab

e. Automatic pagination and renumbering

f. Automatic carriage return and line feed (Option to set automatic carriage return at designated line length)

g. Whole word wraparound

h. Deletion capabilities of single character, word, line, and areas of text

i. Mechanism for text insertion

j. String search mechanism capable of finding strings of at least 20 characters

k. Replacement text (from a buffer) and search and replacement capabilities will be supported

l. Moving text within files and between files will be supported

m. Copying text, the ability to replicate selected areas of text, will be supported

n. Merging text files will be supported

o. Saving text to non-volatile secondary storaged at any time during an editing session shall be supported

p. Text shall be automatically adjusted, with respect to spacing, lines, and pages, for editing the functions of insertion and deletion

### A.3.3.4 Print Options

Text created with the word processor shall have the following print attributes available for the user to specify:

a. Number of lines per page

b. Number of copies

c. Print type (e.g., draft)

d. Line spacing

e. Number of characters per inch

f. Stop printing at the end of each page

g. Automatic page number; top, bottom, left, and right margin settings

All of the previous attributes listed will have default values.

### A.3.4 Memory

A miminum of 128K bytes of memory is required. The workstation must be expandable to at least 512K bytes (by memory card of chip insertion). Secondary memory must have both diskette and hard disk. The hard disk must be removable and a second hard disk could be fixed. Disk storage must be at least 5M bytes.

### A.3.5 Display

The display must support the following minimum requirements:

a. 80 columns by 24 rows

b. Display full 95 ASCII characters

c. Monochrome and color displays should be interchangeable by disconnecting the display and changing the display adapter card .

d. The color display will be a RGB monitor .

e. The color display will have a minimum resolution of 512 x 350 pixels.

f. The color display will at least have the following colors: red, green, yellow, blue, black, white, cyan, and magenta.

g. 12-inch diagonal screen

h. Screen must be flicker and jitter free and not susceptible to moire patters with or without TEMPEST shielding.

i. Display must have user adjustable screen controls.

j. Display characters must be readable four feet from the screen.

### A.3.6 Interfaces

All interfaces described in this section shall be implemented on cards that are plugged into the workstation bus. The following standard interfaces will be supported by:

a. Color video output to support a second display.

b. Three serial asynchronous ports configured to any of the following standards: MIL-STD-188C; MIL-STD-188/114 balanced; MIL-STD-188/114 unbalanced; EIA Standard RS232C.

c. Bi-synchronous communication channel for direct interface to H6000/Level 6 hosts.

d. Parallel interface

e. Interface to support peripherals like a mouse or joystick

f. Interface to GFE LAN

g. Two spare bus slots after fullfilling WIS Workstation requirements.

### A.4 Physical, Electrical, Reliability, and Maintaince Requirements

The workstation and its existing peripherals must be transportable without the need of special moving equipment. Dimensions of the workstation shall not exceed 22 inches in width, and 30 inches in depth.

Power sources, single or three phase, unfiltered commercial power of 110V to 125V or 220V to 250 V at 50 or 60 Hz shall shall be used for the workstations and peripherals. Power supply must be adequate for the population of new boards to the spare bus slots.

Mean-time-between-failures for the workstation and workstation printer shall be at least 2000 hours.

Repair considerations for the workstation and workstation printers are based on the following sequence of events:

a. Detection

b. Diagnosis

c. Repair (replace component)

d. Alignment

e. Checkout

f. Bring Unit back on-line.

Repair time should be on the average 15 minutes and not to exceed 30 minutes. TEMPEST and non-TEMEPEST components must be mark so that replacement does not change prior configuration type.

### A.5 Standalone Mode

In a standalone mode the workstation will be able to execute COTS software that contains the following elements as a minimum:

a. Operating system

b. Word processor

c. Basic graphics

d. Spread sheet

e. Database

f. High order language

### A.6 Man-Machine Interface

Both hardware and software should incorporate human factors into the designs of their interfaces. The following characteristics should be stressed in the interfaces:

a. Present a simple CUS interface to the user.

b. Interface should accomodate both novice and experienced users.

c. Step the novice user through selection of CUS functions, while providing feedback with respect to errors.

d. User should be able to cancel all CUS request without producing fatal system errors or long response time for termination of previous request.

e. Interface design should be evaluated based on maximum physical efficiency and minimized physical fatigue.

f. Hardware and software designs and equipment must be in compliance with MIL-H-46855B (Human Engineering Requirements for Military Systems, Equipment and Facilities - Section 3) and MIL-STD-1472C (Human Engineering Design Criterela for Military Systems, Equipment and Facilities).

### A.7 LAN Interface

The WIS workstation will have access to the LAN through a Government provided host front-end interface (HFI). Protocols used to communicate across the LAN are contained in the HFI. Therefore, information to be sent through the LAN from a workstation or host is sent to the HFI, which encapsulates the message for transmission.

The interface is composed of six primitives: open, send, receive, close, status, and abort. These primitives are essentially equivalent to those defined and described in MIL-STD-1778 for the Transmission Control Protocol (TCP).

Before communication can occur between two hosts a connection must be established (protocols are described in terms of finite state machines, the established connection indicates that both peer protocols are in the establish state). The open primitive can establish a connection by two methods: active or passive open. An active open is sent to a destination host to request and establish a communicaiton connection. A passive open directs the host to wait for an active open from a specific host or group of hosts.

Connections are bidirectional full-duplexed channels. Data is transferred over an established connection by the send primitive. Established connections can be normally terminated by the close primitive. This is accomplished by both sides acknowledge termination and transmit remaining data in their buffers and wait for data already send from destination host. The abort is an abnormal termination in which the host receiving the primitive cannot guarantee (to the application process) that all data sent to and received by the destination was successful.

The receive primitives reserves buffer space for incoming data during an established connection. A status primitive enables the application process to monitor the connection. In order to give a more precise understanding of these interface, Figure 9 is an Ada specification of the primitives described above.

```
with Buffer_Data;
with System_Bits;

package Interface_Service is

type Bit_Length_16 is System_Bits.Data_Field_16;
type Bit_Length_24 is System_Bits.Data_Field_24;

type Open_Type is (Active, Passive);
type Connection_Name is access Buffer_Data.Connection_Name_Ptr;
type Buffer_Ptr is access Buffer_Data.Buffer_Ptr;

subtype Max_Packet_Size is Integer range 0..Buffer_Data.Limit;

type Push_Flag is System_Bits.Data_Field_1;
type Urgent_Flag is System_Bits.Data_Field_1;

type Concetion_State_Type( Closed, Active_Open, Passive_Open,
                           Established, Closed );

procedure Open( Local_Port : in Bit_Length_16;
                Foreign_Net : in Bit_Length_24;
                Foreign_Host : in Bit_Length_24;
                Foreign_Port : in Bit_Length_16;
                Active_or_Passive : in Open_Type;
                Connection_ID : out Connection_Name_Ptr) ;

procedure Send( Connection_ID : in Connection_Name_Ptr;
                Buffer_Address : in Buffer_Ptr;
                Byte_Count : in Max_Packet_Size;
                Push : in Push_Flag;
                Urgent : in Urgent_Flag);
```

Figure 9. Communication Primitives (Sheet 1 of 2)

```
procedure Receive( Connection_ID : in Connection_Name_Ptr;
                   Buffer_Address : in Buffer_Ptr;
                   Byte_Count : in Max_Packet_Size);

procedure Close( Connection_ID : Connection_Name_Ptr);

procedure Connection_Status( Connection_ID : in Connection_Name_Ptr;
                             Packets_Sent : out Bit_Length_16,
                             Packets_Receive : out Bit_Length_16;
                             Retransmission_Count : out Bit_Length_16;
                             Free_Buffers : out Bit_Length_16;
                             Allocated_Buffers : out Bit_Length_16;
                             Connection_State : out Connection_State_Type);

procedure Abort ( Connection_ID : in Connection_Name_Ptr);
```

Figure 9. Communication Primitives (Sheet 2 of 2)

## Appendix B. Differences between the WIS 3270 PC/XT and the COTS IBM 3270 PC/XT

Differences between the IBM 3270 PC/XT and the WIS Workstation are listed in Figure 10. Figure 11 shows WIS peripherals and Figure 12 lists WIS software. Modifications to the IBM 3270 PC/XT are required for the following reasons:

a. WIS workstation keyboard layout must conform to ANSI standard X4.14-1971. An IBM Keyboard III was used. Figure 13 shows key groupings.

b. The WIS workstation must support the display requirements as listed in 4.3.5.

c. Video Output - second display.

d. Printer Port (parallel)

e. Three serial asynchronous ports (configurable to MIL-STD-188C, MIL-STD188/114 balance, MIL-STD-188/114 unbalanced, and EIA Standard RS232C

f. Interface to H6000 Datanet and Level 6 systems

g. Interface to GFE LAN

h. Able to connect standard devices(e.g., mouse, joystick, etc.)

i. Two spare slots on bus after installation of WIS boards.

j. Memory - minimum 128K bytes expandable to 512K bytes.

k. Bus - must not be a company proprietary design.

l. Color Graphics Device - graphics capabilities for transparencies (8X10 inch) and 35 mm color slides, from screen images .

Minimum Requirements CUS Workstation

| IBM 3270 PC/XT | WIS Workstation |
|---|---|
| 3270-PC Keyboard | ANSI X4.14 compatible Keyboard |
| 3279-PC Keyboard Adapter | Modifications |
| Enhanced Display Support | Modified Display Adapter for RGB Video |
| 3270 Communication Adapter | Real-Time Interface Card (X.25 support) |
| | Additions |
| | Slot Saver Card (clock/calendar, keyboard interface and 384K bytes of memory) |
| | Adaptec Hard Disk Controller Card |
| | Frontier Asynchronous/ Bisynchronous Communication Card |

Figure 10. IBM 3270 PC/XT vs WIS Workstation

Minimum Requirements CUS Workstation

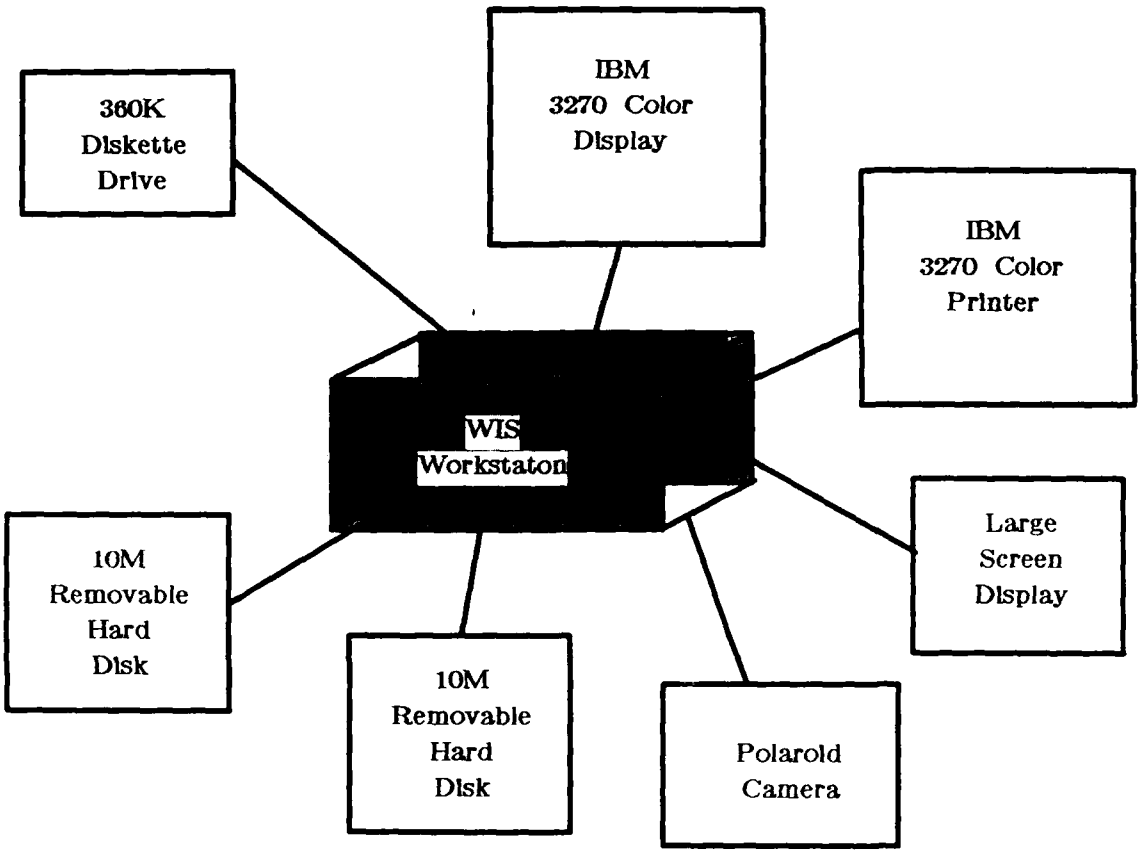



Figure 11. WIS Peripherals

WIS 3270 PC Control Program
(IBM Proprietary Product)

Simultaneously Supports
- Four 3270 Sessions
- One PC/XT DOS Session
- Two Notepads

Supports SNA

TELNET Applications software

TCP/Service Access Point Client Process Software

X.25 Board Interface Software

COTS Software

WIS Workstation Software

Figure 12. WIS Software

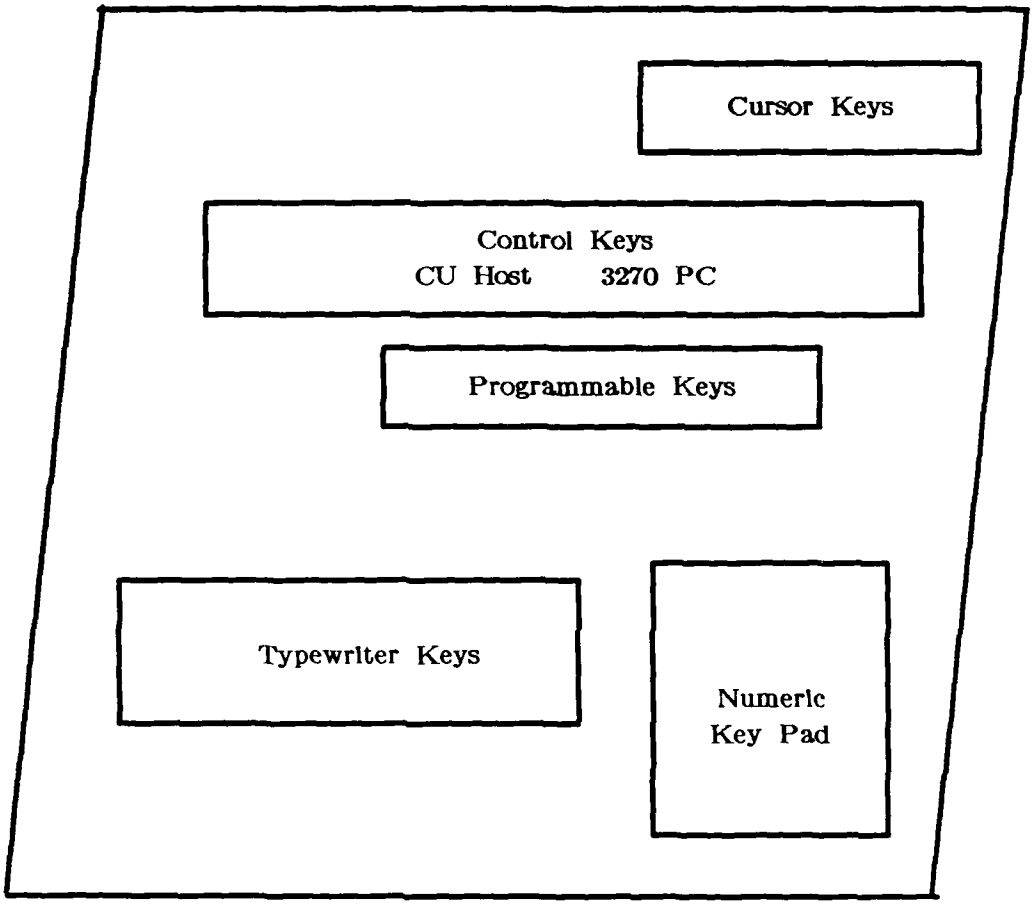



Figure 13. Keyboard Grouping

**Minimum Requirements CUS Workstation**

IBM has designed a display adapter that combines several functions into one card. The card is used drive either a IBM 5151 monochrome 12 inch or IBM 5272 color 14 inch 720 x 350 pixel eight colors displays. A second display channel is used to drive a Talaria large screen display or a Polaroid Mod 68 35mm camera unit.

The IBM 5182 color printer is connected from a combination memory/printer/keyboard/async card. An additional 384K bytes of RAM extends the system memory to 640K bytes. A separate parallel channel is provided for the printer. A RS-232 and keyboard ports are located on the board along with a non-volatile clock.

Secondary storage is provided by one IBM 360K byte 5 1/4 inch floppy disk drive and two removable Adaptec 10M byte hard disk drives. Two adapter cards are needed.

An ADCOM2-M Frontier adapter card provides both asynchronous and bisynchronous communication. Direct connection to the H6000 host processor uses the bisynchronous capabilities of the card when the workstation is in the VIP 7705W Emulation mode (emulates functions of Honeywell VIP 7750W terminal).

The interface to the WIS LAN is supported by an IBM-built card, the Realtime Interface Co-processor (RIC). It provides X.25 capability with software local to the board. Two ports are available on the adapter (EIA-RS-449) for simultanous connections to the LAN. For example two sessions, an AMH and H6000, could be executed between two windows.

The only differences between the TEMPEST and non-TEMPEST versions of the WIS workstation are with respect to the enclosures used for shielding signal emanations. All software is identical for both TEMPEST and non-TEMPEST workstations.

A list of IBM WIS workstation TEMPTEST characteristics follows:

a. Display - source suppressed display head.

b. Secondary Storage - (1) shielded disk drive assembly (2) sealed disketted drive chamber allows access to diskettes.

c. Keyboard - special process and shielded electronics.

d. Cabinet -

(1) Lightweight aluminum casting to reduce weight
(2) Deeper cabinet to allow filters
(3) Mother board, power supply, and I/O signal cables filtered
(4) External cables shielded

A list of the WIS TEMPEST Printer characteristics follows:

a. On/Off switch on front of printer

b. Parallel Centronics port

c. Sheet metal shielding or circuit board

d. Motor cable shielding

e. Improved grounding

f. Filters on power lines

g. Filters on I/O signal lines

h. Filters shielded

The A-specification [WIS 84] defines the interface between the workstation and LAN. Protocols to communicate between hosts and workstations on the LAN are GFE in a Host front-end interface (HFI). Communication between the workstation and the HFI is through a X.25 connection. Figure 14 shows the hardware and its relationship to the protocols.

Minimum Requirements CUS Workstation

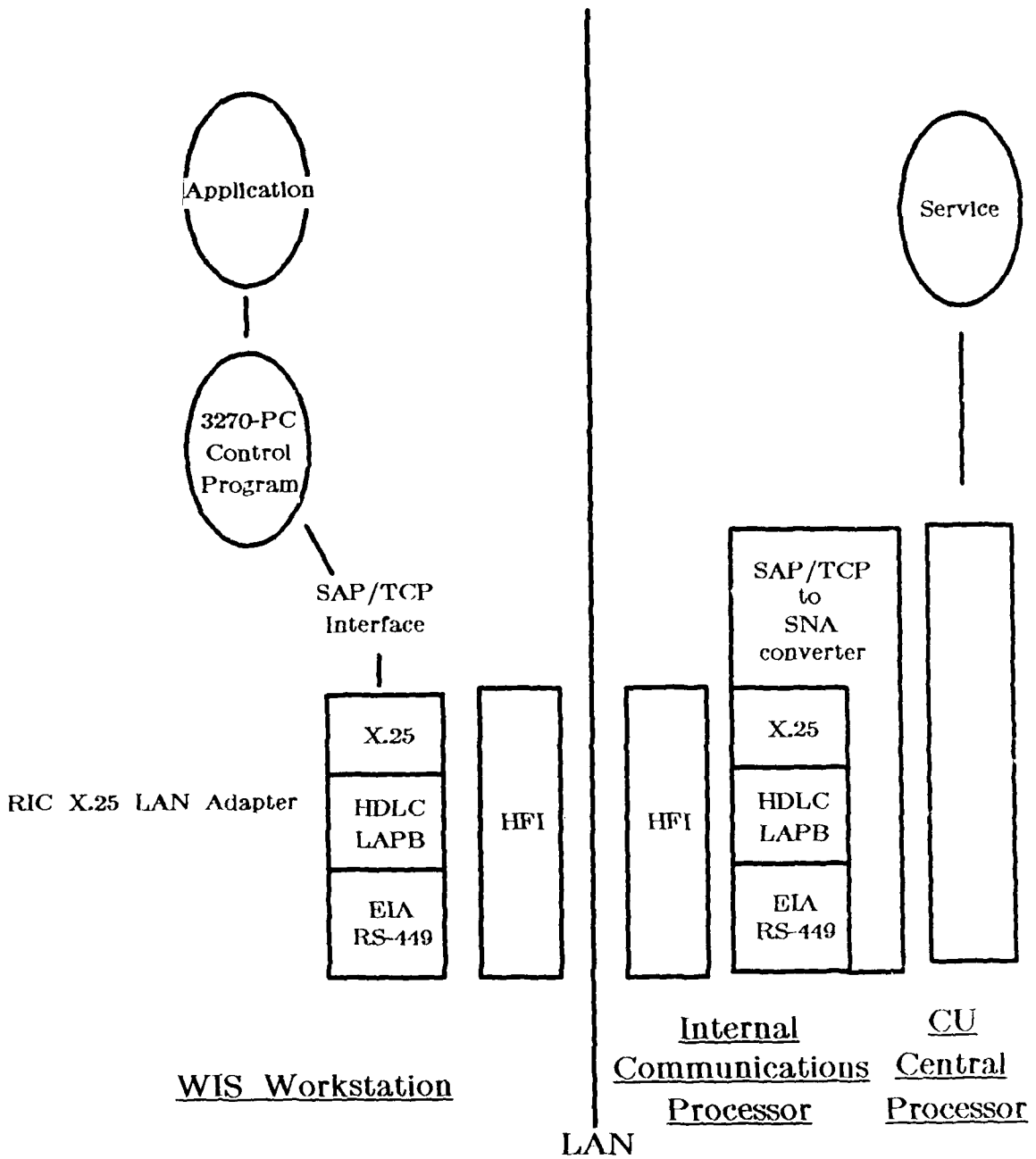



Figure 14. WIS Communication Protocols

## List of Acronyms

| | |
|---|---|
| ADP | Automated Data Processing |
| AMPE | AUTODIN Message Processing Exchange |
| ANSI | American National Standard Institute |
| AUTODIN | Automated Digital Information Network |
| BIOS | Basic Input/Output Services |
| C2 | Command and Control |
| C2IS | Command and Control Information Systems |
| C3 | Command, Control and Communications |
| C3SJRIM | Command, Control and Communications Systems Joint Requirements Integration Management |
| COTS | Commercial Off the Shelf |
| CUS | Common User Subsystem |
| DDN | Defense Data Network |
| DOS | Disk Operating System |
| GOSIP | Government Open Systems Interconnection Procurement |
| HFI | Host Front-End Interface |
| ISO | International Standards Organization |
| IP | Internet Protocol |
| JCS | Joint Chiefs of Staff |

| | |
|---|---|
| LAN | Local Area Network |
| MMI | Man-Machine Interface |
| NetBIOS | Network Basic Input/Output Services |
| OSI | Open Systems Interconnect |
| PC | Personal Computer |
| PC/AT | Personal Computer/Advance Technology |
| PC/XT | Personal Computer/Extended Technology |
| RIC | Real-time Interface Card |
| RFC | Request for Comments |
| ROM | Read Only Memory |
| SAP | Service Access Protocol |
| SNA | Systems Network Architecture |
| TCP | Transmission Control Protocol |
| UDP | User Datagram Protocol |
| WIS | WWMCCS Information System |
| WWMCCS | World Wide Military Command and Control System |

## Distribution List for IDA Paper P-2040

| NAME AND ADDRESS | NUMBER OF COPIES |
|---|---|
| **Sponsor** | |
| Lt. Col. Frank Graves<br>C3 Systems, JRIM, JCS<br>Room 1D776<br>The Pentagon<br>Washington, D.C. 20301 | 3 copies |
| **Other** | |
| Defense Technical Information Center<br>Cameron Station<br>Alexandria, VA 22314 | 2 copies |
| **CSED Review Panel** | |
| Dr. Dan Alpert, Director<br>Center for Advanced Study<br>University of Illinois<br>912 W. Illinois Street<br>Urbana, Illinois 61801 | 1 copy |
| Dr. Barry W. Boehm<br>TRW Defense Systems Group<br>MS 2-2304<br>One Space Park<br>Redondo Beach, CA 90278 | 1 copy |
| Dr. Ruth Davis<br>The Pymatuning Group, Inc.<br>2000 N. 15th Street, Suite 707<br>Arlington, VA 22201 | 1 copy |
| Dr. Larry E. Druffel<br>Software Engineering Institute<br>Carnegie-Mellon University<br>Pittsburgh, PA 15213-3890 | 1 copy |
| Dr. C.E. Hutchinson, Dean<br>Thayer School of Engineering<br>Dartmouth College<br>Hanover, NH 03755 | 1 copy |

| NAME AND ADDRESS | NUMBER OF COPIES |
|---|---|
| Mr. A.J. Jordano<br>Manager, Systems & Software<br>Engineering Headquarters<br>Federal Systems Division<br>6600 Rockledge Dr.<br>Bethesda, MD 20817 | 1 copy |
| Mr. Robert K. Lehto<br>Mainstay<br>302 Mill St.<br>Occoquan, VA 22125 | 1 copy |
| Mr. Oliver Selfridge<br>45 Percy Road<br>Lexington, MA 02173 | 1 copy |
| **IDA** | |
| General W.Y. Smith, HQ | 1 copy |
| Mr. Philip Major, HQ | 1 copy |
| Dr. Robert E. Roberts, HQ | 1 copy |
| Dr. Jack Kramer, CSED | 1 copy |
| Dr. Robert I. Winner, CSED | 1 copy |
| Dr. John Salasin, CSED | 1 copy |
| Ms. Anne Douville, CSED | 1 copy |
| Mr. Terry Mayfield, CSED | 1 copy |
| Mr. James Baldo, CSED | 2 copies |
| Ms. Katydean Price, CSED | 2 copies |
| IDA Control & Distribution Vault | 3 copies |