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MAINTENANCE AND REPAIR SUPPORT SYSTEM (MARSS)

by
Francis Wessling III

The Boeing Company - McDonnell Douglas Corporation

February 1999

Final Report
April 1995 - December 1997

Approved for Public Release; Distribution Unlimited

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Soldier Systems Center
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13. ABSTRACT *(Maximum 200 words)*

The Defense Advanced Research Project Agency (DARPA), in conjunction with the U.S. Army Soldier Systems Center (SSC), U.S. Army Test Maintenance Diagnostics Equipment Activity (TMDE), and the McDonnell Douglas Corporation, a wholly owned subsidiary of the Boeing Company, developed the first Pentium class body-wearable computer. Under the DARPA-funded NATICK Contract DAAK60-95-C-2029, the McDonnell Douglas Corporation researched, designed, developed, built, and tested an advanced portable tactical information assistant called the Maintenance and Repair Support System (MARSS). The MARSS system established a revolutionary approach to the human/machine interface for information systems. The need for the system is derived from the increasing complexity of weapon systems and the reduction in armed forces personnel. Portable multimedia information systems are required to access information from remote locations, enhance mobility while referencing information, decrease required training of personnel, and increase operational readiness by decreasing- repair time for weapon systems. The Maintenance and Repair Support System (MARSS) is a body-worn portable information computing system that allows the user to access needed information hands-free.

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Preface

This report documents the development and lessons learned in the process of researching, designing, and building the Maintenance and Repair Support System (MARSS). The MARSS system was a concept that was presented to the Defense Advanced Research Projects Agency to develop a body-worn computer for Maintenance Applications. Through the development of the program, the utility of the product was recognized by other organizations. This final report provides information to government agencies to allow for the further development of wearable computer systems to advance the concept of humionics – The integration of electronics onto human beings.

Acknowledgments

The development of new technology is a process that takes hard work and a great deal of dedication. The development of MARSS, the first Pentium™ body-worn computer system, was a technical challenge. Particular individuals were key to the development and support of the MARSS system. Through Dick Urban, the Defense Advanced Research Projects Agency (DARPA) provided the program funding and the management that allowed for the development of the MARSS system. Henry Girolamo of the U.S. Army Soldier Systems Center (Natick) worked tirelessly for the development of the system and provided the daily oversight of the entire program for DARPA. Charlie Bosco of the U.S. Army Test Maintenance Diagnostics Equipment Activity (TMDE) provided insight to the development of the system. Mark Darty of the McDonnell Douglas Corporation and Charlie Bosco were responsible for the original concept of MARSS and worked to obtain the funding for the 486 MARSS and the Pentium MARSS systems. Special thanks go to the entire McDonnell Douglas MARSS Development team. Special thanks also go to Vivek Saxena and Uma Mondal of American Megatrends Inc. for the detailed development of the MARSS motherboard electronics. Thanks also go to Norman Tarlton of Honeywell for tireless support in developing the MARSS Head Mounted Displays. Recognition is also given Dean Levey and Bill Hoge of Ultralife for their efforts in developing the MARSS Battery. On a final note, Vernon Love of TMDE is credited for the naming of the MARSS system.

Summary

The Defense Advanced Research Projects Agency (DARPA), in conjunction with the U.S. Army Soldier Systems Center (Natick), U.S. Army Test Maintenance Diagnostics Equipment Activity (TMDE), and the McDonnell Douglas Corporation, a wholly owned subsidiary of the Boeing Company, developed the first Pentium™ class body-wearable computer. Under the DARPA-funded NATICK Contract DAAK60-95-C-2029, the McDonnell Douglas Corporation researched, designed, developed, built, and tested an advanced portable tactical information assistant called the Maintenance and Repair Support System (MARSS). The MARSS system established a revolutionary approach to the human/machine interface for information systems.

The MARSS program proved that high-end wearable computers are feasible to build and this new tool can provide multimedia access to a mobile user. MARSS was a beginning step in the field of humionics. To gain a full embrace by the user community improvements in size, battery capacity, power management, voice recognition, and packaging are needed. But, the process has begun and the success of the MARSS program shows that the development of a wearable computer system to support the needs of many users is possible and should be pursued. Using technology to enhance the capabilities and increase the productivity of individuals will allow more work to be accomplished at a reduced cost. For example, in the maintenance arena, the MARSS system can be loaded with Integrated Electrical Technical Manuals and the weapon system can off-load the corresponding manuals, reducing the load and providing more space for other supplies such as fuel, food, water, ammunition etc. With the proper software loaded on the MARSS system, a decrease in required training of personnel and an increase operational readiness by decreasing repair time for weapon systems can be realized.

The Maintenance and Repair Support System (MARSS) has provided an excellent first step in the development of wearable computers. The lessons learned during this endeavor will serve the future development of wearable computers and humionics.

MAINTENANCE AND REPAIR SUPPORT SYSTEM

1.0 Introduction

The Defense Advanced Research Projects Agency (DARPA), in conjunction with the U.S. Army Soldier Systems Center (Natick), U.S. Army Test Maintenance Diagnostics Equipment Activity (TMDE), and the McDonnell Douglas Corporation, a wholly owned subsidiary of the Boeing Company, developed the first Pentium™ class computer that can be worn on the human body. Under the DARPA-funded NATICK Contract DAAK60-95-C-2029, the McDonnell Douglas Corporation researched, designed, developed, built, and tested an advanced portable tactical information assistant called the Maintenance and Repair Support System (MARSS). The MARSS system established a revolutionary approach to the human/machine interface for information systems.

The need for the system is derived from the increasing complexity of weapon systems and the reduction in armed forces personnel. Portable multimedia information systems are required to access information from remote locations, enhance mobility while referencing information, decrease required training of personnel, and increase operational readiness by decreasing repair time for weapon systems.

The Maintenance and Repair Support System (MARSS) is a body-worn portable information computing system that allows the user to access needed information hands-free. The MARSS system consists of a Central Processing Module, a Head-Mounted Display (HMD), lithium ion polymer battery, Personal Computer Memory Card International Association (PCMCIA) modular peripherals, pointer device (mouse), and associated cables. The MARSS system is body integral, that is, configured in a vest to allow freedom of movement. The MARSS system establishes a new paradigm for weapon system maintenance. MARSS provides computing power with the addition of voice actuation and wireless peripherals (i.e. MIL-STD-1553 and instrumentation modules) giving the maintainer the capability to move in and around a weapon system while the computer is gathering data, processing diagnostics, and illustrating removal and replacement instructions on the display. The HMD, with voice-activated software, provides the hands-free environment which enables the users to work in an efficient matter. In addition, a pointing input device (mouse) is provided to access desired functions. The computer that drives the display and software has the processing power of a desktop Pentium™ Personal Computer (1996 vintage) with the additional advantage of being worn by the user in a comfortable vest.

2.0 Program Description

The MARSS program was a two year research and development endeavor to develop an advanced wearable computer for use in the maintenance arena. The final deliverables for the program were four MARSS systems.

2.1 Goals and Objectives

The goal of the MARSS program was to design an advanced wearable computer system capable of supporting "Near Real Time Video" and audio playback for maintenance applications. The goals for the MARSS system were to provide:

a. A highly advanced system capable of Pentium™ processing power

b. Rapid system reconfiguration to support different maintenance systems

c. Incorporation of an Active Matrix Electrolumninescent (AMEL) display in the Head-Mounted Display (HMD)

d. Audio input for voice recognition and audio output for feedback to the user

e. High density "Safe" batteries that can be worn on the body

f. Wireless interface to the vest

The MARSS system has met all of the goals and objectives. MARSS provides a highly advanced system capable of Pentium™ 120MHz processing power. The MARSS system provides for rapid reconfiguration to support different maintenance systems through the use of PCMCIA cards. The MARSS system incorporates an Active Matrix Electrolumninescent (AMEL) display in the Head Mounted Display (HMD) with an amber gray scale and 640x480 resolution. The MARSS system provides audio input for voice recognition and audio output for feedback to the user. High-density lithium ion polymer batteries that can be worn on the body power the MARSS system. In addition, the MARSS system provides a wireless interface to the vest. The MARSS program has been a success.

2.2 Schedule

Figure 1 shows the MARSS Schedule. The MARSS program began in May 1995 and

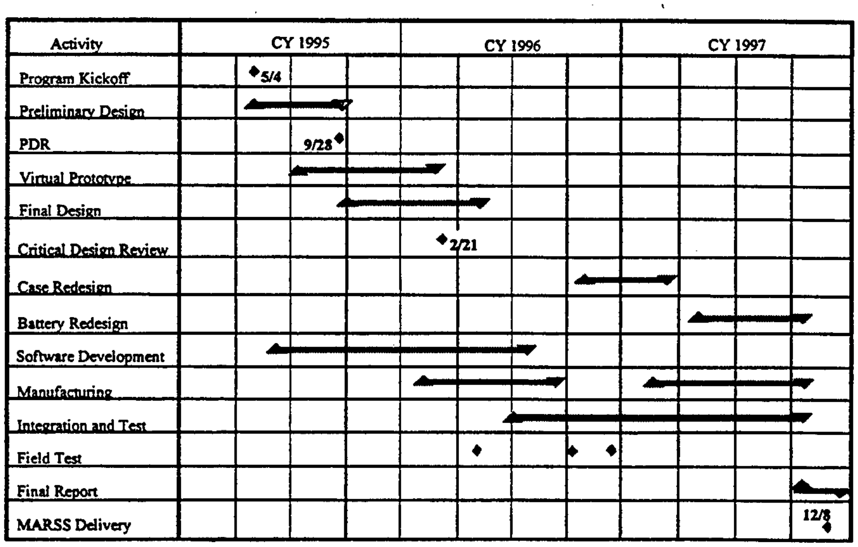


FIGURE 1. MARSS SCHEDULE

the original contract schedule called for the contract to end in April of 1997. Due to a rebuild of the batteries, the program end date slipped to December 1997. The program extension was required to build additional batteries for DARPA because the four experimental batteries built earlier in the program had a short operational life span. More details on the batteries can be found in the power source section of this report.

2.3 Team Members Roles and Responsibilities
The Defense Advanced Research Projects Agency was the funding and program management agency. The US Army Soldier Systems Center was the contracting agency that provided technology insertion and soldier systems integration expertise. US Army Test Measurement and Diagnostic Equipment Activity (TMDE) provided technology insertion support and testing support. The McDonnell Douglas Corporation served as the prime contractor for system design and integration. American Megatrends, Inc. (AMI) provided the computer motherboard design and the Basic Input Output System (BIOS) expertise. Honeywell Technology Center (HTC) provided the Head-Mounted Display technology. Ultralife Batteries Inc. provided the lithium ion polymer batteries.

3.0 Program Details
The MARSS program went through a classical program approach of initial design, Preliminary Design Review (PDR), final design, Critical Design Review (CDR), system manufacturing, integration, test, rework, final test, and delivery. The PDR was held in September 1995 and was very successful. The Critical Design Review was equally successful and was held in February 1996. The system manufacturing and integration occurred during 1996 and 1997 with final delivery of the MARSS systems in December 1997.

3.1 Program Highlights
The MARSS program provided the groundwork for follow-on programs in the field of wearable computers and humionics. The MARSS program specifically accomplished the development of the first Pentium™ class wearable computer. Unique features of MARSS were the computer design for torso mounting, six PCMCIA slots, and 128Mbytes of memory capacity. MARSS was also the first wearable computer capable of utilizing a 2-gigabyte hard disk drive. The MARSS system was the first vest-mounted wearable computer. The MARSS program pushed the field of wearable computers to develop a Pentium™ computer-based advanced maintenance aid.

3.2 Program Milestones/Achievements
Program Kickoff, May 1995
Preliminary Design Review (PDR), September 1995
Critical Design Review (CDR), February 1996
Ft. Polk Field Test, May 1996
Association of US Army (AUSA) display, October 1996
COMDEX display, November 1996
MARSS/Turbine Engine Diagnostics Demonstration at Ft. Polk, December 1996
Final Delivery, Transfer of 4 MARSS systems to ACT II Integrated Maintenance Logistics Support System (IMLSS), December 1997

4.0 Results

This section discusses the detailed program accomplishments and major design decisions that formed the MARSS system. The major subsections consist of the computer subsystem, audio/video subsystem, power generation, software, human integration, and deliverables. The System Requirements Compliance Matrix is shown in Table 1 and the MDC Detailed Design Goals Compliance Matrix is shown in Table 2.

TABLE 1. SYSTEM REQUIREMENTS COMPLIANCE MATRIX

SYSTEM REQUIREMENT	COMPLIANCE	COMMENTS
Design an advanced wearable computer system capable of supporting "Near Real Time Video" and audio playback	Y	MARSS provides a highly advanced system capable of Pentium™ processing power
Provide for Rapid Reconfiguration to support different maintenance systems	E	MARSS is capable of supporting maintenance and other types of systems through rapid reconfiguration by changing PCMCIA cards and software
Incorporate a Government Furnished Equipment (GFE) Active Matrix Electrolumninescent Display in the Head Mounted Display (HMD) with re-designed electronics for MARSS	Y	AMEL display chips provided in Honeywell HMD
Provide audio input and audio output	Y	Voice recognition and audio feedback to user possible. Supports speech recognition software
Provide high density "Safe" Batteries that can be worn on the body	Y	Lithium-ion (polymer) Solid electrolyte
Provide a wireless interface to the vest	Y	Wireless data and voice transmissions possible

"Y" (Yes) denotes compliance, "N" (No) denotes non-compliance, and "E" (Exceeds) denotes better than compliance

TABLE 2. MDC DESIGN GOALS COMPLIANCE MATRIX

DETAILED DESIGN GOAL	COMPLIANCE	COMMENTS
Windows/Integrated Diagnostic Repair Information System (IDRIS) compatible multimedia computer	E	System will run Windows, Windows 95, Unix, and OS/2 operating systems
CPU - Low Voltage 75MHz Pentium	E	75, 90, and 120 low voltage Pentium™ processors supported
Controller Chip Set - Mobile Triton	Y	Began design before publicly available
L2 Cache - 256K or 512K	Y	256K used to reduce chip count
Main Memory - 64 Megabytes	E	Prototypes were built with128 Megabytes, but delivered with 64 Megabytes to reduce case height
Enhanced IDE Disk Drive (170 Megabytes)	E	1.0 Gigabyte EIDE, 2.0 Gigabyte possible
PCI Bus - Rev 2.1Compliant	Y	
Six PCMCIA Slots with two spare slots	E	Six PCMCIA Slots with four spare slots
Super Video Graphics Array (SVGA)	Y	640 X 480 VGA output for HMD and 1280 x 1024 output for standard monitor
Power Conversion	Y	Integrated onto CPU/Memory Board
Keyboard Interface - PS/ 2	Y	
Serial Port Interface - RS-232	E	Serial and Parallel ports available
Mouse Interface - PS/2	Y	
Audio output	E	16 bit Compatible Daughter Board (ESS ES1688)
BIOS firmware - Flash	Y	Custom AMI BIOS
Operational Environment -20°C to 50°C	Y*/N	Temperature limits 0°C to 50°C due to battery specs. *0°C to 50°C (32°F to 122°F) to boot system electronics. Temperatures below zero °C possible with the electronics self-heating by operating.
Non-operational Environment -35°C to 65°C	Y	By Design
Electromagnetic Compatibility	Y*	*Designed in electronics and filters but overall case is not EMI shielded
PCB design and fabrication of best commercial practice	E	Developed new method for Flex Board PCB population

"Y" (Yes) denotes compliance, "N" (No) denotes non-compliance, and "E" (Exceeds) denotes better than compliance

4.1 Hardware

The MARSS hardware consists of the Central Processing Module (Computer Subsystem), Head Mounted Display (Audio/Video Subsystem), lithium ion batteries (Power Source), PCMCIA cards, and associated cables.

4.1.1 Computer Subsystem

The MARSS computer is the MARSS Central Processing Module. The MARSS Central Processing Module consists of protective polymer hard cases, flexible cases, and the MARSS Electronics Assembly (CPU/Memory Board, PCMCIA Board, Sound Board, Global I/O board, Hard Disk Drive, and Loop Heat Sinks). The details of the MARSS Central Processing Module design can be found in the MARSS Users Manual MDC 97W5159 and the MARSS Drawing Package. See Appendix for MARSS drawings.

4.1.1.1 Microprocessor Study

The microprocessor study covered the major microprocessors of the time. The different types of processors considered were the Intel based X86, and Pentium™ based processors, Motorola Power PC processors, Silicon Graphics RISC based processors, Digital Equipment Corporation Alpha processor, and the Sun SuperSPARC processor. Refer to Table 3 for the X86, Pentium™, and Power PC Processor comparison.

TABLE 3. MICROPROCESSOR COMPARISON MATRIX

CPU	CPU (MHz)	RISC/CISC	SPECint92	SPECfp92	POWER TYP/MAX WATTS	WINDOWS CAPABLE 1-10 (10 best)
PPC 601*	80	RISC	77	85	11	5
PPC 603*	66	RISC	75	85	2.2 / 3	5
PPC 604*	66	RISC	160	165	9 / 14	5
PPC 620*	66	RISC	200	280	20	5
486DX4 100	100	RISC/CISC	54.6	26.9	3.54 / 4.29	10
Pentium 75 LV**	75	RISC/CISC	83.3	60.8	3.0 / 6	10
Pentium 90 LV**	90	RISC/CISC	100.9	73.5	3.5 / 7.3	10
Pentium 120 LV**	120	RISC/CISC	140	104	4.5 / 8.0	10
Pentium 120	120	RISC/CISC	140	104	4.7 / 11.9	10

*1995 Motorola Power values
**LV is short for Low Voltage Pentium, Intel's Voltage Reduction Technology

Due to the U.S. Army software requirements of maintenance computer systems (laptops, Integrated Electrical Technical Manuals - IETMs, and SPORT) being Windows 95 compatible, the decision was made to build the MARSS system capable of running Windows 95 in native mode. This would allow for the greatest base of user acceptance, compatibility of existing software, compatibility with U.S. Army Integrated Electrical Technical Manuals (IETMs), and ease of programming. Therefore, the system needed to be an Intel™ based microprocessor. Tradeoffs between power consumption and processor performance were needed. Intel has its own index for measuring microprocessor performance. The Intel Comparative Microprocessor Performance index (iCOMP) values for the Intel-based microprocessors were compared against the power used by each processor. Figure 2 shows the iCOMP values LV denotes the Intel Voltage Reduction Technology or Low Voltage CPUs. The greater the number the more capable the processor.

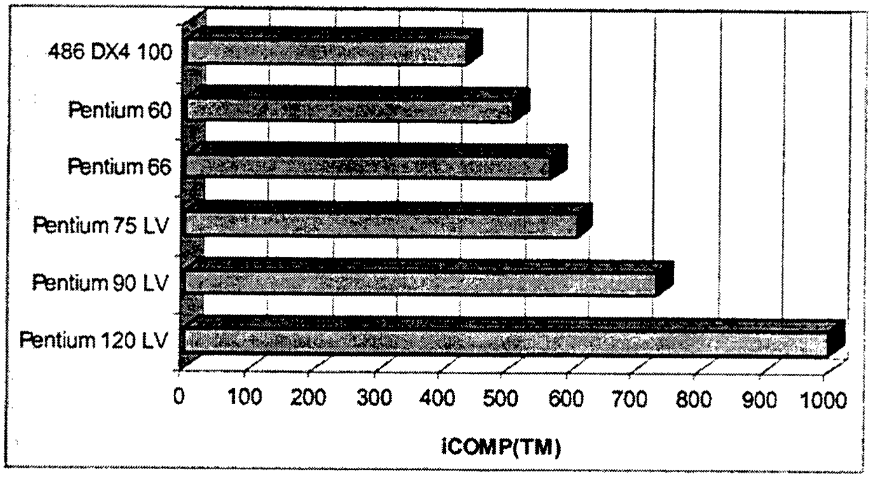


FIGURE 2. MICROPROCESSOR iCOMP VALUES

The microprocessor power consumption is shown in Figure 3. The Typical Power represents power consumption of the CPU running typical applications using power management.

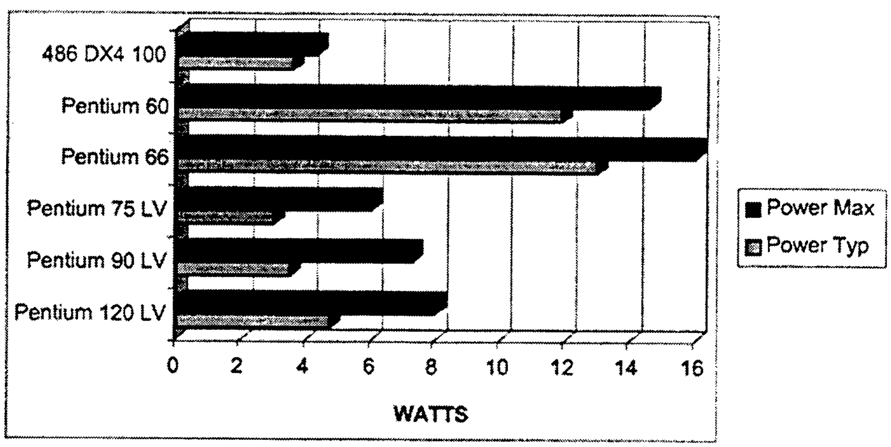


FIGURE 3. MICROPROCESSOR POWER VALUES

The power difference between the Pentium™ 60 and 66 MHz processors as compared to the Low Voltage Pentium™ 75, 90, and 120 MHz processors show the advantage of the Intel Voltage Reduction Technology. The core CPU logic runs at a lower voltage thus using less power. If the iCOMP value of the Pentium™ 120 LV processor is compared with the Pentium™ 75 LV processor there is an increase in performance of approximately 64%. The additional performance of the 120 MHz processor comes at the expense of an increase of power. Due to the capability of having a power consumption/performance tradeoff, the decision was made to allow the electronics to handle 75, 90, or 120 MHz low voltage processors. This allows the user, at time of manufacture, the capability to decide what power/performance tradeoffs are needed for the given application. To provide DARPA with the best processor speed performance, the Low Voltage Pentium™ 120 MHz processors were delivered in each of the MARSS systems.

4.1.1.2 Computer Architecture

The overall system architecture required a Pentium™ microprocessor, cache, memory, PCMCIA interface, Enhanced Integrated Drive Electronics (EIDE) Hard Disk Drive, and a Peripheral Component Interface (PCI) bus. A Write-Back Policy architecture was chosen to separate the system and host bus for simultaneous operation. This allows the CPU to access the memory while peripherals are operating. The MARSS computer architecture block diagram is shown in Figure 4. The Computer system is divided into four major boards to allow for reconfiguration. These boards are the CPU/Memory Board, PCMCIA Board, Sound board, and Global I/O Board.

4.1.1.3 CPU/Memory Board

The CPU/Memory board is the most complex and densely populated board of the system. The CPU, Mobile Triton Chip set, Level 2 cache, main memory Dynamic Random Access Memory (DRAM), Super VGA output, SVGA Video DRAM, power conversion, and Single In-line Memory Modules (SIMM) all reside on the CPU/Memory board. American Megatrends Inc. provided the motherboard design and software BIOS expertise. Issues were worked with AMI in a team environment. Each chip in the design had to be carefully selected to increase the performance and reduce the size and power consumption of the motherboard.

The Pentium™ processor resides on a Host Address/Data/Control bus. Different processors require different system clock frequencies. Therefore, a method to select the clock frequencies was required. Typically, jumpers are placed on the motherboard around the CPU that "select" a given configuration. Jumpers consume a large amount of board area so they were replaced by using zero ohm surface mount resistors to free board space. Zero ohm resistors were also used as jumpers for the selection of the memory banks. The Mobile Triton chip set contains the Mobile Triton System Controller, Mobile Triton Data Path, and Mobile Triton PIIX. The Mobile Triton chip set was targeted as the desired chip set for use in the system because of superior power management support. AMI provided the inroads to Intel products. Thus, use of the most advanced chip set available at the time was possible.

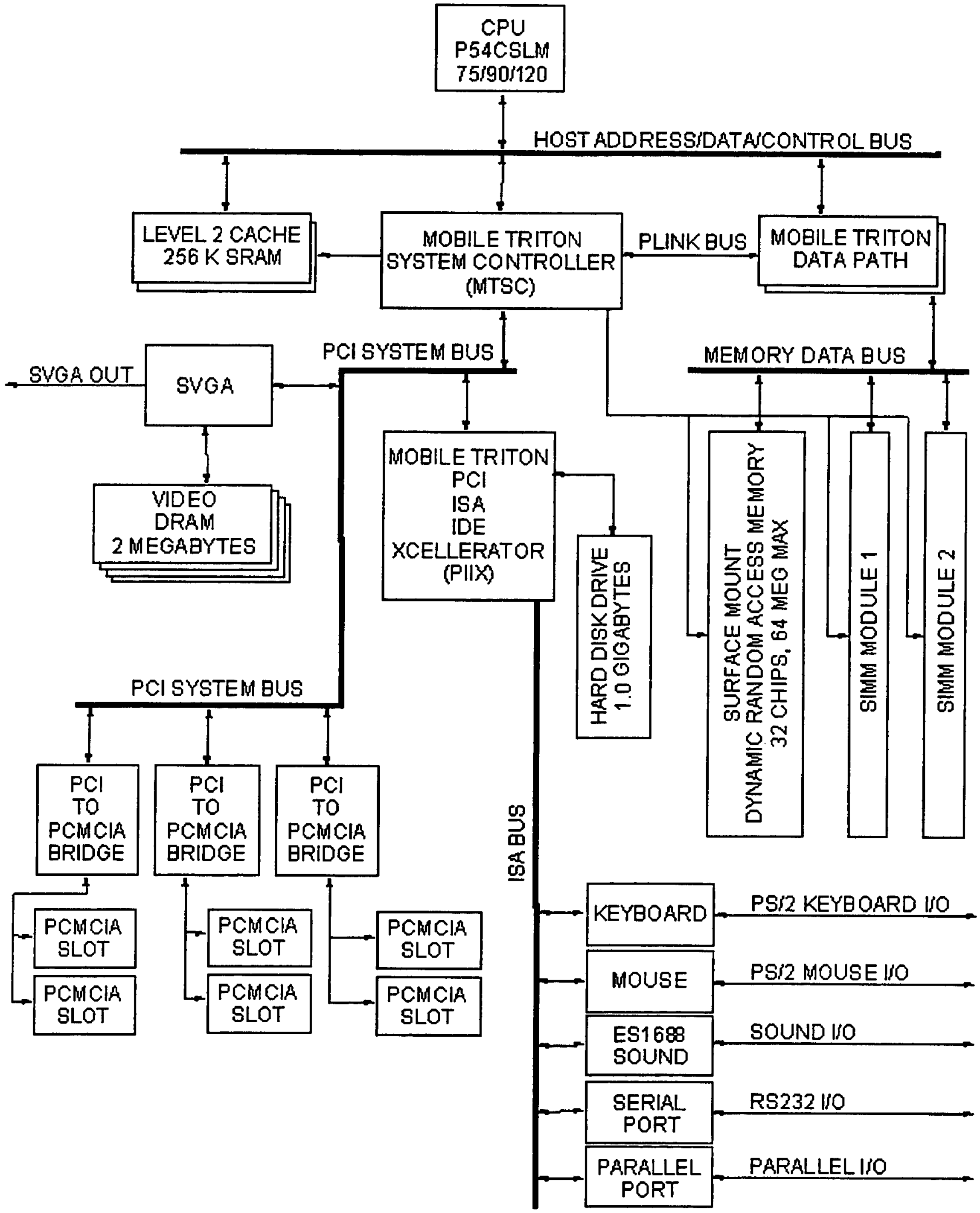


FIGURE 4. MARSS COMPUTER ARCHITECTURE BLOCK DIAGRAM

Decisions also had to be made concerning the amount of Static Random Access Memory (SRAM) to place in the system. SRAM (Level 2 cache) is required to reduce the wait states of the CPU. The SRAM holds the latest program information and allows faster access than the main memory, Dynamic Random Access Memory (DRAM). Using 512K of cache would increase system performance, but at the cost of increased power and double the board area due to the additional integrated circuit chips. In "real world" applications more than 512K of memory is used. Therefore, using the 256K cache instead of 512K cache would be a minor impact to actual application performance. Using 256K over 512K would reduce the amount of board space and the power consumption. 256K cache was chosen.

The amount of DRAM was also a concern. Obtaining a large amount of memory was desired to operate applications from memory, thus avoiding massive read cycles from the hard disk drive. The Mobile Triton chip set has 22 address lines for DRAM. The 22 lines allow an addressable memory space of 4 Million addresses. A total of 128 Megabytes of DRAM was desired to allow for the maximum amount of memory. The highest density of DRAM chips available were 4Mb x 4 chips. A memory size of 128 megabytes would require 64 chips. Memory alone would consume a massive amount of board area. Tradeoffs had to be made. Typically an application would use several megabytes. The recommended amount of minimum memory for running Windows 95™ was 16 megabytes and IETMs were on the order of 40 to 60 megabytes. The chosen configuration of 64 megabytes (32 chips) on board and 64 megabytes using SIMMs allowed for the reduction in board area while sacrificing vertical height off of the board. But, the SIMMs could remain unpopulated allowing a lower case height. In addition, 3.3 Vdc DRAM was used to conserve power over the 5.0 Vdc standard chips available. The MARSS systems were delivered with 64 Megabytes populated on the CPU/Memory Board. The memory type is 60 nanosecond access Extended Data Out Dynamic Random Access Memory (EDO-DRAM).

The SVGA interface required Video Dynamic Random Access Memory to support "Near Real Time Video." Two megabytes of memory were chosen over 4 megabytes to allow for video support with a reduction in power and chip count.

To obtain the most advanced chips for the MARSS design, the operational temperature ranges of the commercial chips had to be accepted. The semiconductor industry does not support military standard temperature ranges required for this advanced design. Typically the operational range of a commercially available chip was 0°C to 70°C. Therefore, the system had to keep the electronics below 70°C and above 0°C. To overcome the commercial limitations, temperature sensors were added on the board to shut the system down at a sensor temperature of 65°C and hold the system in reset if the components were below 5°C. Visual Indicators, Light Emitting Diodes (LEDs), indicate the condition of the MARSS system. Refer to the MARSS Users Manual MDC97W5159 for additional information on the LED indicators.

One of the most difficult areas of building the system was the CPU/Memory board signal routing. The area used to route the board was so small that very small components had to be used and these components had to be densely packed. The design required that both sides of the flex board be populated with surface mount components. The density of the board resulted in the system having to be hand routed over a period of four months using a high end workstation.

4.1.1.4 PCMICA Board and Hard Disk Drive

The physical placement of six PCMCIA slots was studied carefully to minimize the impact of placement on the human body. Originally six slots were desired to allow for a Wireless LAN PC Card, MIL-STD 1553 PC Card, Sound PC Card, Head Mounted Display (HMD) PC Card, and two slots for user expansion. In addition, the PCMCIA board had to support a Hard Disk Drive (HDD). The final configuration realized a Wireless LAN PC Card, MIL-STD 1553 PC Card, four open slots for user expansion, and a 2.5" Enhanced Integrated Drive Electronics (EIDE) Hard Disk Drive. The explanation of the elimination of the Sound PC Card and the HMD PC Card follows.

Knowledge gained from the development and use of the MARSS 486 unit weighed upon design decisions for the DARPA Pentium™ MARSS unit. Experience gained on the 486 unit showed that the commercial Sound PC Cards were fragile and prone to failure. In addition, the Sound PC Cards required external wiring that was bulky and not easily re-configurable. Therefore, a new sound solution was desired. The decision was made to develop a custom sound board. Refer to section 4.1.1.5 Sound Board for details.

Honeywell proposed using a PCMCIA slot for the Head-Mounted Display support electronics. They proposed using power from the PCMCIA slots and passing the video signals through the PCMCIA bus to the HMD PC Card and out to the HMD. MDC recommended changes to the proposed design to send the VGA/SVGA signals directly from the SVGA interface to the HMD and free a PCMCIA Slot. An SVGA interface could interface directly to the PCI bus to provide a faster interface than using PCMCIA. Passing video through the PCMCIA bus was nonstandard and a slower interface than passing SVGA signals directly from the PCI bus. Using the output from the SVGA signal source would allow MARSS to interface to desktop monitors or Head Mounted Displays. This would also allow Honeywell to have a standard interface to their HMD; Honeywell agreed. The design incorporated a stand alone AMEL Video Processing Unit that accepts signals from the VGA output. This change freed another PCMCIA slot for the user.

Mass storage was also a requirement that had to be considered carefully. The different options were the use of a 2.5" Hard Disk Drive (HDD) or the use of a PCMCIA Hard Disk Drive (PC Card Hard Drive). The MARSS 486 design utilized a PCMCIA card as the boot drive. The hard drive that was chosen had to store the operating system, application software, and provide the capability for the system to boot. PCMCIA Card HDD capacity at the time was on the order of 170 to 240 megabytes. The 2.5" Hard Disk Drives had a capacity of 850 Megabytes and 1.0 gigabyte drives would be commercially available during the contract. Therefore, the 2.5" EIDE Hard Disk Drive was chosen. Using the 2.5" drive kept the system from utilizing an open PCMCIA slot and it also provided a higher storage capacity. The MARSS system was delivered with a 1.0

gigabyte 2.5" Hard Disk Drive. A 2.0 gigabyte Hard Disk Drive can also be placed into the system.

The PCMCIA Board was designed as a separate board from the CPU/Memory Board. This separation allows for reconfiguration if a user wants to develop a different interface than PCMCIA. The board is separated from the CPU/Memory Board by two connectors. A 152 pin Mictor connector (AMP767007-4) carries the PCI and EIDE signals. Power is supplied to the PCMCIA Board through the 20 pin and header connector (AMP 178751-9). If desired, a new board could be developed using the signal and power interface to replace the existing PCMCIA technology. The boards are designed as separate printed circuit boards for future reconfiguration.

4.1.1.5 Sound Board

The decision to develop a custom sound board resulted from the commercial Sound PC Cards fragility, its bulky external wiring, and the desire to free a PCMCIA slot for the user. The options for implementing the sound board were to either have a separate board or to integrate the sound components directly onto the CPU/Memory Board. The decision to make the sound board a separate daughter board was driven by two factors. First, using a separate daughter board would allow for easy upgrades by simply designing another compatible sound board. Second, implementing the sound board as a daughter board would isolate the audio signals from the digital signals on the CPU/Memory board. The isolation provided by the daughter sound board would reduce interference on the other board. Therefore, the MARSS Sound Board was implemented as a daughter board to the CPU/Memory Board. The MARSS Sound Board connects to the CPU/Memory Board by a 76 pin Mictor Connector (AMP767007-2). The MARSS Sound Board is a 16-bit stereo sound card built around the ESS Technologies ES1688S audio drive. It provides speaker output, audio input, and a microphone input.

4.1.1.6 Global I/O Board

The MARSS Global I/O board provides all of the I/O connector interfaces and switches required for the computer. The switches include an On/Off switch, Reset switch, and Suspend/Resume switch. The connectors include a parallel port, serial port, mouse interface, keyboard interface, VGA interface, audio line-in, microphone in, and sound out. The Global I/O board also provides LEDs for low temperature, low battery, battery charge (future use), and high temperature indications. Standard commercial connectors were used to allow the system to operate in a "shop" or bench top configuration as well as a wearable configuration. The Global I/O board was designed to interface to the CPU/Memory Board through a 76 pin Mictor Connector (AMP767007-2). The semi-rigid flex design of the board allows the board to wrap around the users side while the MARSS vest is worn.

4.1.1.7 Advanced Power Management

The proper use of system resources is critical. To conserve as much battery power as possible and to reduce the heat produced by the system, power management had to be aggressive. The implementation of the Advanced Power Management (APM) had to allow the system to conserve power transparent to the user. The CPU/Memory Board and PCMCIA board were designed to support Advanced Power Management by splitting the power planes within the printed circuit board to allow different power planes to be turned on and off as required to save power. The power management system is divided into three major levels. These levels are CPU Standby, Local Standby, and System Suspend. CPU Standby allows the AMI BIOS power management to throttle the CPU clock during idle periods. Throttling the clock on the CPU cuts the power consumption of the unit without severely affecting the performance of the software. Local Standby places I/O devices such as the hard disk drive, parallel port, and serial port in a standby state after a timer is timed out. When an I/O device is placed in standby, power can be removed from the device. The System Suspend power management level saves all the memory to the hard drive and places the system in the Suspend state. System Suspend supplies the greatest power savings. The BIOS setting in the delivered configuration allow the hard disk drive to time out at 1 minute, video time out at 3 minutes later, and system suspend approximately 10 minutes after video time out. The user may also place the unit into system suspend by pressing the Suspend/Resume switch on the Global I/O board. Figure 5 shows the electrical current measurements for a MARSS system with and without power management.

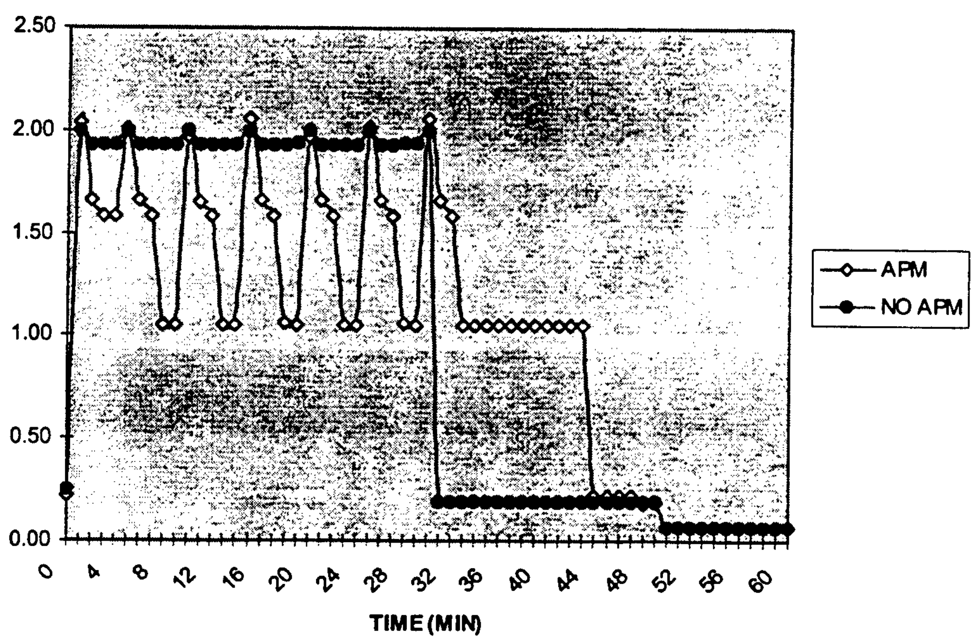


FIGURE 5. MARSS SYSTEM CURRENT PROFILE

In Figure 5 a "Near Real Time Video" is run for approximately 30 seconds at the 1 minute, 5 minute, 10 minute, 15 minute, 20 minute, 25 minute, and 30 minute time marks. The system is then shutdown or left alone. The "No APM" line shows the current profile for a system running without power management. The "APM" line shows the current profile for a system running with power management. The "No APM" line shows power switch OFF (manual shutdown) after the video is run at the 30-minute mark. The "APM" line executes an automatic shutdown using Advanced Power Management after the 30-minute video run.

During execution of the "Near Real Time" video the MARSS system is in full utilization and the current reading is approximately 2 amps for both cases. The "NO APM" line maintains a current of approximately 1.93 amps between video runs until manual shutdown and HMD removal.

The "APM" line utilizes Advanced Power Management. The MARSS system current with APM active fluctuates around 2.0 amps during the run of the "Near Real Time" video. However, between runs the CPU Standby current is approximately 1.66 amps and the Local Standby Current is approximately 1.58 amps before video time-out. After video time-out the HMD video is shutdown and system current drops to 1.08 amps. The process resets each time the user initiates an input to the system by the touch of a mouse. A touch of the mouse wakes up the system so the user can execute an application.

After the 30-minute mark the system utilizing APM was left alone to perform an automatic shutdown. The CPU Standby drops the current to 1.66 amps, Local Standby drops the current to 1.58 amps, video time out drops the current to 1.08 amps, System Suspend drops the current to 0.22 amps. The system is then suspended. To return to the state before suspend the user can simply press the Suspend/Resume button.

Manual turnoff of the MARSS power switch cuts the current to 0.19 Amps. By disconnecting the HMD the current drops to 0.08 amps. During operation the use of Advanced Power Management allows the MARSS system to cut the current consumption to save battery life. If there is no user input and the system is left alone it will automatically shutdown using System Suspend provided voice recognition is not active. The best operational use is to operate the MARSS system with Advanced Power Management active (as delivered) and manually turn off the system or press the Suspend/Resume Switch when not using the system. When storing the MARSS system or not using it for a long period of time the HMD should be disconnected and the battery should be disconnected from the system. This will keep the MARSS system from using battery power. Figure 5 measurements were made from a MARSS unit configured with a Central Processing Module, Honeywell HMD, MARSS mouse, keyboard, external power supply, and a DEC Digital Roam About Wireless LAN Card (DEINA-AA).

4.1.2 Audio/ Video Subsystem

The Audio / Video subsystem for MARSS allows the user to view an AMEL display for a 640 x 480 visual output from the computer, hear commands from the computer, and speak to the computer for voice recognition applications. Both AMEL and Liquid Crystal Display (LCD) head mounted displays can operate with the MARSS computer.

4.1.2.1 Honeywell Head-Mounted Display

The Honeywell Technology center developed the MARSS AMEL Head Mounted Display. Honeywell leveraged the HMD headband, optics, and display from a previous contract. Honeywell added the Active Matrix Electroluminescent (AMEL) Video Processing Unit, speakers, and a microphone to existing IMA HMDs to produce the MARSS HMD.

The Electroluminescent (AMEL) display is a developmental display. HMD Serial Number 2 and HMD Serial Number 4 have problematic displays. The displays were provided GFE. MDC has worked with Honeywell to replace the displays, but no additional displays were available during the duration of the MARSS program. It was also observed that the gray scaling resolution is much better in LCD displays as compared with the AMEL displays. A "Near Real Time" video will look smooth in an LCD HMD, but the same video appears blotchy in the AMEL. The AMEL has much better temperature performance, by specification, but the display technology needs further development.

4.1.2.2 Microphone

The microphone had to be a 2.5 Vdc bias, noise canceling, 2 wire microphone to interface properly with the Sound Board and provide the required functionality. The microphone had to work well with voice recognition software. The Gentex Boom Model 5210 with a 3062M2 microphone element was found and worked very well in the system. The microphone is mounted onto the HMD and provides the interface for the user to send verbal commands to the software.

4.1.2.3 Speakers

The speakers had to be mounted on the HMD and provide an 8 ohm load for the Sound Board. The speakers provide the interface for MARSS to supply audio commands, information, or instructions to the user.

4.1.3 Power Source

Since the MARSS system is a wearable computer system, batteries had to provide the power required to run the Central Processing Module, Head Mounted Display, and all of the peripherals. These batteries had to provide a high energy density and be "safe" for the user.

4.1.3.1 Battery Study

A battery study was conducted to determine the best battery type for the MARSS system. Different chemistry types were considered. Those considered were Lead-Acid, Nickel-cadmium, Nickel-metal hydride, Zinc-air, Lithium-metal solid electrolyte, Lithium-metal liquid electrolyte, and Lithium-ion solid electrolyte. Table 4 references the different battery types. The safety of the battery, memory effect, and energy density were the primary factors in choosing a battery. The new Lithium-ion solid electrolyte batteries from Ultralife provided very good energy density and safety for a body worn application. Ultralife was chosen.

TABLE 4. BATTERY COMPARISON MATRIX

Battery	Lead-Acid	Nickel-cadmium	Nickel-metal hydride	Zinc-air	Lithium-metal solid electrolyte	Lithium-metal liquid electrolyte	Lithium-ion solid electrolyte
Characteristics							
Energy Wh/kg	25	35	60	150	205	90	100
Density Wh/l	65	85	140	160	383	210	150
Cell Voltage (V)	2	1.2	1.2	1.2	3	3.4-3.7	3.7
Discharge profile	Flat	Flat	Flat	Flat	Sloping	Flat	Flat
Cycle Life*	500	1000	800		<150	>1000	>500
Self-Discharge**	6	15	25	5	0.5	5	5
Memory effect	No	Yes	No		No	No	No
Environmental Problem	Yes	Yes	Yes	Open Air		some	OK
Safety	Abuse-	Abuse-	Abuse-	Potential	Metallic	Abuse-	Very
	resistant	resistant	resistant	problem	lithium present	resistant	safe

* To 80% of rated capacity and 100% Depth of Discharge
** %/month
Source: 1995 Ultralife Batteries

4.1.3.2 Battery Configuration

The 1995 Ultralife battery cell construction capabilities consisted of making small cells. The MARSS system needed to run for several hours. To provide the type of energy needed to run MARSS, a large capacity battery was needed. Ultralife suggested making a greater capacity cell than their existing cells to increase battery power. The goal was to produce a 9.6 Amp hour battery. The design would require 12 large hand built cells packed together into a block. MDC liked the idea of a greater capacity cell and instructed Ultralife to separate the distance between the cells to allow for a pack that could flex along the users back. The separation of the cells was an application of MDC Body Integral Electronics Packaging.

Four batteries with the larger cells were delivered to MDC and used at Association of US Army (AUSA) 1996 conference in Washington D.C. and at COMDEX 1996 in Las Vegas. Everyone was very pleased with these batteries. A single charge on the battery would run a MARSS system for 4.5 hours without any power management. Unfortunately there were problems with the battery chemistry of the developmental cells. The battery capacity faded due to a stand time problem. One battery also suffered an internal short circuit. The issue surfaced in the spring of 1997. A failure analysis was conducted on three of the batteries. The analysis revealed that the tab structure of the cell was not structurally strong enough to withstand the bending that occurred through battery use. The tab structure had to be strengthened or reinforced. The original four batteries were not suitable for delivery to DARPA. New batteries were needed.

MDC worked with Ultralife to deliver a new set of fully functional batteries for the contract. Therefore, MDC took money out of the contract profit and subcontracted Ultralife on a 50/50 cost share to develop and build 4 new batteries for the MARSS final deliverable. Ultralife continued to have problems producing the larger cells required to fulfill that subcontract. As a result of their inability to build the larger cells associated with MARSS, with an adequate yield, MDC and Ultralife decided to use Ultralife's alternate prototype cell intended for commercial applications. These different cells are a smaller capacity per cell, and therefore more cells are required in the design (24 cells instead of 12 cells). The final delivery of the MARSS system was delayed due to the additional battery build.

The MARSS system was delivered with a prototype Lithium-ion polymer solid electrolyte battery. The MARSS battery provides over 9.6 amp hours of capacity. In addition, MDC-developed and delivered a backup battery system utilizing Duracell® batteries.

4.1.4 Thermal Results

The thermal design of the system was governed by two major factors. First, the solution had to be a passive design and not draw power from the battery reducing the run time of the system. Second, the thermal solution had to be compact and ergonomic. The best contributor to reducing the thermal load for the system is power management. Figure 6 shows the contributions of utilizing power management while running a "Near Real Time" video at 25°C, 37.7°C, and 50°C (77°F, 100°F, and 122°F) ambient temperature with Advanced Power Management (APM) enabled. The "APM" lines 1, 2, and 3 at ambient temperatures of 25°C, 37.7°C, and 50°C respectively, show the corresponding case temperature when running the "Near Real Time" video every five minutes for approximately 30 seconds with Advanced Power Management (APM) enabled. The "NO APM" line 4 shows the temperature increase while running the "Near Real Time" video every five minutes for approximately 30 seconds with APM disabled. Using APM allows the MARSS system to go into CPU clock throttle and Local Standby dependent upon the required CPU utilization. When clock throttling the CPU and using Local Standby, the system is ready for the user at any moment. The system activity during the test does not allow the system to utilize the Suspend to disk APM state. Lines 1, 2, and 3 all run for 180 minutes and then the system is manually shutdown to show the cooling curve. Lines 1, 2, and 3 all distinctly show the effect of using APM. During the test, the temperature of the system actually decreases when APM functions are initiated by the computer BIOS. This variation in temperature is seen as the "wavy" look of lines 1, 2, and 3. Line 4 does not utilize APM and therefore the temperature of the MARSS case rises dramatically in comparison to line 1 (effectively same ambient temperature). Therefore, it is shown that APM helps control the temperature of the system. Due to the gradual slope of lines 1, 2, and 3 it is observed that putting the system into Suspend and allowing the system to cool for as little as 10 minutes will substantially decrease the temperature of the case effectively "resetting" the run time temperature.

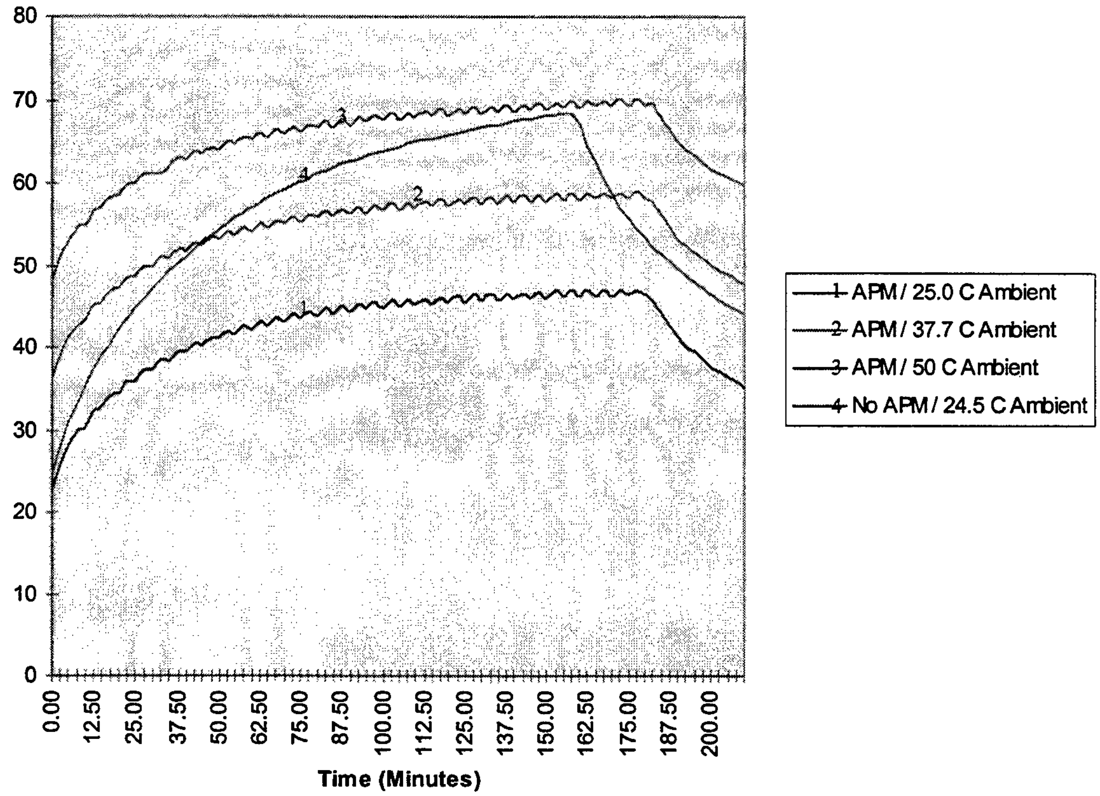


FIGURE 6. MARSS TEMPERATURE PROFILE

The APM settings used during the test are delivered configuration APM settings. The specific BIOS settings are listed in Appendix B Table B-1 of the MARSS Users Manual. The temperature tests were conducted on the Central Processing Module of the MARSS system and the temperature sensor was placed under the MARSS vest Central Processing Module flap on the MARSS CPU CASE TOP RM110710 just above the CPU. The Central Processing Module (Computer) functioned properly during the entire test. Figure 6 measurements were made from a MARSS unit configured with a Central Processing Module, Honeywell HMD, MARSS mouse, external power supply, and a DEC Digital Roam About Wireless LAN Card (DEINA-AA).

4.2 Software

The MARSS system was designed to operate software that can run on an IBM clone Personal Computer (PC) or laptop computer.

4.2.1 Operating System

Windows 95 was the operating system chosen for the project. It has worked well with the MARSS wearable computer. This is particularly true when using PC Cards to implement the various IO configurations.

Windows 95 installed flawlessly using the procedure described in 4.2.5 and it recognized all of the hardware in the system including the 6 PC Cards.

4.2.2 Special Drivers Required

Only two special drivers were required. They were the Cirrus Logic 7548 display driver and a driver for the MARSS mouse which was used. Both drivers were standard OEM Windows 95 drivers. They did not have to be modified in any way to support the MARSS system.

4.2.3 Verbex 95

Verbex 2.0 for Windows 95 was used for voice recognition. The software was pre-loaded on the HDD using the procedure described in 4.2.5 Software Installation. The software installed using the vendor provided procedures and is fully compatible with the built-in sound card and the Honeywell HMD audio system.

4.2.4 Integrated Diagnostic and Repair Information System (IDRIS) 95

The Integrated Diagnostic and Repair Information System (IDRIS) provides a common user interface for Integrated Electrical Technical Manuals (IETMs). A user configurable version of IDRIS was developed for use with Windows 95. In the version developed the user can define the instrument button labels and call user selected applications by configuring the setup file. The options which are configurable include Communications, Training, Auto Test, Logistics (RPSTL, etc.), Technical Manual selection (when supported), Fault Location, instrument and card self-test, and System Manual to be available during diagnostics.

4.2.5 Software Installation

Software installation is unique on the MARSS system because of the fact that the hard disk must be pre-loaded before the system is assembled. When a hard disk is replaced the same procedure must be followed.

4.2.5.1 Hard drive pre-loading

During prep and pre-loading the new hard drive must be installed in a system which supports a 2.5" hard drive. This can either be a special development system or a standard desktop with a special adapter to connect between the 2.5" HDD and the HDD cable that would normally be connected to a standard EIDE hard drive. The special adapter is available from most 2.5" HDD manufacturers. The system being used must be running Windows 95.

To prepare and pre-load the hard drive, the following procedures are followed :

a. Fdisk the new hard drive.

b. Format the new HDD by entering format d:/s/u at the dos prompt.

c. Copy the contents of an OEM Windows 95 CD subdirectory \Win95 to d:\Win95 on the new HDD. This will load everything needed to install Windows 95 plus it will eliminate the need to insert the Windows 95 CD every time the configuration is changed. This is important since the wearable computer does not have a CD-ROM drive or a floppy drive.

d. Create a subdirectory d:\drvrs95 on the new HDD.

e. Copy the contents of the Cirrus Logic 7548 display driver diskette to d:\drvrs95\CL7548.

f. Copy the contents of the VersaPoint mouse drive diskette to d:\drvrs95\VersaP95.

g. Copy the contents of the DEC Wireless LAN driver diskette to d:\drvrs95\wlan95.

h. Copy the utility hdprepez.exe to d:\drvrs95\hdprep.

i. Copy the contents of the Verbex installation set to d:\drvrs95\verbex95.

4.2.5.2 Operating System and driver installation

Install the pre-loaded hard drive into the system.

When the system is turned on it should come up at the DOS prompt. This is normal since the Graphical Users Interface (GUI) portion of Windows 95 is not loaded yet.

At the C: prompt enter cd \drvrs95\hdprep. This will change the current directory to hdprep. Enter hdprepez at the DOS prompt to setup the HDD for power management. When hdprepez is completed enter cd \ to return to the root directory.

At the C: prompt enter c:\win95\setup to load Windows 95. Follow the prompts just like you would on a laptop or desktop computer.

When Windows 95 installation is complete install the Cirrus Logic 7548 display driver and the VersaPoint mouse driver.

4.2.5.3 Loading User Software

There are basically three ways to load user software to the MARSS system. The three methods are:

a. Copying the software installation set to a PC Card HD, inserting the PC Card HDD into a PCMCIA slot on the MARSS system and installing from the PC Card HDD. This is the easiest and preferred method.

b. Installing the software from a portable CD-ROM drive. The CD-ROM driver software must be installed using method a. Once the software drivers are installed all you have to do to use the CD-ROM drive is insert the interface card and reboot the system with the portable CD-ROM system in place.

c. Installing software from a shared floppy drive located on a laptop which is on the wireless LAN.

4.2.6 Voice LAN

VoiceLan is a software package created by MDC that uses a wireless Local Area Network (LAN) as a communications channel to transmit/receive normal voice transmissions. This software allows an operator on one workstation or MARSS system to talk into a microphone and have his voice heard in near real time at one or more workstations or MARSS systems connected by a Local Area Network (LAN). VoiceLan is designed to run on computer systems which are based on standard PC architectures running the Windows 95 operating system.

The design of VoiceLan was built around the Windows Communications API that provides for voice digitization, encoding, and playback in a number of formats. VoiceLan software is triggered by holding down the right mouse button within the application and talking into a microphone similar to a push to talk radio. The software packetizes the data and uses a double buffer scheme to transmit it to the receiving station(s). Each station in the receive list will receive these packets in the order transmitted, and using the appropriate Windows API functions, convert the digital packet back into an analog signal which is played back on the computers speaker system. The transmission is made in near real time. A receiving station can quickly convert to a transmitting station by simply pressing the right mouse button. If no digitized voice data is incoming the station will become the transmitter and can communicate with any other workstation tied into the network.

4.3 Human Integration

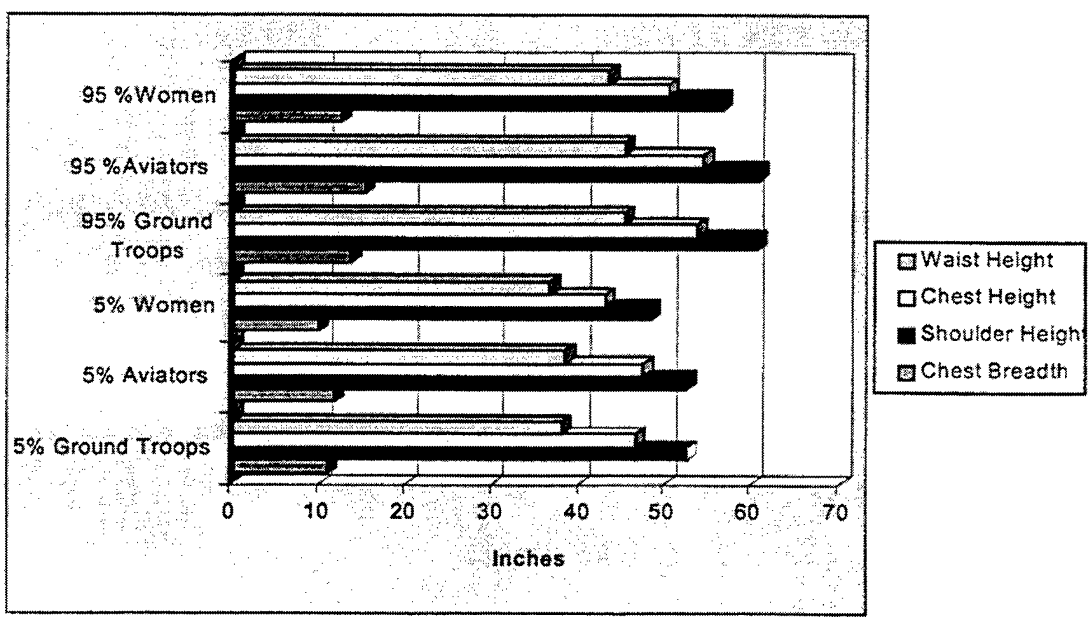
Building a computer is relatively easy. Computers are mass produced commercially and shipped by the thousands. Building a computer that can be worn on a belt is more difficult. Building a computer such as MARSS that can be unobtrusive that forms to, and moves with, the human body is very challenging. The driving concept behind the development of MARSS was to produce a unobtrusive computer that can be worn (i.e. a computer system that will allow the user to move in and around weapon system easily while giving voice commands and receiving audio and video instructions).

4.3.1 Computer Packaging Design

The original MARSS design concept envisioned components spread across a vest. This design would allow small components to be placed uniformly around the vest to effectively make the computer transparent to the user. Specifically, the early concept design had components on the left and right sides of a vest with the signal interface running behind the neck. This concept had to be re-evaluated due to PCI bus length and PCMCIA limitations. The design had to trade-off the size of the system on the body, modularity of the units, thickness off of the chest, thermal design, and ruggedness. The size of the system on the body was studied. Anthropometric data was used to size the electronic boards. Figure 7 shows the measurements used.

The average chest height subtracted from the average shoulder height is approximately 6 inches. The average waist height subtracted from the average chest height is approximately 8 inches. The average chest width is approximately 12.2 inches. That means that the average usable area on the chest is approximately 12.2 inches in width and 14 inches in height. This area has to include the electronics, case, and clearance for limbs. A system height of 11.3 inches leaves a 2 inch clearance for the head and neck on the top and a 0.7 inch clearance about the waist. A width of 10.2 inches on the PCMCIA portion of the electronics allows a 1.0 inch clearance for the arms on either side of the Central Processing Module.

MIL-STD-1472C Measurements



Height is measured from the floor

FIGURE 7. ANTHROPOMETRIC VALUES

The units were designed to be modular to allow for future updates to the electronic design. The Computer system is divided into four major boards to allow for reconfiguration. These boards are the CPU/Memory Board, PCMCIA Board, Sound board, and Global I/O Board. The use of multi-chip modules was considered but eliminated due to the design risk, cost, and dye release restraints by Intel. Acquiring the voltage reduction technology CPU dye from Intel was not possible. A new packaging methodology had to be developed. The circuits had to be close together due to the bus lengths, but needed to be apart for flexibility. The resolution of this dilemma gave rise to the concept of Body Integral Electronics Packaging™. Body Integral Electronics Packaging allows the use of conventional electronic components, but still allows the user freedom of movement.

To reduce the thickness (height) of the system off of the chest the PCMCIA slot height was limited to two Type I PC Cards, two Type II PC Cards, or one Type III PC Card in a double slot stack. In addition, the cases were designed to accept the electronics boards without the SIMM slots populated. This would allow for 64 megabytes of memory. The cases could be redesigned with a greater height to allow for an additional 64 megabytes of memory.

4.3.2 MARSS Vest Design

The MARSS Vest was designed to allow the user the most flexibility and comfort. The Central Processing Module is on the front of the vest while the battery is secured on the back of the vest. Separating the battery from the computer allows the MARSS system to be properly balanced on the user. The cables are contained within the vest and routed around the vest through cloth conduits to allow the minimal amount of cable lengths to be exposed. The vest also provides adjustment straps on the shoulders and waist for the user to adjust the vest. Detailed information on the vest design is found in the MARSS Users Manual.

4.4 Deliverables

The MARSS deliverables to DARPA include four complete MARSS systems. Refer to Table 5 for the deliverables list. The operation of the MARSS systems is detailed in the MARSS Users Manual MDC97W5159 and the design of the system is detailed in the MARSS drawing package. The user is advised that the MARSS systems are research and development prototypes. The systems should be handled with care during operation.

#	ITEM	Q
1	MARSS Vest, USSCOM NRDEC Experimental Sample	4
2	Central Processing Module (MARSSPD100-1)	4
3	MARSS Power Cable (MARSSPD001)	4
4	MARSS HMD Cable (MARSSPD002)	4
5	Mouse (MARSSPD005)	4
6	UltraLife Battery (UBB-103-02)	4
7	Honeywell Head Mounted Display (LG1272AA)	4
8	MARSS Battery Charge Cable (MARSSPD003)	4
9	MARSS External Power Cable (MARSSPD004)	4
10	MARSS Users Manual	4
11	ILD DDC MIL-STD-1553 PCMCIA card, in Central Processing Module PCMCIA Slot	4
12	Digital RoamAbout PCMCIA card (DEINA-AA), in Central Processing Module PCMCIA Slot	4
13	Digital RoamAbout PCMCIA Network Adapter (DEINA-AA), in vest LAN Adapter Pocker	4
14	Microsoft Windows 95™ CD ROM	4
15	Verbex Listen for Windows Getting Started Guide	4
16	BK Precision Power Supply Part Number 1735	4
17	MARSS Final Report, MARSS Users Manual, and MARSS Drawing Package	1

TABLE 5. MARSS CONTRACT DELIVERABLES

5.0 Lessons Learned

MARSS was a ground-breaking research and development program in the field of high-end wearable information technology. The following subsections review the lessons learned during the MARSS program. The different areas encompass a wide range of issues and should be considered carefully when designing future wearable computer systems.

5.1 Flex Circuit Fragility

Semi-rigid flex boards were utilized to allow computer system flexibility on the human body. Initial board builds reveled that standard manufacturing techniques would not allow enough flexibility or reliability. The first semi-rigid flex boards built during the MARSS program experienced rigidity problems and broken traces. Broken traces on the board caused failure of the electronics. The boards were too fragile to be placed in a vest and operated on a user. To obtain operational units for the Association of US Army (AUSA) 1996 conference, MDC worked with AMI to produce semi-rigid flex boards and mounted them in cases and secured them to Plexiglas surfaces to maintain the integrity of the circuits. Two flex MARSS systems (semi-rigid flex boards mounted to Plexiglas), and one rigid MARSS system operated successfully at the October 1996 AUSA in Washington, DC. Although AUSA was successful, a better solution was needed for the final deliverable system to DARPA.

As a result of the earlier issues, manufacturing and population of the semi rigid flex boards had to change. Printed Circuits Incorporated had developed a technique that split the flex layers into groups between the semi rigid portions of a board. The grouping and splitting of the flex portions of the board would allow for more flexibility. A modification to the method of populating components on the board was required to improve trace integrity. Limits on board movement were also needed. An overall manufacturing change was necessary to build the boards. Population of a flex circuit requires that that board be baked and then populated within two hours of removal from the oven. The CPU/Memory board was so complex that population and debug of the board required over four days. The CPU/Memory board required hand soldering of the components to populate the board. The board was too complex for the surface mount pick and place machines. Moisture build-up in the board could cause vias and traces to rupture and break when a hot soldering iron was placed onto the board. Many technical discussions were held between MDC, AMI and Printed Circuits Inc. The final solution to resolve the board population issue consisted of baking the bare boards for 16 hours at 250°F and then placing the board into a dry air desiccated chamber. The boards would remain in the chamber when not being populated. The population of the board consisted of having a test board follow the MARSS board to mirror its environmental changes. The MARSS board would be populated by hand and every hour the test board would be over stressed with a soldering iron for 10 seconds. If an inspection of the test board revealed any damage the soldering process would stop and the MARSS board would be returned to the desiccant chamber. Population on the board could continue the following day. Whenever the technician working on the board took a break, the MARSS board and test board were returned to the desiccant chamber. The MARSS board and test board were also kept in the desiccant chamber every evening during the board population process. This allowed moisture to be drawn out of the boards at night.

To protect the traces, physical limits on board movement was needed. This gave rise to the innovative case structure of rigid cases under a flexible case. Encasing the MARSS electronics into rigid cases would allow for protection of the circuit components while the outer flexible polymer cover (Flex Case) would allow the unit to still conform to the user while limiting board movement.

All MARSS semi-rigid flex boards delivered to DARPA followed the desiccant chamber population procedure and are encased in the flex covers.

5.2 Thermal / Heat Stresses

As seen with laptops, MARSS gets warm when used continuously. Direct skin contact to the Heat Sink area of the CPU may cause discomfort (>55°C). The temperature of the system correlates to its use. Continual use of the system causes high temperatures. Every instance where Advanced Power Management (APM) features can be utilized will reduce the temperature of the system. APM efficiency is highly dependent upon the application software being used. The APM system uses idle program time to reduce power consumption. If an application continuously demands CPU processing time, AMP will give the user the power he needs to run the application. Therefore, continuous processing equates with greater power consumption and higher temperatures. A wearable computer system is designed to be a "reference tool". As a reference tool the system should be used occasionally and placed into a power savings state while the user performs the work tasks at hand. When the MARSS system is in suspend it will dissipate heat while the user performs their given work tasks.

5.3 Hard Disk Drive / Movable Media

An extensive study on the failure of Hard Disk Drives was not conducted, but losses of Hard Disk Drives occurred during the development of the MARSS systems. The Integral 2.5" EIDE Hard Disk Drive Platinum/1010 Model 21010 has shock specifications as shown in Table 6.

TABLE 6. INTEGRAL HARD DISK DRIVE SHOCK SPECIFICATIONS

DISK STATE	FORCE	PULSE CHARACTERISTICS	DATA
Non-Operating	300 G	1/2/sine pulse @ 2ms, in X,Y, or Z axis	Recoverable
Operating	30 G	1/2/sine pulse @ 2ms, in X,Y, or Z axis	Recoverable
Idle	100 G	1/2/sine pulse @ 2ms, in X,Y, or Z axis	Recoverable

Listed in Integral Manual # 10005094 Rev. A 2-96

Even with the shock ratings for the Integral drives, three Hard Disk Drives were damaged to a point that they were non-recoverable. One disk drive stopped operating for unknown reasons and two were damaged during Fed-Ex shipment between AMI and MDC. During the design phase of MARSS solid state memory devices were available with a capacity of only 20 Megabytes. Solid state memory did not supply adequate capacity to hold the operating system and the application software. Therefore, using solid state memory was not an option for MARSS. As solid state memory PC Card capacity increases it should be incorporated into future designs and replace the movable media of a Hard Disk Drive for rugged environments.

5.4 Manual User Interface

Using questioners developed by Dr. James Sampson (US Army Soldier Systems Command) user feedback was obtained from the soldiers at Fort Polk Louisiana. User voice input was accepted well by trial users but manual navigation through the software needs to be studied further and modifications need to be made. The major I/O suggestion was to change the mouse to a tab type input device. A single button that the soldier could push to navigate through the application code would be faster than using a mouse type pointing device. To implement a change to an input device, the application software that requires the I/O of a mouse would need to be modified to accept input from a custom device. Application software would have to be developed considering the custom input device. Navigation through the operating system would also have to be considered. Due to the scope of the MARSS contract software was not modified and a custom input "tab" device has not been developed. Further work in the I/O devices and software are needed for mass acceptance of wearable computers. A standard keyboard and mouse work well for desktop computers and applications but not for wearable computers. A new I/O concept for wearable computers has to be developed for those users interested in interfacing with the computer without using a voice input. A Battle Lab Warfighting Experiment with MARSS was conducted at Ft. Polk, LA from 14-17 May 1996. A Human Factors Lessons Learned report from this experiment is attached to this report as an appendix.

5.5 Design Enclosure

The design of the case allows for the protection of the electronics under a controlled environment. Due to the issues with the flex circuits a double case structure was developed. A flexible case is bonded to the rigid cases that protect the electronics. This double case adds weight and bulk to the design. Future designs need to reduce the case size and bulk. In addition, further case development is required to allow a wearable system to survive military use.

5.6 Voice Recognition

General observations were made when using the Verbex voice recognition software. Training the Verbex software on particular words increases the probability of successful recognition for most users. However, it was observed that the software did not "train" properly with some users and the use of the Verbex generic training worked better for those users. Therefore, it is recommended that the development of voice recognition software applications use key phrases and words from the generic training set to cover the greatest number of users. That would allow the highest probability of recognition without training. The filed of voice recognition continues to make advances. Improvements will allow for an even better voice interface on future systems.

5.7 Global I/O board

The Global I/O board was developed to allow the user to interface with desktop type keyboards and monitors to allow the user to operate in a shop environment. Although this allows flexibility without having a bench-top interface box, there were drawbacks to this approach. Commercial desktop components require standard commercial interface connectors. The commercial connectors are not optimized for size or large numbers of insertion/desertion cycles. Future wearable computer systems should be developed using rugged connectors that can handle a severe environment.

5.8 Size and Weight

The MARSS system looks large at first. This is due to the extensive functionality of the MARSS system. Each MARSS system contains six PCMCIA slots and has the electrical capability of 128 megabytes of DRAM. In comparison, a high-end laptop has two PCMCIA slots and 48 megabytes of DRAM. The weight of a MARSS system is also greater than a laptop. This is due to a higher capacity battery, vest, cables, and the double case for the Central Processing Module. Although the weight is greater, the MARSS system distributes the weight well on the body. Therefore, the weight feels lighter because of the correct distribution of the components on the front and the back of the user. Elimination of four PCMCIA slots and a re-design of the double case could reduce the size and weight for future systems.

5.9 Mass Production

The development of the MARSS system pushed the state of design for mounting conventional circuit components on a printed circuit board. Due to the restricted size of the system, and the density of components on the board, parts had to be placed on both sides of the board. The placement of surface mount components on both sides of the board eliminated (for all practical purposes) the use of automated pick and place machines. The components were too close together and the use of adhesive on the bottom side of an automated line causes problems and is discouraged. The elimination of the automated machines requires the population and soldering of the board to be done manually by a skilled technician. The close proximity of the parts also caused routing problems because of the large number of vias required. Surface mount parts do not require through holes on the printed circuit board that can be used as test points for production. Therefore, additional test points (vias) were needed for production. Due to the routing complexity, test points had to be eliminated to maintain the small size of the system. As a result, the boards had to be debugged manually. Manually debugging boards of this complexity requires detailed engineering knowledge of the design. The manual component placement, manual component soldering, and manual debug makes production of the current MARSS design impractical. Mass production requires surface mount component placement on one side of the board, test points for debug, and automated placement of components. As the density of chip circuitry increases, a single sided approach becomes feasible and mass production of a new design could be realized.

5.10 Time to Market

The design of the MARSS system began in 1995. Moore's law states that the processor performance will double every eighteen months to two years. The MARSS contract took over two years. To deliver a system with cutting edge processors to DARPA and compete in a commercial market an even faster development cycle than achieved on the MARSS program is required.

5.11 Parts Availability / Limited Life Items

Due to the speed of development in the commercial electronics sector, certain parts are "retired" and the companies stop manufacturing and shipment of the devices. For example, the 2.5" Integral Hard Disk Drives (Platinum 1010 Model 21010) are no longer available from Integral. A replacement 2.5" drive would required if any Hard Disk Drives fail. Fortunately, in this case, other manufacturers make compatible drives. In other cases, replacement parts may not be found. Therefore, items that are going to be "retired" should be bought in bulk and stored or the system design will be invalidated and the system will not be able to be manufactured. Parts availability is a typical problem that must be aggressively worked during the development and production cycle.

5.12 System Suspend Mode and Wireless LAN Incompatibility

The Advanced Power Management mode for MARSS allows the user to conserve battery power and reduces the thermal load of the system. The System Suspend mode of Advanced Power Management saves the memory states of the system to the hard disk drive and powers down the system. When the user presses the Suspend/Resume Switch to resume operation, the software is reloaded into DRAM and the CPU states are reset. The boot sequence of the computer is skipped when resuming from the System Suspend state. This allows for the system to quickly return to the software state before the suspend was executed. Due to skipping the boot sequence the DEC Digital Roam About Wireless LAN card (DEINA-AA) is not configured properly and will not operate. The wireless LAN card will operate correctly after boot and will operate properly after CPU Standby and Local Standby but not after System Suspend. Improvements in the functionality of the Wireless LAN card are required to resolve the issue.

5.13 Voice Recognition and APM Conflict

The Voice Recognition software is an application that runs continuously. The microphone provides a continual input and does not allow for video time out or automatic System Suspend. The voice recognition software affects the power consumption of the system. CPU Standby and Local Standby operate with voice recognition operating yielding a current drain of 1.88 and 1.80 amps respectively. Turning off the voice recognition software allows the CPU Standby and Local Standby currents to drop to 1.66 and 1.58 amps respectively. The voice application should be shut down when not in use. Future software approaches should develop the controls to quickly turn the voice recognition software on and off to enhance the power savings of the system.

6.0 Summary and Conclusions

The Defense Advanced Research Projects Agency (DARPA), in conjunction with the U.S. Army Soldier Systems Command (USSCOM), U.S. Army Test Maintenance Diagnostics Equipment Activity (TMDE), and the McDonnell Douglas Corporation a wholly owned subsidiary of the Boeing Company developed the first Pentium™ class body wearable computer. Under the DARPA funded NATICK Contract DAAK60-95-C-2029, the McDonnell Douglas Corporation researched, designed, developed, built, and tested an advanced portable tactical information assistant called the Maintenance and Repair Support System (MARSS). The MARSS system established a revolutionary approach to the human/machine interface for information systems.

The MARSS program proved that high-end wearable computers are feasible to build and this new tool can provide multimedia access to a mobile user. MARSS was a beginning step in the field of humionics. To gain a full embrace by the user community improvements in size, battery capacity, power management, voice recognition, and packaging are needed. But, the process has begun and the success of the MARSS program shows that the development of a wearable computer system to support the needs of many users is possible and should be pursued. Using technology to enhance the capabilities and increase the productivity of individuals will allow more work to be accomplished at a reduced cost. For example, in the maintenance arena, the MARSS system can be loaded with Integrated Electrical Technical Manuals and the weapon system can off-load the corresponding manuals reducing the load and providing more space for other supplies such as fuel, food, water, ammunition etc. With the proper software loaded on the MARSS system, a decrease in required training of personnel and an increase operational readiness by decreasing repair time for weapon systems can be realized.

The Maintenance and Repair Support System (MARSS) has provided an excellent first step in the development of wearable computers. The lessons learned during this endeavor will serve the future development of wearable computers and humionics.

This document reports research undertaken at the U.S. Army Soldier and Biological Chemical Command, Soldier Systems Center, and has been assigned No. NATICK/TR-99/017 in a series of reports approved for publication.

APPENDIX
Human Factors

Lessons Learned from Battle Lab Warfighting Experiment (BLWE) with the Maintenance And Repair Support System (MARSS) Tested using the Heavy Equipment Transporter (HET) and the PALADIN M109A6 Howitzer Tracked Vehicle

14-17 May 1996.

A prototype of the Maintenance And Repair Support System (MARSS) was tested at Ft. Polk, LA in May of 1996 with a group of 20 full time National Guard maintenance personnel who performed simulated tasks on two vehicles: the Heavy Equipment Transporter (HET) and the PALADIN 109A5 Howitzer vehicle.

The BLWE began with an overview of the MARSS program. This consisted of program background, a MARSS technology overview, a hardware/software description and an outline of the BLWE mission.

The exercise started with voice training each soldier for enabling his/her use of the voice recognition speech input. All soldiers were assigned to perform maintenance tasks using the MARSS system on either the HET or the PALADIN. Faults in each weapon were defined so that diagnostics and repair procedures would be the same for all soldiers.

After each soldier completed their maintenance session, which lasted approximately two hours, they were provided with a questionnaire/survey to evaluate all parameters of the MARSS system. Questions included issues associated with the interface to subsystems, fit, comfort, display resolution, text, reading ease and software etc.

Following the experiment, an After Action Review (AAR) was held to capture all comments from the soldiers in a group setting. Major categories of the after action report (AAR) pertained to the form, fit, function and comfort of the MARSS vest and the HMD; the loadbearing and electronics placement; software functionality; electronic technical manual presentation and ability to print data; and a miscellaneous category which included system/HMD ruggedness; weather resistance and a HMD vs. handheld display. During the AAR the Chief Warrant Officer addressed the soldiers telling how this technology may allow them to more effectively perform their tasks. The following is a Summary of Issues identified from both the after action discussion group and the questionnaires. Individual comments from the questionnaires are summarized following the Summary of Issues to provide some detailed experiences with the MARSS. Comments are grouped by questions for both the HET and PALADIN.

After Action Report from Battle Lab Warfighting Experiment (BLWE) with the Maintenance And Repair Support System (MARSS)

1. Issue: **Seeing the display outside.**
Response: Needs a shade guard. Light reflects on display.
Comment: This was a common comment while working outside with the HET. Technicians recommended a non-glare screen.

2. Issue: **Resolution of display.**
Response: Words seem too small in some cases.
Comment: Text size for desktop use of display probably not adequate. Extra cognitive attention required while ambulatory will require larger or more contrasting text when used. Excessive use of text should be avoided for tasks requiring user to be mobile. Written text or instructions might be presented auditorily.

3. Issue: **Eye fatigue.**
Response: Yes - many experienced eye fatigue. Some thought those who tried to shut the other eye might experience more fatigue. Some thought having a shield in front of the other eye might help reduce strain.
Comment: Since looking at the vehicle is very important in the use of the HMD a shield in front of the other eye would defeat the purpose of having an HMD. Part of the strain is from trying to process information from one eye and ignoring information from the other eye. Fatigue may diminish with practice. One trick that can be used is to look at backgrounds with relatively blank surfaces to help reduce information to the non-displayed eye.

4. Issue: **Comfort of HMD.**
Response: The Kopin HMD became uncomfortable on the forehead of users over time for many of the users. Comfort of the Honeywell HMD seemed to be better, although most of the personnel did not wear the Honeywell HMD for a very long period of time. Some like the hearing cups of the Honeywell HMD saying that in a noisy environment it would be nice. Others pointed out that you need to hear others around you and that the ear cup might interfere. The larger cups also tend to be warm. There was also concern about having to wear the combat helmet with the HMD under some situations. The Honeywell mounting would be a problem when wearing headgear.
Comment: Simplicity and compatibility are potential problems with adjustment and comfort. The Kopin mounting is a better design for simplicity and the capability to easily move the display out of the way or to the other eye. It comes at the cost of comfort to the forehead. The Honeywell cost of simplicity and obstruction. A design somewhere between the two might be the solution.

5. Issue: **Hearing and ear protection.**
Response: See previous response on Comfort.

Comment: Users have several needs that should be addressed: 1) They need hearing protection from high decibel noises in the environment, 2) they need to listen to events around them and converse with each other, and 3) they may need to have a voice communication channel engineering as part of the overall system.

6. Issue: **How Many MARSS needed by a small unit?**
Response: More than one. At least two, issued in pairs as backup and coordination of activities. Need multiple systems for multiple vehicle use (more than one type of vehicle).
Comment: Basis Of Issue (BOI) will have to be determined.

7. Issue: **Microphone.**
Response: Tends to pick up background noises. Seems to affect Voice Menu system in that with loud background noises the individual speaks differently than the way they trained and thus the voice system is less responsive.
Need noise-canceling mike.
Comment: Need to look more closely at microphone requirements, select appropriate kind and capabilities. There was no mention of the obstruction or safety problem with microphone mounting but this needs a careful looking into. Bone conducting mike may be a possible option to investigate.

8. Issue: **MARSS Vest.**
Response: Needs to be more flexible, components are too low, interferes with crouching down. Cable around neck a problem but at the same time need extra cable in situations where you can set vest down but keep the HMD on while working. Sizing a concern. A 'haltertop' type of vest might work better (roadside safety vest). How about a belt system?
Comment: There is and will be various options to be evaluated. Body flexibility as well as maneuverability around equipment an important consideration. Consideration also needs to be given to heat buildup from both the computer and the human body during physical work.

9. Issue: **Vest Size.**
Response: Need to accommodate people of different sizes and body build. Adjustment and stable positioning also concerns.
Comment: More than one size is being considered. Might get by with one size using the 'haltertop' type of vest. However, gender dimensions may require more than one size/shape.

10.Issue: **Software.**
Response: Liked PALADIN system. HET system more of a problem. Overlays and

scrolling seem to be problems needing improvements.

Comment: Important not to design system based on desktop computer considerations. Things that work for a desktop computer may not work as well with HMD and a user who moves around. There should be de-emphasis on a pure WINDOWS-like environment. Software should work as well with specially designed input devices. Mouse may not be best option for Maintenance activities and operations. An effective input/output device needs to be mountable on the vest. Keystrokes are easier and more reliable than free-field mouse operations. Text should be de-emphasized and more emphasis given to analog or graphical information. Software should probably include auditory channels. Text might be read by voice to supplement written text.

11. Issue: **Hardware.**

Response: See above discussions.

Comment: Other options vests, displays and input devices should be explored simultaneously with an emphasis given to designing to user needs. Notebook sized displays, pocket displays, wrist displays and HMDs all need to be investigated for various uses and users.

12. Issue: **Paperwork.**

Response: System needs to include ways of completing necessary paperwork by allowing it to be done automatically by system and by printing via a remote printer. Parts ordering system presented is a great idea.

Comment: This (along with elimination of hard copy manuals) is the most important aspect of the system to the user.

13. Issue: **Wrist display.**

Response: See #11 above. Some users have a problem with a wrist display. They say they often need to reach in tight spaces where a wrist device would be a problem. May be useful for some users.

Comment: All options need to be explored.

14. Issue: **Ruggedness.**

Response: System needs to be very rugged and must work in a dirty environment. It should be water resistant and cleanable. It has to work in wide range of temperature, moisture and dirt environments. Must survive a drop test and a dropped-on test. Sweat/dirt buildup must not be a problem...cleanable. It needs to be repairable.

Comment: Maintenance personnel are also in the battlefield so will be wearing protective equipment and be subject to some of the same threats as the combat units.

15. Issue: **Radio information transfer range.**

Response: Must be at least 150 yards. Might need a greater range given the way vehicles are setup for inspection and repair. Range selection might be a good option. System will be competing for limited channel space.

Comment: Need to consider all aspects of radio transmission on the battlefield. What is the impact of jamming, etc.

16. Issue: Safety.

Response: See discussions above. Users did not say much about safety issues.

Comment: Safety specialists need to review system use in the field. Protruding objects like the display, microphone, and connecting wires are a problem. Users had problems climbing on or getting into vehicles because display blocked part of their view needed to see where objects or openings where.

17. Issue: Power.

Response: What's the possibility of having the system use solar power?

Comment: To be considered.

USER COMMENTS FROM THE MARSS QUESTIONNAIRE Heavy Equipment Transporter (HET) and PALADIN M109A6 Howitzer

Q: How easy to use Integrated Electronic Technical Manual (IETM) Maintenance And Repair Support System (MARSS) for troubleshooting?

HET:

+ MARSS simple to use.
+ Once you understand how the MARSS works I find it easy. It goes step by step. It's clear and to the point.
+ Once you familiarize yourself with the system it is very easy.
+ Less time spent on finding components.
- Voice commands were not always recognized. Hard to read.
- Could not move pages easily.
- Could not get to proper page. (incomplete IETM) has potential.

PALADIN:

+ It's a lot faster and hands are free for work.
+ It goes very fast, the computer does the troubleshooting for you.

Q: Compared to TM how is IETM w/MARSS/HMD for trouble-shooting?

HET:

+ You don't have to start in one book and then go to 2 or 3 more. It's all right there for easy access.
+ Much easier.

PALADIN:

+ Less time for finding components.
* TMs are all I've used in the past.

Q: IETM w/ MARSS/HMD for electrical troubleshooting?

HET:

+ The schematic was much easier to find.

PALADIN:

+ Only slightly easier but more efficient.
- Did not actually function; found that it would potentially be much easier.
- I assume with more time using MARSS/HMD it will become much easier.

Q: IETM w/ MARSS/HMD for mechanical troubleshooting?

HET:

+ The graphics were clear and could be enlarged.
- Slightly easier but need more time on MARSS.

PALADIN:

+ The locator was very useful, especially for personnel working on the track for the first time.
- IETM w/ MARSS HMD seems to be easier to follow as long as you have some computer background.

Q: Rate ability to find info in IETM vs paper TM.

HET:

+ Slightly easier.

Q: Rate ability to find info in IETM vs paper TM. (cont.)

PALADIN:

+ 100X easier to reference than paper TM.
+ All you have to do is talk vs. turning pages.
- Much easier, but could not find general information on the HET like engine size.
- It would probably be much easier with a little more experience.
- Slightly more difficult: Voice commands were not working at times.

Q: IETM better organized than paper TM?

HET: - No comments

PALADIN:

- Both seem to be in same order.

Q: Once familiar w/IETM, could you find info faster/slower than paper TM?

HET:

+ Much faster.
+ Much faster, No paper flipping involved.

PALADIN:

- Slightly faster, but familiarity with mouse, using Verbex, i.e. training voice took more time.

Q: ITEM illustrations easy to read?

HET:

+ Once you have adjusted the screen it's like reading a book.
- Hard to distinguish what they were talking about. Once it's in color, it will be easier.
- If you could use both eyes it would be very easy.

PALADIN:

- Moderately easy but image needs to be darker.
- Very easy but eyes tired after viewing display over 1 hour.

Q: Display (IETM) text easy to read?

HET:

+ It's clear and well written.
+ No eyestrain.

PALADIN:

- Moderately difficult. Clarity of words needs improvement.
- Eyes tired after viewing display over 1 hour.

Q: Integrated Electronic TM system easy/difficult?

HET:

+ Very easy but I have prior Windows experience.
- Somewhat easy once you remember the commands.

PALADIN:

+ Somewhat easy but knowledge of Windows helps out a lot.
+ Very easy. Once you learn the commands, it's easy to go through the computer.
+ Neither easy/difficult. Just had to get started and it got easier.

Q: Parts ordering function effective?

HET:

+ Found part number easily.

PALADIN:

- Did not relate w/ this function other than classroom explanation.

Q: IETM quick for locating repair info?

HET: No comments.

PALADIN:

- Did not relate w/ this function other than classroom explanation.
- Moderately slow: Several times punched (hit return key) by the time system responded I spent a lot time waiting.

Q: Enough information on page?

HET:

- More than enough but need to find schematics.

PALADIN:

- Could use more illustrations.
- Not quite enough for location of parts.

Q: Display image resolution?

HET:

- Moderately good but had some problems in the sunlight.
- Moderately poor: Could not tell what the illustrations were talking about, very hard to distinguish things.
- Extremely good, unless maybe you have glare behind you.

PALADIN:

- Moderately poor: Words not clear.
- Moderately good: The second headset I viewed was much better.
- Extremely good. So long as you had no glare from behind.
- Extremely good. Where glasses are required w/proper adjustment glasses may not be needed.
- Moderately good but all words need to be darker for better and quicker reading.
- Extremely good. Prefer the green monochrome over amber.

Q: Do you like the hands-free feature?

HET:

+ Yes. Saves time.
+ Yes. Leaves your hands free, all you have to do is speak to the computer and everything you need to know or easy to access.
+ Yes. Much easier to troubleshoot when the manual is in front of your face.
+ Yes. You don't have to worry about turning pages to find next step while you are working.
+ Yes. More work can get done without having to turn pages.
- Sometimes: Looking away from HMD can screw up your focusing. The vest is somewhat cumbersome. HMD headband needs work also.

Q: Do you like the hands-free feature? (cont.)

PALADIN:

+ Yes. It is a lot easier to perform tasks when the manual is right in front of your face.
+ Yes. Hand free lets you grasp components, climb on and around the vehicle when safety 3 point contact is required. Accessing vehicle was extremely good.
+ Yes. Having hands free gives you more time to repair/replace parts.
+ Yes. It's faster and easier to use voice commands.
+ Yes. Can do your work and keep looking through TMs. Look up/order parts. You're free to do whatever you need.
+ Yes. Hands-free really is a big change, time saving, I could get used to MARSS/HMD easily.
+ Yes. Use hands for working on job not flipping through pages.

Q: Ease of movement with vest & HMD?

HET:

- It is somewhat difficult. The vest is too stiff to bend and move liberally.
- It was neither easy nor difficult. Did not really have enough time working with, but the little I did was easy, flexible, didn't seem to get in my way.

PALADIN:

- Same as moving around with LBE on.
- Was very easy but we did not really move around or crawl under anything.
- It was somewhat easy. Moving in/thru/under was sufficient.
- It was somewhat easy. When bending over, the jacket opens. Maybe a zipper would work better.
- It was very easy. Ran out of time, wore vest, didn't do many elements of this equipment/tests however.

Q: Does vest affect ability to use tools?

HET: No comments.

PALADIN:

+ No, no problem for most part. About the same as LBE.
- No, no problem for most part. Vest needs to be more durable.
- No, no problem for most part. Didn't actually perform repair but this is my belief.

Q: Would MARSS be useful for garrison shop maintenance?

HET:

+ Extremely useful. Perform PMCS and write any faults on your 2404 without thumbing through 10 manuals.

PALADIN:

+ Would be extremely useful for ordering parts.
+ Would be extremely useful for all maintenance.
+ Would be extremely useful tool in training an individual.
+ Would be extremely useful. I would like to try it. Come up to Seattle, Ft. Lawton so I can try it.

Q: Would MARSS be useful for initial vehicle inspections?

HET:

+ Extremely useful. Would have PMCS from IETM right in your vision.

PALADIN: No comments.

Q: Would MARSS be useful for field maintenance?

HET:

+ Would be extremely useful. Much faster.
+ Would be extremely useful. The ability to repair a piece of equipment in my opinion would be greatly enhanced and would reduce the amount of repair time and troubleshooting, the information is so readily available and hands-free.
+ Would be extremely useful. Troubleshooting especially.
- Would be extremely useful if proper care taken.
- Would be moderately useful depending on the knowledge of the mechanic. A more knowledgeable mechanic would probably hindered by MARSS in rush situations.
- Not sure. Depends on durability.
- Would be extremely useful but have concern for durability.

PALADIN:

+ Would be extremely useful. Less time spent on maintenance as to locating TMs on equipment.
+ Would be extremely useful. Cuts repair time, cuts troubleshooting time, could be very accurate in diagnosis of problems.
- Extremely useful. However, I would be concerned about durability, weather, etc.
- That depends on weather conditions and proper care of the equipment.

- Extremely UN-useful) - 1.) Weather conditions/rain. 2.) Compatibility with equipment needed in the field, i.e. helmet, LBE, NBC. 3.) Durability - seems like you'd have to be really careful with equipment, too easy to disconnect wires, access to mouse in vest used.
- Would be moderately useful. Need to modify it to wear with helmet and other field gear.

Q: Is voice-activated menu easy to use?

HET:

- Somewhat easy. However, would pick up voice but not show menu you desired at times.
- Somewhat easy. Training voice was slow.

PALADIN:

- Very easy. As long as no loud background noise was involved.

Q: Is voice-activated menu responsive?

HET:

+ Very responsive. Tested menu commands in excess of 100 ft., very responsive, behind vehicle and structure.
- Somewhat unresponsive. Had problems with the computer recognizing commands at times.
- Somewhat unresponsive. Commands were recognized but were not initiated.
- Somewhat responsive. Slow at times.

PALADIN:

- Somewhat responsive. With the engine running, I spoke louder and the voice activated menu did not respond.
- Somewhat responsive. Had to retrain on several commands.
- Somewhat unresponsive. Commands needed to be repeated 2-3 times. Voice level needed to get response could be deadly in field environment.

Q: Voice activated menu fast enough between pages?

HET:

- Neither fast nor slow. It's faster than you can look through 2 or 3 TMs.

Q: Voice activated menu fast enough between pages? (cont.)

PALADIN:

- Somewhat fast. Could be faster.

Q: HMD comfortable?

HET:

- Somewhat uncomfortable. The HMD often sagged in the front.
- Somewhat uncomfortable. Hurt my eye after a long time.
- Somewhat comfortable. It needs to have a strap across the head to keep it from slipping down.
- I found the heads-up display harness uncomfortable around my forehead after a period of about 30 minutes.

PALADIN:

- Somewhat. Needs more support from across the head.
- Somewhat uncomfortable. After long period of time.
- Somewhat uncomfortable. Maybe a head harness or something like a CVC.
- Somewhat uncomfortable. Some discomfort after 30 mins.

Q: MARSS vest comfortable?

HET:

+ Somewhat comfortable. More even distribution.
- Somewhat uncomfortable. Would be very hot in warm weather, and would not be big enough to put over clothing in cold weather.

PALADIN:

- Somewhat uncomfortable. Need to have large size.
- Somewhat uncomfortable. The MARSS vest was hot and heavy.
- Somewhat comfortable. Bulky on one side.
- Somewhat comfortable. Little heavy.

Q: Microphone in acceptable position?

HET: No comments.

PALADIN:

+ Very well placed. Easily accessed.

Q: Would MARSS be useful to other MOS (Military Occupational Specialty)?

HET:

+ Extremely useful. - Supply section, PLL.
+ Extremely useful. - 63H/45K/all maint. MOSs.
+ Extremely useful. - All.
+ Extremely useful. - 45T, 63T, 45K, 63K, and wheels.
+ Extremely useful. - Medical.
- Extremely useful. - 45K - DS. All track vehicles as long as DS capabilities are available.
+ Moderately useful. To any maintenance MOS and possibly supply.

PALADIN:

+ Extremely useful. - 45D - 45K etc; could be useful for most maintenance MOS with compatible IETM programs.
+ Moderately useful. - Supply section, PLL section.
+ Extremely useful. - DS portion on all track vehicles, 45B small arms.
+ Extremely useful. - Nearly all MOS.
+ Extremely useful. - 63H/45K/45G/all maintenance fields.
+ Extremely useful. - 63T/45T.
+ Extremely useful. - Supply, armament, personnel.
+ Moderately useful. - Any logistics.

Q: Recommendations for improvements?

HET:

- Weatherproof all parts. Come up with a way to clean vest after field use. Come up with a vest that would not hinder your movement as much. Link MARSS and .U1LS(?). Logistics on batteries in a field environment. Way to mount to Kevlar helmet yet not be obstructive. Make all parts very durable. Possible heads-up display similar to flight helmet with see through visor.
- Needs improvement on the heads-up display.
- Changes need to be made on the eyepiece.
- Make sure the HMD fits a little snugger on your head.

Q: Recommendations for improvements? (cont.)

HET: (cont.)

Move the mouse up to the upper chest area and be operated with one hand. The vest could be a little more flexible around the abdominal area. Make the HMD screen more nonreflective to the sun.

- Some other means of looking into the heads-up display so you don't strain your eyes, maybe a dual heads-up display for both eyes.
- Improvements to the headset. Vest is too bulky. Basically the same improvements I suggested for the M109 system.
- More durable vest w/protective pockets to protect components. Communication cable from vest to HMD cable protected in vest. Connections for components attached more securely to vest. Locks-spring clips to hold board in place or flaps area securely to hold connects to connects/binder Weight distribution of components throughout vest (diagram). HMD = eyepiece slides forward/away from eye. Possibly cut down outside (?) double image.
- Mount mouse on upper chest with pad and buttons exposed.
- A save type function that would allow you to store deficiencies with part numbers similar to an automated DA 2404 would be great. You would be able to download or print this information as required to either order parts or for recordkeeping. This type of system would allow tech inspections to be conducted much quicker.

PALADIN:

- Volume adjustment to compensate for outside engine noise.
- Improvements - vest, image resolution. Recommendations - have the steps read to you, volume control for voice activated menu.
- Higher resolution screen on headset. Relocation of components on vest. Change cable exit out of vest from side area to rear area of neck. Will you have two different headsets? One headset for the garrison where no head protection is required, and one for field use with some type of helmet for protection. Some type of alert system to let you know that the battery is running low.
- More even distribution in vest.
- Some experience with Windows. MARSS seemed to be very well developed for a prototype. I think it would be an excellent system if support and further development continues but worthless if allowed to stagnate like past programs.
- Display should be a binocular type. This would relieve eyestrain. A see-through or heads-up display would be great.
- More versatile to ? the components when moving in/around/on vehicle. Voice activation enhancement at the same time during high frequency noise. Hearing cover possible and type instead of cover Recommend MARSS program for M-1 Abrams tank, eng/xmsn/turret. Trial basis in field environment, i.e., camps with proper representation in field, also to see what adjustments or improvements are required during operation.
- Maybe a voice in headset to tell you what you are looking at during PMCS, instead of continually looking into monitor. The headset would be useful in the turret of a Bradley,

but a walk-around of a vehicle on the outside if you also had a monitor mounted on your wrist could also be useful. However the system is implemented, it can do nothing but help in a big way.

- Solar panels for recharging batteries. Have more flexibility in the abdomen section. Put the mouse on the upper part of the chest or shoulder; the mouse should be one-hand, user-friendly. Better support headband for the commercially bought HMD; the headband for the updated HMD is almost perfect. Make sure headband is sweat-resistant and sticks to the human skin while sweating or rained on.
- Noticed conflicts between mouse and voice commands. Volume control needed on HMD headphone. Sensitivity to voice volume ability to adjust depending on environment in garrison or field. Could you send an on-line address to be contacted in the future.

END